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The Impact of Supplemental Instruction on the Performance and Attitudes of General Chemistry Students

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ABSTRACT: Supplemental Instruction (SI) has been a successful implementation into institutions worldwide. It serves as a means of reducing attrition and increasing the overall learning of course material. The City College of New York (CCNY) has recently implemented SI to General Chemistry I courses to examine whether or not SI would help students succeed in the course and understand and grasp the course material better. SI was made available several times a week during flexible times to students who are struggling in the course. Our method of data collection is a Likert-type and open-ended questionnaire that was distributed at the end of each of the semesters to SI participants in an anonymous fashion. Furthermore, we compared the grades and performance of students participating in SI with those who did not. The collected data enabled us to examine the impact of implementing Supplemental Instruction (SI) in General Chemistry I at CCNY. Our data show that SI was beneficial, contributed to improving students' understanding of course material, and increased their success rate. About 80 percent of students who failed the first exam and participated in SI obtained a passing grade compared to 11 percent of those who did not.

Keywords: supplemental instruction, chemistry education research, student learning

INTRODUCTION

Supplemental instruction is derived from the term developmental education and stems from a branch of Learning Assistance Centers or LACS [1]. To better understand the origins of Supplemental Instruction, we must first understand the framework that set up this type of education. Developmental education originates in the 1600s and focuses mainly on the assumption that each student has multifaceted talents that can be developed academically, opposed to focusing on the deficits of a student [1]. The main goal was to naturally adapt the students' population to higher education through means of social and academic domains allowing the students to grow in multiple dimensions in their academic skills [1].

Developmental education later paved the way for academic programs such as Learning Assistance Centers (LACs). It was viewed as an extension of the classroom and did not discriminate between faculty and students, and within the student population did not discriminate between students who performed to standard and those who performed below par. LACs were for everyone who wanted to be academically enriched [1]. As a new program, LACs had six main objectives: "higher course grades for participating students; central location for students to receive tutorial assistance; a referral source to other helping agencies; a comprehensive library of basic study aids; a training agency for paraprofessionals, peer counselors, and tutors; and a center for faculty development." [1]. These goals made it very clear that this service was not to be mislabeled as remedial, which was a main topic of interest when it comes to implementing new services, like this one, in schools. LACs are essentially a tool used to attain higher education, not provide a remedial course. Another important reason as to why LACs were adopted into other higher education institutions is to increase student retention [1]. LACs jump-started improved learning across campuses not only in the United States but across the world.

In the 1990's developmental or remedial courses were not allowed to be offered at public four-year universities, thus making supplemental instruction a very attractive candidate to solving the issue with students' academic integrity and attrition [1]. College faculty members were drawn to SI due to its minute

fiscal commitment and that it strongly promoted individual self-learning for the students, this meant less time spent teaching for instructors [1].

SI or supplemental instruction is as it states - supplemental instruction offered to the students enrolled in a course. SI gives the students the opportunity to work in a cooperative setting on problems and is supported by peer instructors [2]. SI works to increase academic performance and retention but utilizing both collaborative studying in addition to independent studying and analysis of study strategies. SI sessions are offered for traditionally difficult high risk course; 'historically difficult' courses are also identified by analyzing the grade distribution of courses throughout each academic division, "courses in which 30% or more of the students receive D or F grades or withdraw, become targets" [3]. One of the main factors that attribute to the individuality of SI programs is that it focuses on historically difficult courses [4] and large classes where students have little opportunity for interaction with the professor or other students [5]. Labeling a course as historically difficult allows you to categorize the class as challenging without placing blame on the professor or the students.

SI sessions are scheduled on a weekly basis and all students enrolled in the course are encouraged to join. SI sessions act as a continuation of the lesson learned during in-class lecture with the instructor. Being that SI sessions are not tied down to class time, students can attend whenever and however many times they wish without the restriction of a required course preventing them. Constant feedback will be given based on the student's grasp of the material taught in class, thus giving them ample time and motivation to alter their study methods to adapt, if need be. Research on SI suggests that problem-solving skills and study strategies learned in SI courses are transferable to other courses which leads to improved performance [6]. Supplemental instruction sessions are typically led by an SI leader, who would be a former student that succeeded in the same course, however it is not uncommon for a professor to join an SI session for a course. SI may improve students' retention and graduation because it offers the students the opportunity to network socially which speeds up the acclimatization to the college experience [7].

SI provides a way to combine "how do I teach myself this" with "what do I need to know". While SI helps students gain a more thorough understanding of the material, it also helps students to condition themselves and alters their thinking to accommodate for the type of information they are processing. SI differs from a remedial tutoring course because it is created based on the course versus the students [1]. This potentially makes attending SI sessions more attractive to students who are afraid or shy to ask for help.

SI is not a remedial course, it is considered a mediator connecting the gap between the new information presented to students and the students current knowledge and practices, "SI bridges the gap between the current knowledge base and the acquisition of new knowledge by focusing on the refinement of the learning skills indispensable for acquiring new knowledge" [8]. Successfully implemented SI programs were able to track those students who attended and the impact it made towards their grade, for data that was collected institutionally [9]. SI can be effectively used to develop study skills, increase motivation and improve performance in participants [10].

According to Wolfe, "…there appear to be benefits of SI in courses where students are being newly introduced to chemical concepts and methods, but these benefits seem to drop off when students are more experienced with the material." [5]. The results further go on to conclude that SI is most beneficial to entry level science courses such as, General Chemistry I and Organic Chemistry I. It seems as though SI is a great addition into institutions to overall help attrition rates and more generally help students improve within their courses. More research has been done to give us a wider range of knowledge on SI within Chemistry courses [9]. SI can be used to address the continuous decline of fundamental chemical knowledge noticed in recent college graduates [11].

In large lecture classes, there is a disconnect between the lecturer and the student. Supplemental Instruction (SI) is often offered in a more intimate setting where the SI instructors can have one-on-one time with students to individually hone in on their specific problems, whether it is conceptual or problem-solving. As for learning environment, SI is usually held in a smaller more accommodating room where it is a less intimidating more inviting space. This setting provides a social interaction component in which usual Chemistry lectures don't provide. In addition to the more personal tutoring time available, students are also encouraged to interact in a common social setting. This allows for an opportunity of collaborative learning and may help foster a sense of community [12].

The attraction to SI in a college setting is due to its short and long-term effects. The short-term effects of SI sessions are to instill a deeper understanding of the coursework within students. Whereas the long-term goals are two-fold, the academic goal is to change the way students learn, study, and understand

information so that the knowledge stays with them. Students who participate in SI earn higher grades not only the course but in subsequent semesters, which is due to improved study habits and is considered a long-term positive outcome of SI [13]. The second long-term goal is to develop better social interaction skills within these students.

Many public institutions have implemented SI and thus have uncovered several significant findings. Findings that were previously mentioned pertaining to the outcomes of SI includes achieving higher percentages of passing grades [1,14]. Some studies also found higher graduation rates among participants [1]. Despite their better performance, SI takers often score lower on academic success predictors such as the SAT and ACT exams [14]; increases in performance, therefore, appear to not occur because stronger students use SI.

SI helps promote problem-solving skills because it involves the learner in the construction of knowledge and information processing based on their prior experiences which could contribute to cognitive development [15-16]. Furthermore, SI has been shown to improve motivation and enhance study habits and understanding difficult concepts [17]. Participants in SI have been found to have better control on their achievement, self-esteem, and confidence [18]. SI has also been found to higher academic self-efficacy and grades [19]. Studies have reported that students who participated in SI in introductory courses in Biology or Chemistry courses tended to continue onto upper level courses in the field; SI has a positive effect on students' enrollment in upper level courses [20,21]. We should note that Rabitoy and co-authors reported that SI enhanced students' achievement in STEM fields and this was greater for females and students of color [22].

METHODS

While researching the topic of SI as a whole, we were able to uncover many studies that were in favor of this new implementation in institutions. Our research study is unique because it targets only at risk students and provides an added value to the curriculum. SI was implemented into The City College of New York (CCNY) as a test run in the Department of Chemistry and Biochemistry. The CCNY is an urban minority serving institute that offers a diverse selection of classes, which vary from the arts to the sciences and everything in between. We wanted to try implementing SI into the sciences to see if at risk science students can benefit from it. Grasping the S in stem, our main goal is to use the successful methods of SI to see what benefits it can bring to general science courses.

Beginning during the Spring semester of 2018, SI was implemented at The CCNY's General Chemistry I course which is composed of lecture, lab, and Peer-Led Team Learning (PLTL) workshop. PLTL is implemented as an integrated part of the course [23]. In the General Chemistry course, after exam one was distributed and grades were given back, an announcement was made introducing SI. The lecture professor would encourage students who received a failing grade, classified as a grade below a 65 out of 100 on exam one, to attend SI as means of improving in the course. This makes our study unique since we are only targeting students who are struggling the course and are not likely to earn a passing grade. It is noteworthy that PLTL offers a collaborative learning experience for all students. SI instructors targeted weaknesses in study habits, socialization, conceptual-understanding, and problem-solving skills.

SI was made available for five days a week and on those days, SI was scheduled around classes times which makes it easier for students with busy schedules involving work and class to attend. During SI sessions there are instructors that have been hand-picked by instructors from a cohort of recitation leaders and who have successfully completed the course and have received a grade of A in the course. SI attendance was not mandatory.

Throughout the first session available after the Supplemental Instruction announcement was made to the lecture class, those who chose to attend, because SI was not mandatory and it was strongly recommended for struggling students. Students brought their first exam with them to be discussed. This initial discussion is a one-on-one between the student and instructor, which serves as a more social component to learning whereas that isn't available during class time. The first exam was then discussed so that the instructor can now sift through the student's strengths and weaknesses to later target them in the weeks to come. The overall composition of our Supplementary Instruction sessions was influenced by the previous studies done and researched, hand-picking methods that seemed to work and leaving off ones that were less successful. SI sessions included cooperative learning activities, and addressed students' misconceptions and difficulties, explored difficult concepts in depth, and enhanced problem-solving skills [24].

Every week during Supplementary Instruction sessions students were encouraged to come back to further work through their weaknesses. During this trial specifically, it was noticed by the SI instructors that a lot of students actually struggle with basic problem-solving skills and reasoning. To help combat this, worksheets were made each week based on the lecture topics covered in class, based on problem-solving to help build their skills. Aside from doing the worksheets, students were encouraged to bring in topics or questions they have on the material so the SI instructors can further clarify and explain. Furthermore, students came to SI with questions that they were struggling with. Students provided questions for the SI instructor to explain which created a mutually beneficial relationship [11, 25].

Our research question is: How does Supplemental Instruction in General Chemistry I impact students' learning, conceptual understanding, retention, and attitudes?

In order to properly assess how beneficial SI is to the way students learn Chemistry, data were collected at the end of the Spring and Fall of 2018 semesters, as well as Spring 2019. We used a combination Likert-type and open-ended questionnaire, as well as, grade comparisons. The Likert-type section included a five-point scale, where (1) Strongly Disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly Agree. For each question, the average was taken which helps make sense of the data. For the open ended questions, questions 1 through 3, we created and used a rubric to score the questions on a scale from 1 to 5 similar to what was mentioned above. For question 4, we compiled the answers and created pie charts based on the type and number of responses.

As previously stated, at the end of the semester surveys were printed and distributed to each SI session. Students that attended SI were all encouraged to participate in this survey. A total of 44 out of 60 students were available and willing to participate in the optional survey.

RESULT AND DISCUSSION

Graphical depictions of each Likert-type question along with average responses are shown in Figure 1.

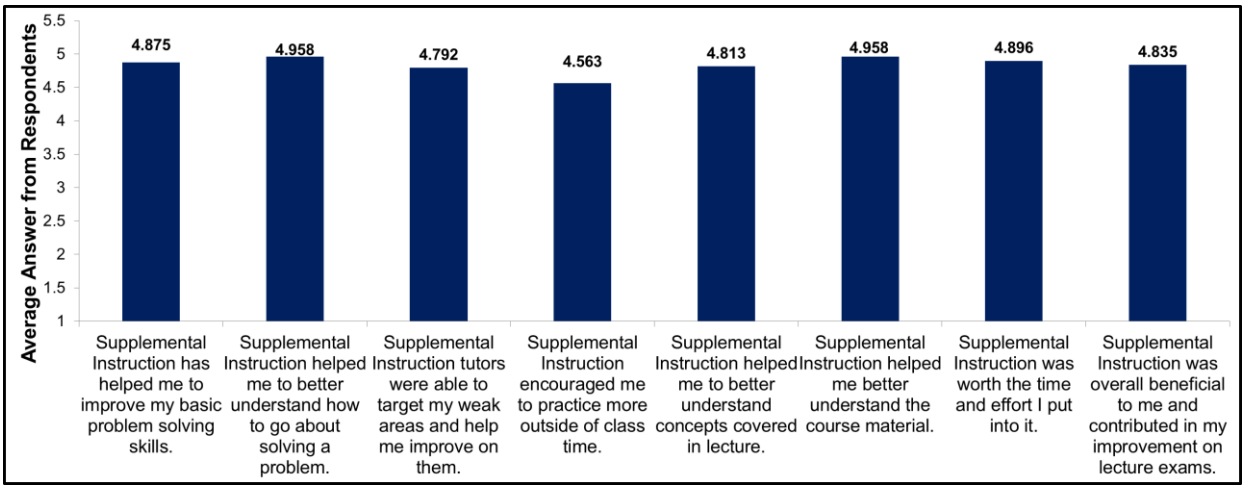

FIGURE 1. Averages for the answers for each of the Likert-type questionnaire.

Our data clearly shows that students overall had a positive learning experience with SI. The students agree that SI improved their basic problem-solving skills, understanding of concepts covered, and attaining a better grade in the course. Furthermore, SI participation encouraged students to practice problems and tackle their weaknesses in the course. SI participants believe that the SI instructors targeted their weak areas and helped them improve. Finally, students felt that SI was worth the time and effort they put into it and that it was beneficial and contributed to improvements in grades.

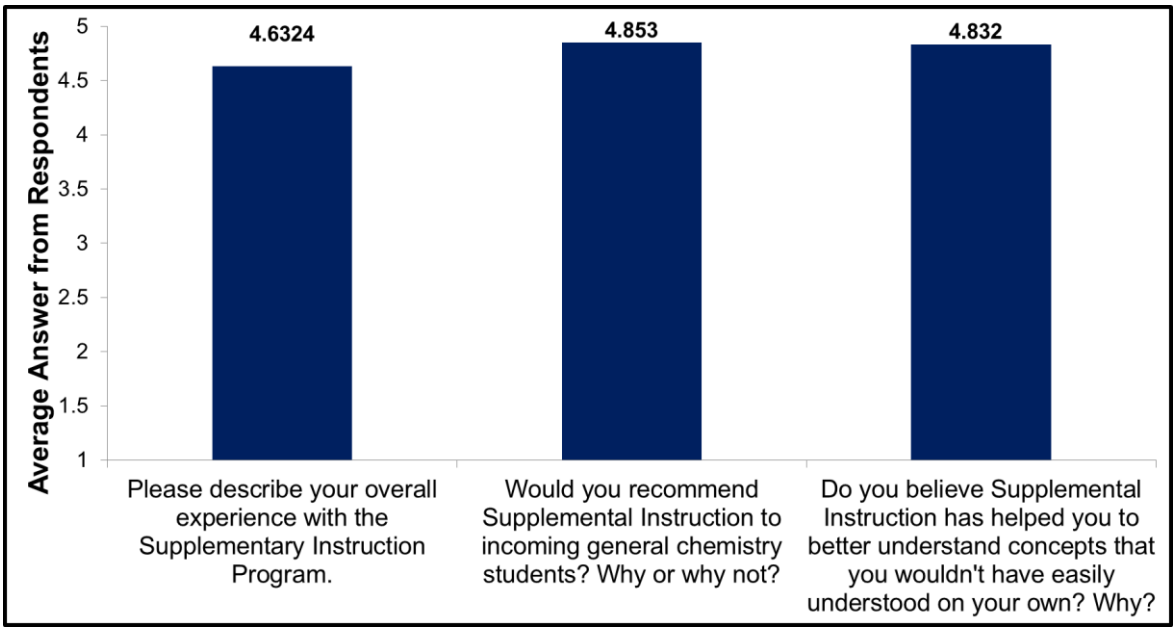

FIGURE 2. Averages of the short-answer responses were numerically scaled using a rubric.

Figure 2 shows that students overall had a positive learning experience with SI and that it helped them better understand the concepts. Furthermore, the participants would enthusiastically would recommend SI to other Chemistry students.

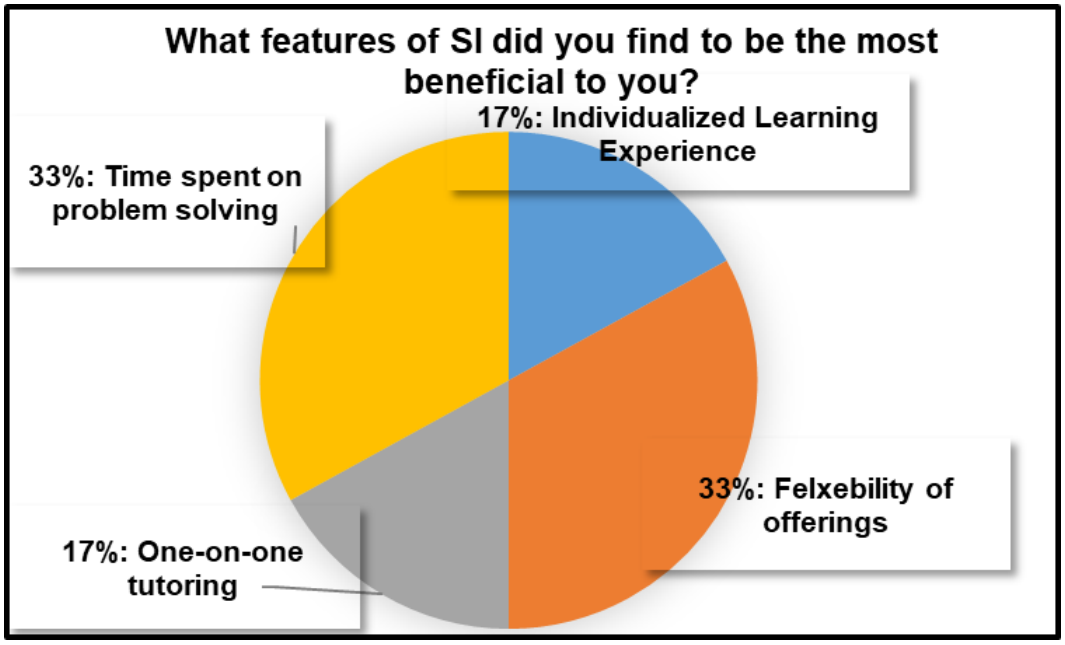

FIGURE 3. The pie chart above shows the beneficial components of SI to students.

Figure 3 shows the parts of SI that students found beneficial. Overall, there were many useful features of the SI program that facilitated students' learning and succeeding in the course. The students appreciated the time spent on problem-solving, the flexibility of the offerings – refers to the times and days,

the individualized learning experience, and the one-on-one support, guidance, and tutoring.

From the Likert-type questions given in part one of the survey, responses were broken down for each given question in order to visualize the impact of SI for the students/participants. The average of the responses can be seen above and was about 4.8. The corresponding results can be viewed above as shown in Figure 1. To turn our attention to Figure 1 'SI has helped me to improve my basic problem solving skills', upon meeting with the SI instructor team at The CCNY we were made aware that students have trouble with basic problem-solving which leads to the disconnect in understanding how to build upon this knowledge. When students lack this basic skill, it is difficult for them to move on and build upon this skill as the course progresses, which ultimately leads to their failure to meet the level of understanding for each lecture exam. From the responses, we can see that majority of the students feel as though their problem solving skills have developed as a result of participating in SI.

Questions 6-8 deal with an overall belief about the experience of SI participation. Based on Figure 1, SI helped students better understand the course material, and had an overall positive response as 100% of students felt like they did have a better understanding of the course material after attending SI. Students overwhelmingly agree that SI is very beneficial to the way they learn Chemistry. Our data show that SI is well received by the participants which is consistent with other researchers [11].

Short answer questions 1-3 were made in order to have a more in-depth understanding of the student experience with SI this past semester. These questions were formed as short answer so students were more inclined to share their opinions of SI. The collected data shows that the students strongly agree that SI has been very beneficial for ways unique to each student. Some students enjoyed the SI instructors and their way of teaching and helping the students understand the material. While others enjoyed how personal the experience was. It wasn't a 'one size fits all' experience but an experience that was personalized to each student's needs, strengths, and weaknesses.

Short answers for question 4 also had very personalized responses. Question 4 in particular – 'What features of SI did you find to be most beneficial to you?' was very helpful in understanding what students appreciate most about SI, and served as a standard to which should be upheld. Responses ranged from the flexible times SI was offered to the small class setting which is extremely different than the lecture, and more comfortable. Students also enjoyed and benefited from the one-on-one attention they received in SI session. For that reason, students would make time to attend the SI section of their 'favorite instructor'. Furthermore, the individualized learning experience was appealing to SI participants. The overall goal is to get each student to understand complex concepts and if one instructor can better help someone to reach this goal; SI is a success. The overall responses show that SI is very beneficial and contributed a great deal to the way that students learn Chemistry.

One main issue we have encountered during this initial phase of implementation is low number of students who self-select to participate in SI. Only about 10 percent of students who failed the first exam, participated in SI. One reason could be that students might not buy into the philosophy of SI. A second reason might be that students do not think that SI would help them better understand the content and succeed on the course. A third reason could be due to lack of motivation in these students. Another reason could be attributed to the lack of maturity in students who are taking General Chemistry I. We use the term 'lack of maturity' loosely in this sense to mean the lack of knowledge of how to conduct oneself in a college setting [26]. Most commonly, freshman students come straight from high school where they have not yet acquired good study techniques or methods which work best for them. These reasons combined with the hardship required to understand such complex concepts that they're learning for the very first time can deter students.

Our data show that students who participated in SI after failing the first exam achieved a success rate of about 80%. Students who failed the first exam and did not participate in SI had an 11% chance of passing the course. This data is consistent with several research in the field indicating that students who participate in SI have a higher chance of successfully completing the course with a passing grade [14, 27]. We feel these data make powerful statement for the added value of SI in General Chemistry courses and its impact on students learning and attitudes.

CONCLUSION

In conclusion, our research study on SI provided valuable data into students' learning and conceptual understanding of content in General Chemistry. Furthermore, our findings provide insights into students' attitudes about SI implementation and its benefits to the participants. Our research data supports the

introduction of SI into General Chemistry courses and provides students with learning skills, socialization competencies, problem-solving skills, and the knowledge required to successfully complete the course. We believe that our data supports the notion that SI had a significantly affected the participants grades in a positive manner and it should be noted that that majority of SI participants earned a passing grade in the course. Our results and data on the implementation of SI in General Chemistry courses improved students' attitudes towards the subject matter, learning, socialization, and study habits. We are confident we can reach a larger population and improve our recruitment so more students can experience SI and increase their chances of successful completion of the course. As an implication for curriculum, we would recommend supplemental instruction for all introductory courses STEM fields.

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