

# Supplemental Instruction in Physical Chemistry I

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## **Abstract**

Physical chemistry I at Texas A&M University is an upper division course requiring mathematical and analytical skills. As such, this course poses a major problem for many Chemistry, Engineering, Biochemistry and Genetics majors. Comparisons between participants and non-participants in Supplemental Instruction for physical chemistry were made using analyses that controlled for prior mathematical ability and academic achievement. When controlling for prior mathematical ability, no statistical evidence was found that supplemental instruction attendance increased the final grade in physical chemistry I. However, when controlling for prior academic achievement, students with lower prior achievement were found to benefit from supplemental instruction while high achieving students derived no benefit.

*Keywords:* advanced college students, physical chemistry, supplemental instruction

## **Literature Review**

Supplemental Instruction (SI) has long been associated with improved academic performance (Congos & Schoeps, 1993; Hays, 2010; The International Center for Supplemental Instruction, 2003; Simpson, Hynd, Nist, & Burrell, 1997; Peterfund, Rath & Xenos, 2008; Oja, 2012). The courses in these studies were freshman and sophomore level science, technology, engineering and mathematics (STEM) courses. Entering students frequently have trouble adjusting

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to college and the student SI instructors not only help students with the course material, they also help students learn how to study effectively.

Many factors affect academic performance. McCarthy, Smuts and Cosser (2006) argued that many studies on the effectiveness of Supplemental Instruction failed to control for other factors which may affect academic performance. Because these studies are observational, McCarthy et al. (2006) argues that the students choosing SI may be more motivated or better prepared than those students who attended no SI session, and it is these characteristics which explain why students attending SI do better in the class. In the McCarthy et al. (2006) study, effectiveness of SI in a freshman level circuits course was assessed. The study controlled for prior academic achievement and level of preparedness upon entering university. The advantage of controlling for prior academic achievement is that there are many reasons why students are high achieving, such as being highly motivated and having excellent study and communication skills. Controlling for these factors isolates the effect of SI. The result of the multiple regression analysis done by McCarthy et al. (2006) was that the number of SI sessions attended provided no additional explanatory power in predicting a freshmen level circuits course grade. However, there was strong evidence that prior academic achievement and level of preparedness upon entering university are good predictors of circuits course grade.

### **Description of the Study**

This study examines the effectiveness of SI in helping junior and senior students succeed in a difficult, gatekeeper undergraduate chemistry course. The students taking this course are presumed to have already learned good study habits. Consequently, the benefit derived from SI in this upper level course is limited to improving students understanding of physical chemistry. We control for two outside factors believed to impact performance in physical chemistry I, mathematical ability and prior academic achievement. We chose to use an analysis that allows for the effect SI has on the course grade to depend, in part, on either mathematical ability or prior academic achievement.

The SI sessions at Texas A&M University are conducted by trained undergraduate students, with the goals of improving course performance and retention. Table 1 shows that students who attend the SI sessions more often tend to receive better grades, on average, in physical chemistry I.

**Table 1**

*Average Course Grade for Various SI Attendance Frequencies*

Number of SI Sessions Attended	Average Course Grade	Number of Students
0	2.76	38
1-4	3.00	15
5-9	2.78	9
10 or more	3.50	2

Student participation in SI sessions is voluntary, meaning there may be many other factors associated with both SI attendance and student performance, such as gender, race, educational background, and motivation. This study considers the level of preparedness for the course as measured by overall GPA upon entering the course and average GPA in calculus I, II and III.

As attendance to SI sessions was heavily skewed to the right, attendance was transformed using an approximate natural log scale: 0 = never attended, 1 = attended 1 to 4 times, 2 = attended 5 to 9 times and 3 = attended 10 or more sessions. Figure 1 is a plot of the transformed attendance and final grade in physical chemistry I. This plot does not take into account either prior overall GPA upon entering the course or mathematical ability as measured by average calculus grade. Although there appears to be a slight increase in the course grade with increased number of SI sessions attended, there is no statistical evidence of a simple relationship between course grade and SI sessions attended.

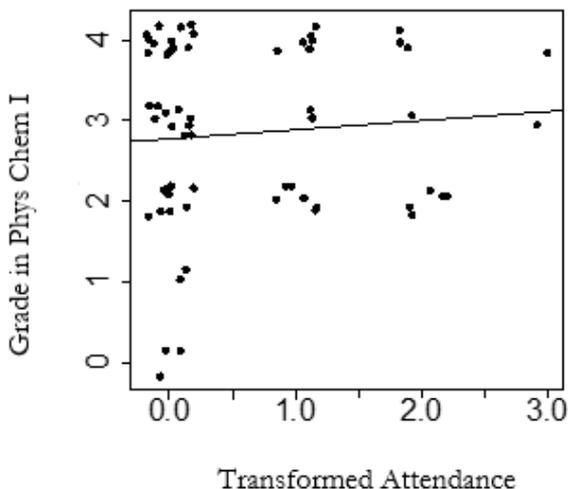


Figure 1. Relationship between course grade and SI sessions attended. Points have been jittered so that the number of individuals at each location are visible.

### Controlling for Mathematical Ability

Since calculus is featured heavily in physical chemistry I, prior ability was measured using the average of past calculus grades. A multiple regression analysis (R-2.15.2©) with SI attendance and average calculus grade was used to test the effect of both predictors on the final grade in physical chemistry I. The outcome from a multiple regression analysis using the transformed attendance grades is given in Table 2.

**Table 2**

*Regression Model Predicting Course Grade from Transformed SI attendance and Calculus Grades*

	Coefficients			
	Estimate	Std. Error	t value	Pr(>  t )
(Intercept)	1.27162	0.55325	2.298	0.0253*
SI Attendance (transformed)	0.02712	0.15471	0.175	0.8615
Calculus Average GPA	0.50815	0.17255	2.945	0.0047**

As we see from Table 2, when we compare students with the same calculus grades, SI attendance is not a significant predictor for course grade ( $P = 0.8615$ ). An interaction term between SI attendance and calculus grade was not significant.

### Results of the analysis when controlling for prior GPA

In Table 3, we find prior GPA averages are higher for students who attended SI sessions more often. Therefore, the influence of SI attendance on students' physical chemistry I grades was measured controlling for prior GPA.

**Table 3**

*Average Prior GPA and SI Attendance Frequencies*

Number of SI Sessions Attended	Average Prior GPA	Number of Students
0	3.12	38
1-4	3.14	15
5-9	2.85	9
10 or more	4.00	2

A multiple regression analysis (R-2.15.2<sup>©</sup>) with SI attendance and prior GPA was used to test the effect of both predictors on grade in physical chemistry I. The effect of attending the SI sessions was found to be different for students with different prior GPA's. Results from the multiple linear regression analysis can be found in Table 4. One interpretation of this model is that students who had lower prior GPA's made a lower grade in physical chemistry I on average, however, attending more SI sessions increased their GPA by around half a letter grade to one and a half letter grades (depending on the number of sessions attended). The effect was not as large for students who already had higher GPAs.

**Table 4**

*Multiple Linear Regression Model for SI attendance controlling for Prior GPA, Using an Interaction*

	Coefficients			
	Estimate	Std. Error	t value	Pr(>  t )
Intercept	-2.2356	0.7103	-3.147	0.00264**
SI Attendance (transformed)	1.6936	0.5517	3.070	0.00330**
TAMU Prior GPA	1.6363	0.2232	7.330	9.85e-10***
(SI Attendance * TAMU Prior GPA)	-0.5095	0.1668	-3.055	0.00344**

Table 4 can be used to estimate the average grade of a student who attended X number of transformed SI sessions and has a TAMU Prior GPA of Y as follows:

$$\text{Estimated Average Physical Chemistry I Grade} = -2.24 + 1.69 * X + 1.64 * Y - 0.51 * X * Y$$

Using the above to compare grades of students who attended no SI sessions with those who attended 5-9 sessions, the estimated increase in the average physical chemistry I grade for students attending SI sessions is 1.35 for students with a prior GPA of 2.0 (out of 4.0) but only 0.33 for students with a prior GPA of 3.0.

Figure 2 is a plot of prior GPA by physical chemistry I grade. Non-transformed lines have been fitted separately based on the number of SI sessions attended. As can be observed in Figure 2, students with a lower prior GPA benefitted the most from attending more SI sessions. However, the final grade in physical chemistry I was not significantly different (confidence interval of 95%) for students with a prior GPA of 3.0 or above, regardless of SI sessions attended.

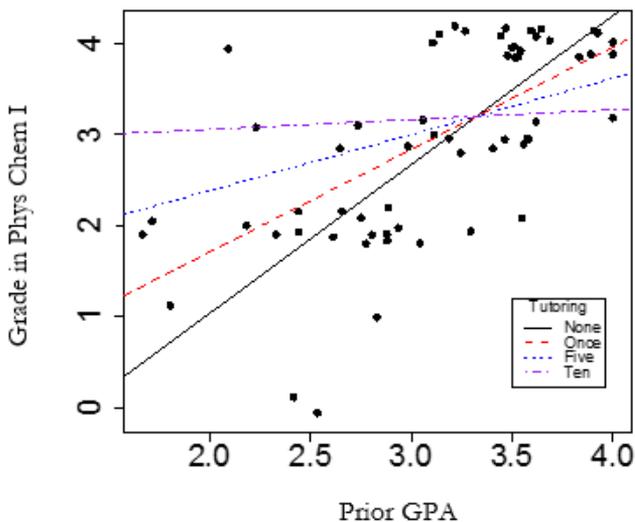


Figure 2. Plot of prior GPA by grade in Physical Chemistry I, with separate fitted lines according to number of SI sessions attended

### Discussion

Previous studies have dealt only with freshman or sophomore level courses. This study examined the effect of SI attendance on the grades in an upper level gatekeeper science course: physical chemistry I. This study provides similar results to McCarthy et al. (2006) based on prior academic performance in calculus courses. However, when we controlled for prior academic achievement as measured by a student's average overall GPA at the beginning of the semester, we found statistical evidence that the number of SI sessions attended does increase average course grade, but only for students with an overall prior GPA below a 3.00. The different outcome of this study, as compared to McCarthy et al. (2006), is due in part to the assumption that the number of sessions attended and prior academic achievement act independently on course grades. McCarthy et al. (2006) assumed that the effect of attending SI sessions on the circuits course grade was the same for all students, regardless of the level of prior academic achievement, or that SI attendance was independent of prior GPA.

## Conclusion

This study allows prior academic achievement to be a factor in the effect of number of SI sessions attended on course performance in physical chemistry I. There is strong statistical evidence that the number of SI sessions attended is a good predictor of the physical chemistry course grade, but the effect on the grade depends on prior academic achievement. This result indicates that students with lower GPA's (<3.00) derive more benefit (higher grades in physical chemistry I) from attending SI sessions.

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