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Supplemental Instruction: Whom Does it Serve?

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Supplemental Instruction (SI) is today a well-known academic assistance program that provides help for students in "difficult" courses. SI has repeatedly been shown to decrease the percentage of failures in the course as well as increasing course grades for students who attended SI sessions. Although SI is open for all students, its main objective is to come to terms with students' high failure rates and retention problems. And even if SI has been shown to reduce failure rates and increase re-enrollment figures, surprisingly few studies have been devoted to determine how well it benefits students with different prior academic ability. These studies tend to show that "weaker" students benefit from SI. The results for "average" and "strong" students are not as clear. The present study focuses on the benefit of SI for "weak", "average," and "strong" first-year engineering students in a calculus course. The results show that all three groups benefit from SI and that the failure rates among students with low prior mathematics achievement who had high SI attendance are almost as low as for students with high prior mathematics achievement who do not attend SI.

Introduction

Supplemental Instruction (SI) was developed in 1973 at the University of Missouri in Kansas City to increase student success in "difficult" courses (Hurley, Jacobs, & Gilbert, 2006). SI as a concept has since spread widely and is used at more than 1500 university colleges and universities in nearly 30 countries (Martin 2008).

What then is SI? First and foremost, it is not just a method but an attitude to learning in which inner motivation and curiosity are the driving forces and the main emphasis is on self-governing and collective learning (Olstedt, 2005). SI is a complement to the regular education in a course. The idea behind SI is that learning a subject is enhanced by an exchange of thoughts and ideas among students. At the School of Engineering (LTH), Lund University, Lund, Sweden, the SI program is connected to an initial, "difficult" course for first-year students in most engineering programs. SI takes place in sessions of some 5-15 students where the discussion is guided by a 2nd- or 3rd-year student. This upper-level student should not act as a teacher, but rather, he or she should help in clarifying difficult questions within the subject: the method is by asking questions, initiating work in small groups, and coordinating presentations of conclusions. The upper-level student receives training in how to be an SI leader, and gets tools to use during his/her SI sessions.

Supplemental Instruction has the advantage of not being a remedial program: it is available for everyone in a course that has an SI program attached to it (Blanc, DeBuhr, & Martin, 1983; Arendale, 2002; Zaritsky & Toce, 2006). Participating students improve their grades and reduce the number of failed exams (Arendale, 2001; Blanc et al., 1983; Blat, Myers, Nunnally, & Tolley, 2001; Bruzell-Nilsson & Bryngfors, 1996; Burmeister, Kenney, & Nice, 1996; Congos & Schoeps, 1993; Hensen & Shelley, 2003; Malm, Bryngfors, & Mörner, 2010; Rye, Wallace & Bidgood, 1993; Ogden, Thompson, Russell, & Simons, 2003; Packham & Miller, 2000; Power & Dunphy, 2010; Ramirez, 1997; Sawyer, Sylvestre, Girard, & Snow, 1996; Webster & Hooper, 1998; Wright, Wright, & Lamb, 2002). But to what extent does SI help students with low, average and high prior academic achievement in a course? A few studies have been made. Arendale (2001) divided 1628 students attending 19 courses at the University of Missouri, Kansas City, during the fall semester 1989 and spring semester 1990 into three groups depending on their prior academic achievement as measured by the mean composite score on a college entrance exam. He found that in all groups (i.e., the groups with "weak", "average," and "strong" prior academic achievement) SI attendees had significantly better final course grades. In a statistics course at the University of Queensland, Australia, Miller, Oldfield, and Bulmer (2004) found an improvement in course grades for PASS-participants (PASS is the Australian equivalent of SI) independent of which group they belonged to: high, average, or low university entrance scores. Kenney and Kallison (1994, p. 80) found that "exposure to SI techniques appeared to help the lower-ability students disproportionately more than the higher-ability students" in a calculus course for business students. Likewise, McCarthy, Smuts, and Cosser (1997) in a study of SI attached to an engineering course at the University of Witwatersrand, South Africa, found significantly higher grades for SI attendees only in the group with the lowest academic ability. For students with higher academic ability no significant differences in course results were found between SI attendees and non-attendees. Murray (2006) reported a clear improvement for students attending SI on the final assessment grade in an engineering course at Queensland University of Technology in Australia independent of their high school rank. However, comparatively better results were found for students with worse rankings.

From the studies above, one can conclude that "weak" students seem to benefit from SI. To what extent "average" or "strong" students improve by attending SI is, however, less clear. The following is a study of SI in a Swedish engineering education context with a course in introductory calculus as the main focus. The main research question was the following:

How beneficial is SI in mathematics for "weak", "average," and "strong" students? Besides accounting for differences in previous ability in mathematics between SI attendees and non-attendees, the investigation also addresses differences in motivation/attitude and study technique/learning strategies.

The Introductory Calculus Course and the Attached SI Program

The introductory calculus course – Calculus in One Variable – is compulsory for all engineering education programs at the School of Engineering (LTH) at Lund University, Sweden (similar calculus courses are common for engineering education programs throughout the world). It is worth 15 ECTS (European Credit Transfer System) credits and constitutes a quarter of the full academic year workload of 60 ECTS credits, thus a rather large course. There are two versions of the course – one faster, that runs over one semester, and one slower, that runs over 1.5 semesters. In the present study, results from eight engineering programs with SI in the calculus course have been included: four programs with the faster version and four programs with the slower version.

The academic year at LTH is divided into four quarters (an autumn and a spring semester with two quarters each). Each quarter consists of seven weeks of scheduled classes and one week of exams. A full workload for a student is usually to take two courses each quarter. The SI program at LTH is usually attached to compulsory courses with comparatively high failure rates during the first two quarters in the first year. For the eight engineering programs considered in the present study, all have SI attached to the Calculus in One Variable course for the first two quarters. In each quarter two-hour SI sessions are offered once a week to each student during weeks two to seven (thus the maximum number of SI sessions a student can attend is six for each quarter). For the academic year 2009/10' from which data for this study were collected, there were in total 648 students participating in the course from the eight engineering education programs. Twenty-seven SI leaders were employed in order to arrive at reasonably- sized groups in the SI sessions (in the order of 10 students at a 40 % attendance rate, which on the average had been the case the previous year). The SI leaders were chosen mainly from sophomore or junior-year students. All SI leaders participated in a 1.5-day training course prior to starting their work.

How does a typical SI session in calculus at LTH look like? First of all it is a scheduled 2-hour session during normal school hours when the students are free from other educational activities. It is generally commenced in a relatively easy-going fashion with some 5- to 10-minute talks guided by the SI leader about occurrences in the course during the previous week. Thereafter the participants decide areas they want to focus on during the SI session; these may range from terminology, theorems/proofs, or concepts that need clarification to problems that have been hard understand and solve. In addition – time allowing, which is generally the case - the participants work with more difficult tasks of exam character that the SI leader has prepared. The SI leader usually divides the group into smaller sub-groups to ensure that all participants may be active and able to contribute in the work with the material. The SI leader's main task is thereafter to work as a facilitator to ensure that the work and discussions in the groups progress smoothly. This is done, for instance, by asking or redirecting questions within the group, helping to break down problems, and encouraging participants to help each other towards understanding or pose critical and probing questions. It is essential that the SI leader works to obtain an open climate in the group whereby all participants are free to ask questions they want answered. The SI sessions are generally concluded with the participants presenting the solutions and answers they achieved, for each other, using the blackboard.

There are several aims with the SI sessions in calculus at LTH. Obviously it is an extra learning opportunity in a difficult course. However, it is NOT a help session for less able students. Instead, the sessions benefit from having students with different prerequisites and abilities in math as they help each other to understand the difficult parts of the relevant course. Other aims are of a more general character. It serves as a bridge between secondary school and the university in the method of studying and in the recognition of what assets fellow students are. Students learn that they can solve problems together which they were not able to do on their own, and they train themselves in learning strategies, in critical thinking, in discussion of course material, and in presentations of problems and solutions in front of others.

The division into "Weak", "Average," and "Strong" Students

Since Calculus in One Variable is the first mathematics course taken by new students at the university, we make the division of "weak", "average," and “strong” students based on their average grade in mathematics in high school. In order to make the numerical values of the average mathematics grade in high school understandable for the reader, some insight into the Swedish high school system is needed: it usually spans over three years and consists of programs with different orientations (natural science, economy, humanities, etc.), and it is composed of some 20-25 courses. In each course each student obtains a grade. Besides Fail, the grades are Pass, Good, and Excellent. When applying to be admitted to the university, one does so on the basis of the average grade in all courses (with compensation for different sizes of courses). Here Pass is given the numerical value 10, Good is given 15, and Excellent is given 20. This means that the high school average grade is a numerical value somewhere between 10.0 and 20.0. Here we used the same approach to determine the average grade in the five math courses in high school in order to obtain a measure of the student ability in mathematics when they enter university.

That the average mathematics grade in high school has a clear relation to success in the Calculus in One Variable course can be seen in Figure 1 below. Therefore, it seems reasonable to use high school mathematics grades as a measure of their initial ability in the Calculus in One Variable course. In the following we define “weak” students as having an average mathematics grade in high school in the range of 10.0-15.0. Similarly, we define “average” and “strong” students as having an average mathematics grade from high school in the range of 15.1-18.0 and 18.1-20.0 respectively. The reason for using uneven grade intervals is partly due to the fact that most students entering LTH have quite high grades in mathematics, and we want our groups of students not to differ too much in number. It is also partly due to the fact that a student with a mathematics grade below 15 (regardless of whether their average high school math grade was 10, 11, 12, 13, or 14) has a very poor chance of passing an exam in Calculus in One Variable, as can be also seen in Figure 1 below. Therefore, it seems reasonable to have a larger grade interval to cover “weak” students.

Results

SI Attendance

The attendance in SI sessions attached to the course in Calculus in One Variable is shown in figure 2. The attendance at the SI sessions was fairly good during autumn 2009: on an average, about 44 %, meaning a small increase from the year before. Eighty-two percent of the students attended at least one SI session. Only 7 % had a perfect attendance record, and the median student attended five SI sessions. The average number of participants at an SI session attached to the calculus course during the autumn semester 2009 was 10.6.

Number of Students Passing the Course Calculus in One Variable as a Function of SI Attendance and Previous Math Ability

In Table 1 the results in Calculus in One Variable, expressed as the percentage of students passing the course, are given as a function of SI attendance. The percentage of students passing the course indicate a pronounced correlation with the number of SI sessions they attended and there is a remarkable difference – 40 % – between students with high attendance records and those who did not attend SI! To see whether these differences are statistically significant, we used a chi-square test. As can be seen in table 1 the differences in students passing the course are indeed highly significant between the two groups with high or average SI-attendance and the non-attendance group. Although the better course results for the low SI-attendance group are not statistically significant, the difference in student success compared to the group that did not attend SI is big enough to suggest that even these students benefitted from the times they participated in SI sessions. However, there is a weak tendency showing that students attending SI had a higher math grade average from high school in general, significant at the weakest level between the high-attendance SI group and the non-attendance group (this result is different from some other studies that have shown weaker pre-entry characteristics for SI attendees: e.g., Congos & Schoeps, 1993; Hensen & Shelley, 2003; McGee, 2005; Rath, Peterfreund, Xenos, Bayliss, & Carnal, 2007). To minimize this effect we divided the students as “weak”, “average”, or “strong” based on their average mathematics grade from high school. By this procedure we neutralized the effect of differences in math grades between SI attendees and non-attendees (the differences in math grades in the weak, average and strong groups were 0.1 or less). In Table 2 the results in Calculus in One Variable, expressed as a percentage of students passing the course, are given for “weak”, “average,” and “strong” students as a function of SI attendance. In all three student groups there are highly significant differences in the percentage of students passing the Calculus course between those having average to high SI-attendance records (except for the average SI-attendance group among the “weak” students) compared to those not attending SI. Obviously the biggest differences are between the high SI-attendance group and the non-attendance group. For the “weak” students the difference in percentage of students passing the course is 37 % higher for the high SI-attendance group, for “average” students the difference

Figure 1
Percentage of Students Passing the October Exam 2007 in Calculus in One Variable Related to their Average Mathematics Grade in High School. (In total 942 students took the exam [from Malm, 2009])

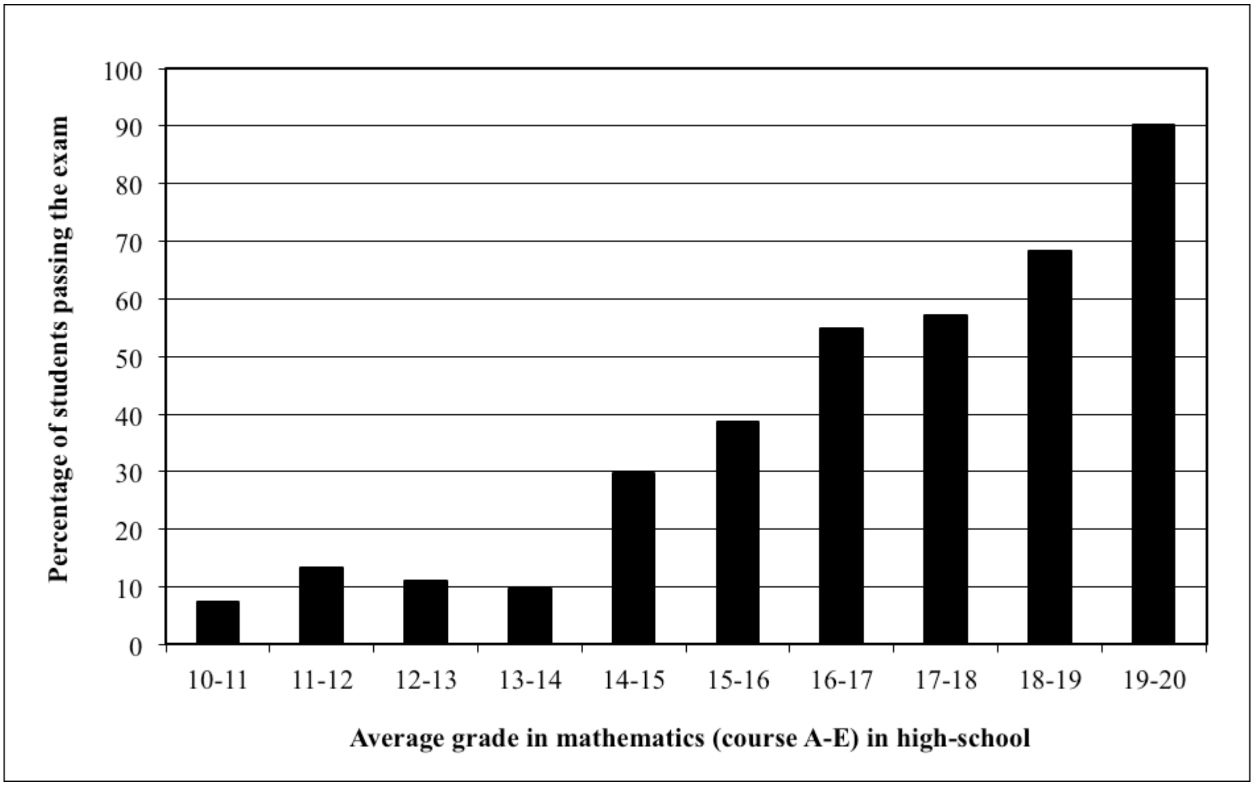

Figure 2
Attendance at SI Sessions in the Course Calculus in One Variable During the Autumn of 2009 (12 SI sessions scheduled for each student)

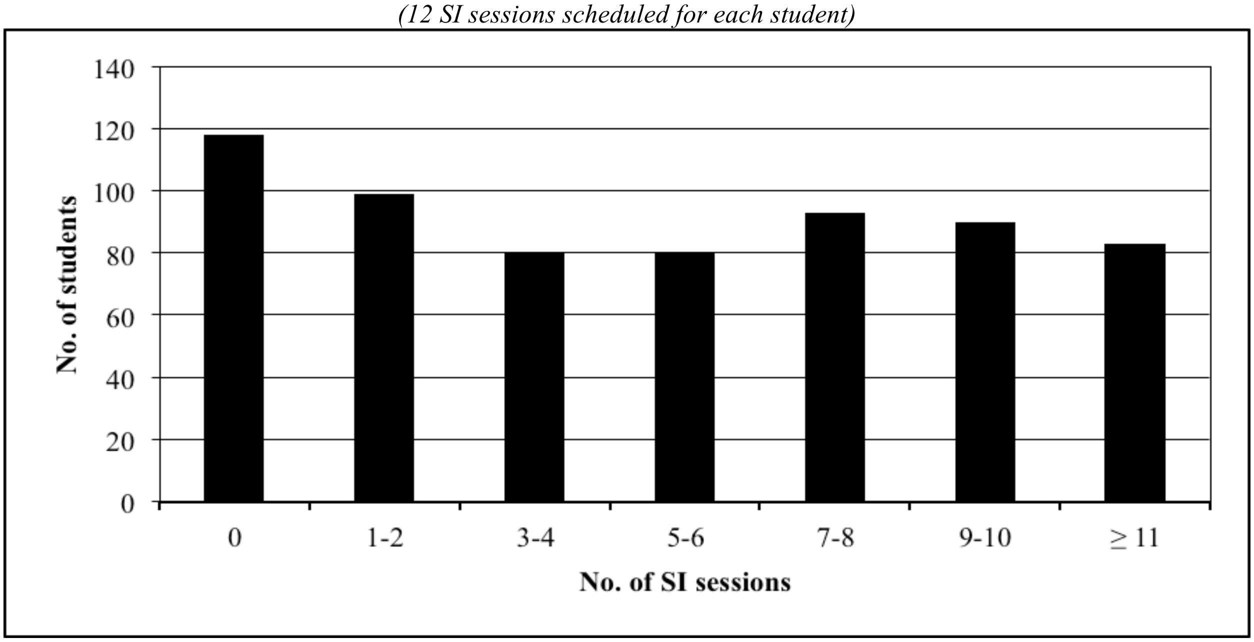

Table 1

Results from the Course in Calculus in One Variable as a Function of SI Attendance.

	Attendance (No. of SI sessions)			
	None (0)	Low (1-4)	Average (5-8)	High (≥ 9)
Registered students in the course	118	179	173	173
Percentage of students passing the entire course after the first academic year	39%	49%	65%***	79%***
Average grade in mathematics in high school	16.6	16.6	16.9	17.2*

Note. Statistically significant differences in results using a chi-square test with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the student group that did not participate in any SI sessions are marked with *, ** and ***.

Table 2

Results from the Course in Calculus in One Variable as a Function of SI Attendance and Average Grades in Mathematics in High Hchool.

SI attendance (Number of SI sessions)	Percentage of students passing the entire course after the first academic year
"Weak" students (group with 10.0-15.0 in average mathematics grade in high school)	
None (0)	19% (9 of 47)
Low (1-4)	23% (14 of 60)
Average (5-8)	35% (19 of 55)
High (≥ 9)	56% (24 of 43)***
"Average" students (group with 15.1-18.0 in average mathematics grade in high school)	
None (0)	38% (11 of 29)
Low (1-4)	51% (33 of 65)
Average (5-8)	68% (38 of 56)**
High (≥ 9)	80% (47 of 59)***
"Strong" students (group with 18.1-20.0 in average mathematics grade in high school)	
None (0)	62% (26 of 42)
Low (1-4)	74% (40 of 54)
Average (5-8)	87% (54 of 62)**
High (≥ 9)	94% (67 of 71)***

Note. Statistically significant differences in results using a chi-square test with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the student group that did not participate in any SI sessions are marked with *, ** and ***.

is 42% higher for the high SI-attendance group, and finally for "strong" students the difference is 32 % higher for the high SI-attendance group. This indicates that, independent of whether a student has a "weak", "average," or "strong" mathematics background from high school, he or she can increase his or her chances for success in the Calculus course by attending SI sessions. The more one attends SI, the more one is likely to benefit.

Perhaps the most remarkable result is that the percentage of "weak" students with high SI attendance passing the Calculus course is very close to the percentage of "strong" students with no SI attendance passing the Calculus course. This surely suggests that SI can make a big difference for students!

Discussion

The results above suggest that SI is a powerful method for achieving better student success in difficult courses. SI success does not discriminate between students who had previous low, average, or high ability in the subject in high school: all perform seemingly better on the average after attending SI. Unfortunately, it is not possible to determine exactly to what degree SI is the cause of SI participants performing better since participation in SI sessions is optional and we therefore experience the potential bias due to self-selection. However, it is possible to at least estimate the influence of some alternate explanations for the fact that SI participants perform better; such differences might include ability, motivation, study techniques, and learning strategy between SI participants and those not attending SI. That a difference in ability (as measured by the average grade in high school) did not have a significant impact on SI participants having better results was shown above. To address the effect of possible differences in motivation, study technique, and learning strategy between the SI and non-SI groups, we passed out a questionnaire with 13 questions to the new students just before the semester started. The questions covered the areas motivation/attitude, abilities (besides high school grades), and study techniques/learning strategies. The results for the groups of SI attendees and non-attendees are shown in table 3. [Obviously more rigorous and scientifically tested methods, like for instance *Study Process Questionnaire* (Biggs, Kember, & Leung, 2001) or *Approaches to Studying Inventory* (Entwistle & McCune, 2004) for measuring learning approach, are needed to conclusively determine whether there are differences between the groups of SI attendees and non-attendees in the areas covered here. However, this would also require several different and extensive questionnaires to be given to the new students, which was not considered possible at the time. Therefore, we decided to employ a simpler and more general inquiry.].

In total 92 % of 390 SI attendees filled in and returned the questionnaire. Of the 285 non-attendees, 85 % answered it. Significant differences in answers between SI attendees and non-attendees were the following:

1. SI attendees are a little more motivated to study.
2. SI attendees are a bit better in working in groups.
3. A slightly higher percentage of SI attendees come from families where a higher education is unusual.
4. SI attendees are also characterized by a better learning strategy in that
   a) they have better attention spans and can study for longer periods of time,
   b) they are less dependent on “last-minute” efforts, and
   c) they are used to helping/being helped by classmates in understanding difficult problems in a course.

In order to see whether these differences could lead to significant differences in study results between the SI attendees and non-attendees, we need to see if students giving different answers to a question have different study results. This can be done by comparing the results on the first major exam in Calculus in One Variable for students giving different answers on a question; see Table 4. In most cases the differences in exam results are small between the students giving different answers on a question. Some more pronounced differences are likely due to the fact that the number of students representing one of the answers is small, leading to larger uncertainties. Statements from students who have significant differences in exam results among them include the following:

1. “I like mathematics.” (Exam results show that the liking is reciprocated.)
2. “I’m worried whether I will be able to pass the mathematics courses.” (Exam results show that these worries to some extent are justified.)
3. “I’m good at solving problems in subjects like mathematics and physics.” (If so, you have on average a better result on the exam.)
4. “My studies usually come easy to me.” (If so, the results are definitely better than if not.)
5. “I took my courses in high school largely by cramming at the last minute before major tests.” (If so, the chances of success on the exam were smaller compared to students who did not resort to “last-minute” studying).

For the first four questions there are no significant differences in answers between SI attendees and non-attendees. Instead, we focus on the last point regarding how differences in studying approaches affect the results on the exam for the groups of SI attendees and non-attendees. It is obvious that better learning techniques benefit the SI attendees on the exam. A simple estimate from the tables shows, however, that this advantage is small – less than two percent more students passed the exam among the SI attendees. We can therefore conclude that the combined effect of differences in motivation/attitude, ability, and study techniques/learning strategy, as measured by the questionnaire, is very small indeed on the results in the calculus course between SI attendees and non-attendees. There are most likely other effects than the ones investigated above that contribute to the comparative success of SI attendees in the calculus course, but it does not seem likely that they completely eradicate the effect of the SI sessions themselves on

Table 3
Comparison of Questionnaire Answers Between SI Attendees and Non-attendees in the First Quarter of the Academic Year (an SI attendee is defined as a student who participated in three or more SI sessions during the first quarter)

Question	SI attendee			Non-attendee		
	True	Neither true nor false	False	True	Neither true nor false	False
Motivation/Attitude						
I 'm confident that the engineering education I've started is right for me	77%	17%	6%	72%	19%	9%
I'm very motivated to study	86%*	11%*	3%*	79%*	18%*	3%*
I like mathematics	75%	19%	5%	73%	20%	7%
I'm very interested in the courses that are included in my engineering program	83%	14%	3%	82%	15%	3%
I'm worried whether I will be able to pass the mathematics courses	39%	30%	32%	32%	29%	39%
Abilities						
I'm good at solving problems in subjects like mathematics and physics	63%	33%	4%	66%	26%	8%
I'm good at working with others in a group	88%**	10%**	2%**	79%**	16%**	5%**
I'm from a family where a higher education is unusual	29%*	19%*	52%*	24%*	13%*	63%*
I'm good at thinking critically/analytically	70%	26%	4%	69%	27%	4%
My studies usually come easy to me	70%	27%	3%	70%	27%	3%
Study techniques/Learning strategy						
I went through my courses in high school largely by cramming at the last-minute before major tests	26%**	26%**	48%**	38%**	28%**	35%**
I'm used to helping/being helped by my classmates in understanding difficult problems in a course	66%**	25%**	10%**	61%**	20%**	18%**
I had a good attention span in high school and could spent a lot of time studying	44%**	29%**	27%**	32%**	30%**	38%**

Note. Statistically significant differences in distribution of answers between SI attendees and non-attendees using a chi-square test are marked with *, **, and *** (corresponding to $p < 0.05$, $p < 0.01$, and $p < 0.001$).

course results. (A small-scale study by Parkinson (2009) in which self-selection bias was eliminated showed significantly better results in mathematics for SI attendees.). One possible factor not investigated here is the "double exposure" to the subject received by attending SI (once by attending the usual lectures and classes and an additional time by attending SI sessions). Kenney & Kallison (1994) did an investigation on a college-level calculus course for business majors to address this question. Two classes with the same lecturer and course content (and equivalence between students in the classes with respect to a list of factors like mathematics ability and achievement measures, gender, ethnicity, etc.) were followed, one where the teaching assistants (TA's) were using a traditional content-only focus and one where the TA's were using SI methodology. A comparison showed that the final course grades were significantly higher for the SI group, thus indicating that the success of the SI attendees is not just a "double exposure" effect.

Table 4

Comparison of Questionnaire Answers to Results on the First Exam in Calculus in One Variable

Question		True	Neither true nor false	False
Motivation/Attitude				
I 'm confident that the engineering education I've started is right for me	Number of students	438	101	32
	Percentage passing exam	60	49	50
I'm very motivated to study	Number of students	483	81	15
	Percentage passing exam	59	52	47
I like mathematics	Number of students	432	114	34
	Percentage passing exam	60*	53*	35*
I'm very interested in the courses that make up my engineering program	Number of students	484	76	16
	Percentage passing exam	59	46	62
I'm worried whether I will be able to pass the mathematics courses	Number of students	208	175	196
	Percentage passing exam	47***	58***	67***
Abilities				
I'm good at solving problems in subjects like mathematics and physics	Number of students	372	175	33
	Percentage passing exam	64***	46***	39***
I'm good at working with others in a group	Number of students	492	70	19
	Percentage passing exam	57	57	63
I'm from a family where a higher education is unusual	Number of students	158	97	325
	Percentage passing exam	56	56	58
I'm good at thinking critically/analytically	Number of students	406	150	22
	Percentage passing exam	59	51	68
My studies usually come easy to me	Number of students	407	153	20
	Percentage passing exam	61*	56*	35*
Study techniques/Learning strategy				
I took my courses in high school largely by cramming for tests at the last-minute	Number of students	188	153	247
	Percentage passing exam	49***	51***	65***
I'm used to helping/being helped by my classmates in understanding difficult problems in a course	Number of students	370	132	76
	Percentage passing exam	58	57	54
I was good at studying continuously in high school	Number of students	227	169	181
	Percentage passing exam	63	56	52

Note. Statistically significant differences compared to the average percentage of students passing the exam using a chi-square test are marked with *, **, and *** (corresponding to $p < 0.05$, $p < 0.01$, and $p < 0.001$).

Conclusions

The study shows that students improve their chances of passing a difficult introductory calculus course by attending SI sessions. The more sessions the student attends, the greater the chances of success in the course. For students with high SI attendance, 79 % of the students received a passing grade in the course within the first academic year (2009/10) compared to only 39 % of the students who did not attend any SI sessions. An average or high attendance at SI sessions significantly increases the chances of passing the calculus course irrespective of prior mathematical ability (expressed in terms of average mathematics grades from high school). Perhaps the most perplexing finding is that students with a "weak" mathematical ability in high school but high SI attendance pass the course almost at the same rate as students with a "strong" mathematical ability in high school and non-attendance at SI.

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