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The potential of supplemental instruction in engineering education: creating additional peer-guided learning opportunities in difficult compulsory courses for first-year students

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ABSTRACT

Supplemental Instruction (SI) can be an efficient way of improving student success in difficult courses. Here, a study is made on SI attached to difficult first-year engineering courses. The results show that both the percentage of students passing a difficult first-year engineering course, and scores on the course exams are considerably higher for students attending SI, compared to students not attending. The study also shows that a higher percentage of female students attend SI, compared to male students. However, both genders seem to benefit to the same degree as a result of attending SI meetings. Also all students, independent of prior academic ability, benefit from attending SI. A qualitative study suggests that SI meetings provide elements important for understanding course material, which are missing from other scheduled learning opportunities in the courses.

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1. Introduction

Engineering education is often considered demanding, leading to both dropouts and students taking longer than stipulated duration to attain their degrees. There are many reasons why it is difficult to keep the pace in engineering studies, but an important one is that several courses are generally considered hard to pass. There are many ways to try to increase students' learning achievements in challenging courses, such as changing the presentation of course material, using different pedagogical approaches as well as providing support measures for students at 'risk'. Another possibility is a low-budget approach called Supplemental Instruction (SI), which is the focus of the present study.

In the study, SI is applied to difficult first-year engineering courses. The emphasis is on the SI methods' potential to enhance student performance – an area of interest for engineering educators who want to improve student success in difficult courses. The article starts with a description of SI, followed by background to the study and resulting research questions. Thereafter, the application of SI in the study setting is outlined, followed by descriptions of the collected data, results from the study and conclusions.

1.1. *Supplemental Instruction (SI)*

SI is a method that was created at the University of Missouri-Kansas City, USA, in the 1970s, to increase both the performance and retention of students in high-risk courses (Hurley, Jacobs, and Gilbert 2006). Since then it has spread widely and the staff at more than 1500 universities and colleges in some 30 countries have been trained in the methodology (Martin 2008). SI is a complement to the

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regular education provided in a course, and targets the part of student time used for self-studies. The idea is to create discussions among students following the course on material covered in lectures, exercises, etc., in a non-threatening environment. In this way you can ask questions about the material you did not understand and did not dare to bring up during the scheduled classes (you don't want to look a fool in front of the professor), get alternative views of the material, challenge your own understanding, etc. In order for the meeting to be ordered and efficient, the meeting is guided by an 'older' student who has successfully taken the course previously and can act as a model-student. This SI leader does not act as a teacher and does not give answers to questions. Instead he/she facilitates the discussions, group work, presentation of results and other activities. The SI leader is trained in the concept of SI, collaborative techniques, group dynamics, etc., before starting his or her work, and is supervised continuously thereafter.

1.2. *Background to the study*

Supplemental Instruction is used in all types of subjects and courses such as languages, literature, philosophy, political sciences, mathematics, physics, etc. If we limit ourselves to science and engineering, there are numerous examples of SI being used in courses such as calculus, algebra, physics, statistics, chemistry and mechanics (e.g. Blat et al. 2001; Cheng and Walters 2009; Hensen and Shelley 2003; Lin and Woolston 2008; Malm, Bryngfors, and Mörner 2011; Webster and Hooper 1998). There are several potential benefits of SI – both quantitative and qualitative, but the two most frequently reported are better student results in courses with SI (e.g. Kenney and Kallison 1994; Packham and Miller 2000; Power and Dunphy 2010) and improved student retention (e.g. Blanc, DeBuhr, and Martin 1983; Bowles, McCoy, and Bates 2008; Rath et al. 2007). However, there are a number of questions regarding the reported results on the benefits of SI. Most studies on how SI affects student success in courses use powerful but crude measures. Participation in SI is generally measured by defining a prescribed minimum number of sessions a student must participate in to become an SI attendee. This minimum number is set rather arbitrarily, usually in the range 1–5 (e.g. Congos and Schoeps 1993; Hensen and Shelley 2003). Thus, the question of SI attendance is reduced to a binary number –you are either an SI attendee or not. Such a definition of an SI attendee is obviously rather questionable. Unfortunately only a few studies have focused on how the degree of SI participation affects the students' results. The results from these studies are not overly clear, but tend to show an increasing success on average with increasing SI attendance (e.g. Jones and Fields 2001; Murray 2006; Webster and Dee 1998). Thus, there is certainly a need for more of these studies in order to get a clearer and more informed picture of how the magnitude of exposure to an information-processing environment, such as SI sessions, affects student results. This is one of the objectives of the present study.

Student success in SI studies is traditionally measured by whether you pass the course or not. And in most cases there is also a differentiation in the grades the students get. However, in order to understand the potential benefits of participating in SI sessions, there is also a need for a finer grading than simply passing the course, or indeed the course grade achieved. By looking at actual examination scores, one can get a better idea of the degree of change for an average individual if he/she participates in SI. This is another objective of this study.

Another problem for the overwhelming majority of studies on student success in SI-supported courses is self-selection, since SI participation is voluntary. Therefore, it is impossible to be certain that the group attending SI share the same characteristics as the group of students choosing not to attend. Thus, the comparison of student success between SI attendees and non-attendees is (almost) always flawed. For ethical reasons it is hard to ascertain. Generally you cannot deny students the opportunity to attend SI just to get similar control groups. And in the rare case that you could divide the students into similar groups, you would have to make it mandatory for one group to attend SI, thereby compromising one of the fundamental ideas of SI. However, even if the comparison of student success between SI attendees and non-attendees will never be a fully valid one, one can try to account for as many potential differences between the groups as possible.

Surprisingly, only a few studies have tried to establish potential differences between SI attendees and non-attendees and considered the effect they may have on student performance results. The clear majority of these studies have focused on differences in prior academic ability, since this is the most obvious factor that could influence student results in a course. Almost all of these studies have shown that students attending SI have similar or lower prior academic ability than students not attending SI and that this is not a factor that explains why students attending SI perform better in course examinations (e.g. Arendale 1997; Kochenour et al. 1997; Ning and Downing 2010; Price et al. 2012). However, prior academic ability is certainly something one has to control for when analysing the impact of SI on student performances. This is also carried out in the present study.

Other potential differences between SI participants and non-participants that can affect student performance, such as gender, motivation, study habits and exposure to scheduled subject events, have received little attention in SI investigations and more information is needed in order to confirm the value of SI. Furthermore, there exist only a few investigations on which student groups (for example, academically 'weak', 'average' or 'strong'), if any, benefit the most from attending SI. The results from these investigations are not clear. There are also only a few attempts to link better performance results for SI attendees, to measurements of potential qualitative factors that can help explain why students attending SI perform better. Several of these areas are addressed below in the research questions of the study.

1.3. *Research questions*

In the present study we thus focus on some of these grey areas regarding knowledge about SI as described above. This is carried out by evaluating results from difficult introductory courses in a first-year engineering environment, based on the following research questions:

- To what extent does attending SI sessions improve student success?
- What impact does SI have on actual examination scores and is the impact different for students of different academic ability?
- Are there differences in prior academic ability, gender and subject exposure between SI attendees and non-attendees that affect comparisons?
- Are there any qualitative factors that students felt they improved upon by attending SI that can help explain differences in course performance, compared to students not attending SI?

2. Description of the SI programme at the faculty of Engineering at Lund University, Sweden

The SI programme at the faculty of Engineering is primarily oriented towards 'difficult' courses for new students. Besides helping new students to better achieve in the selected course/courses, the objective is also to provide the students with study strategies and a network of study partners to ease the transition from secondary to tertiary education, and enhance their overall performance as well as minimising early student withdrawal from their engineering studies.

Typically, a course which has SI sessions attached to it has a rather traditional pedagogic approach, with approximately 10–12 hours of lectures/exercises per week. Exercises are usually focused on individual work with a number of problems to be solved each time. The course/course module lasts eight weeks, concluding with a written five-hour examination to determine the grade for the course. The main part of the exam is usually focused on problem-solving and calculations. Two-hour SI sessions are scheduled each week and are available to all students in the course. An SI session centres on material presented in the course with which students have expressed difficulty. The SI leader organises suitable collaborative exercises to process the material and acts as a facilitator during the work. The SI leader redirects questions to other members of the group and puts emphasis on providing an open and encouraging environment. The SI session usually ends with a summary by the students where they present their conclusions for each other.

To become an SI leader, you have to go through a rather rigorous process. First of all, you have to be an active SI attendee. If you show a good combination of social and leadership skills together with a good understanding of the subject, you can be nominated for the position by your SI leader. The SI staff checks study results and invites the selected students to hand in an application for the position of SI leader. SI leaders are thereafter selected based on the application and an interview. All SI leaders undergo basic two-day training focused on SI methodology and collaborative techniques. Supervision meetings every second week during the course provide ongoing training. The meetings focus on reviewing the SI leaders' experiences, on collectively coming up with solutions to problems encountered, on different activities one can use during sessions as well as on group dynamics. Each SI leader also gets feedback from observations carried out twice during each semester. Other learning experiences for the SI leaders include writing a short reflective report after each session and a visit to another SI leader's session.

What are the incentives for a student to become an SI leader? First of all it is a paid position. Second, SI leaders receive a certificate once they have completed their work, which they can use when they seek employment. Another incentive is that SI leaders, due to their experience of similar situations during their SI leadership, tend to have advantages in project and team work situations as well as developing interpersonal skills in contacts with colleagues (Malm, Mörner, and Bryngfors 2012).

The selection process, training, supervision and observation of the SI leaders assure, as far as possible, that the sessions given actually are based on the SI methodology and collaborative methods. Therefore, the evaluation of students subject to SI sessions should thus be of students who really experienced SI and not something else.

3. Data and research methodologies

Quantitative and qualitative data were collected during the academic years 2010/2011 and 2011/2012. The investigated student group was first-year engineering students from nine engineering programmes (Biotechnology, Chemical Eng., Civil Eng., Computer Science, Electrical Eng., Environmental Eng., Industrial Eng. and management, Information and Communication Technology and Surveying). The size of the student group was approximately 700 each academic year. The quantitative data consist of SI-attendance data, results in the course and data on point grade averages in mathematics from upper secondary school (the measure of prior academic ability that is most relevant here). The courses with an SI programme attached to them are given in Table 1. All courses are run in the first year of the engineering programmes. Attendance data on scheduled ordinary exercises for two programmes in the calculus course were provided by the department of mathematics during the

Table 1. Courses with SI attached to them and the number of registered students (for both the 2010/2011 and 2011/2012 academic years) having access to SI in the courses.

Course	Course credits (ECTS)	Number of registered students
Calculus in one variable	15	1380 (1043 registered students having access to SI over at least two quarters)
Linear algebra	6	651
Mechanics	7,5	71
Introductory chemistry	5	118
General and inorganic chemistry	7,5	91
Organic chemistry	5	80

Table 2. Questionnaire to students attending SI meetings.

	Never true	Sometimes true	True about half of the time	Frequently true	Always true
By attending SI sessions, I got a better understanding of what is expected of me in the course					
The SI sessions have been an efficient support in getting through the course					
The SI sessions have contributed to increasing interest in the subject of the course					
The SI sessions have given me a deeper understanding of the course content					
By attending SI sessions, I have improved my results in the course					
Open-ended questions					
What separates SI meetings from regular exercises in the course?					
What did you get by attending SI meetings (for instance, in terms of skills, knowledge, etc.)?					

academic year 2010/2011. The examination results were analysed with respect to the degree of attendance at SI sessions in the course, prior academic ability and gender. Obtained differences in results between different attendance groups were then analysed using statistical significance tests (chi-square and *t*-tests).

The qualitative data were obtained from a questionnaire that was handed out to SI attendees to obtain their views on potential benefits of SI in relation to the course. The questions from this survey are given in Table 2. The first part of the questionnaire consists of statements regarding how attendance at SI sessions assisted students on different aspects in the course. Here, the responses are rated according to a Likert-type scale in a quantitative manner and are therefore not purely qualitative. The student responses to the two concluding open-ended questions are investigated using content analysis (i.e., dividing student responses into themes such as ‘collaborative learning’ and ‘student-centered learning environment’).

4. Results

4.1. *SI attendance vs. registered students passing a course*

In Table 3 the percentage of registered students passing different courses is given as a function of SI attendance expressed in attendance hours. All courses in Table 3 span one quarter of an academic year. The corresponding results for the course Calculus in One Variable are given in Table 4. It is the most extensive course and spans over two or three quarters (this course has two tracks – one

Table 3. Percentage of students passing courses supported by SI as a function of SI attendance. Data from the academic years 2010/2011 and 2011/2012. The number of students in the courses was fairly evenly distributed between the different SI attendance groups.

	Percentage of registered students passing course				
SI attendance (contact hours)	Linear algebra	Mechanics	Introductory chemistry	General and inorganic chemistry	Organic chemistry
None (0)	49% (83 of 168)	71% (20 of 28)	53% (8 of 15)	29% (7 of 24)	53% (8 of 15)
Low (2–4)	58% (69 of 119)	80% (8 of 10)	57% (13 of 23)	39% (9 of 23)	60% (9 of 15)
Average (6–8)	72%*** (113 of 158)	79% (15 of 19)	61% (28 of 46)	77%** (10 of 13)	76% (13 of 17)
High (≥ 10)	87% *** (176 of 203)	93% (13 of 14)	79% (27 of 34)	89%*** (25 of 28)	100%*** (33 of 33)

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

Table 4. Percentage of students passing the course calculus in one variable vs. SI attendance. Data from the academic years 2010/2011 and 2011/2012, for students having access to SI in the course during one semester (two quarters).

SI attendance (contact hours)	Percentage of registered students passing course
None (0)	37% (36 of 97)
Low (2–8)	36% (69 of 193)
Average (10–16)	54 %** (121 of 224)
High (≥18)	72% *** (383 of 529)

Note: The number of students in each attendance group was 97 (no attendance), 193 (low attendance), 224 (average attendance) and 529 (high attendance). Statistically significant differences in results using the chi-square test with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the student groups not attending SI sessions, are marked with *, ** and ***.

fast and one slow). All students registered in the calculus course and having access to SI over at least two quarters are included in Table 4.

The results show that the percentage of students passing the courses is higher for students attending SI, independent of course subject. For the two mathematics courses, which have many students, the pass rates are significantly better for students attending SI at both the average and high level. In these courses students almost double their chances of passing the course by being frequent participants at SI sessions compared to not attending at all. The tendency is the same for the other courses, illustrating that SI seems to improve results independent of the subject. Here, however, the student numbers are generally too small to obtain statistical significance.

The results in Tables 3 and 4 show that there is a clear relationship between SI attendance and student success in the course. The more you attend, the more likely you are to pass the course. If SI works as intended – helping students to process and reflect on course material, providing insights into other views on course material, training students to become active learners and take responsibility for their studies, etc. – it is natural that student performance will increase the more you attend SI. Thus, the results in Tables 3 and 4 are not surprising. Other studies have shown similar results (Coe, McDougall, and McKeown 1999; Murray 2006; O'Donnell 2004). However, in some studies (Arendale 1997; Jones and Fields 2001), there has not been an obvious ongoing increase in student performance with an increase in SI attendance. This definitely raises the question of how effective SI is in different circumstances.

4.2. *SI attendance vs. exam results with regard to prior academic ability*

The difference in the percentage of students who pass the course provides no information as to what extent an average SI attendee performed better in the course. Also the above numbers do not account for differences in prior academic performance. In order to analyse these items, we will focus on exam scores in the two mathematics courses, where the number of registered students is relatively high allowing for a test on statistical significance. Furthermore, we will account for prior academic ability in the form of grade point average (GPA) in mathematics in upper secondary school. The GPA in mathematics in upper secondary school gives, on average, quite a good indication as to how the student will do in the mathematics courses at the faculty of engineering, as seen in Figure 1. For students with the lowest GPA in mathematics in upper secondary school, about 20–30% pass the two university courses in mathematics. For students with average and high GPA, those percentages are about 50% and 85%, respectively. Thus prior academic ability in the form of upper secondary school GPA in mathematics gives a good indication, on average, of how the student will manage at university in the same subject, and should be taken into account.

The exam results vs. SI attendance for the two mathematics courses are given in Table 5. The exam results are given in percent with correction for prior academic ability. The correction was made based on a linear regression between exam results and GPA in mathematics in upper secondary school. For the calculus course, we used final exam data from the first part of the course. The reason that we focused on this part was that we had about 30% more students who had SI connected to their

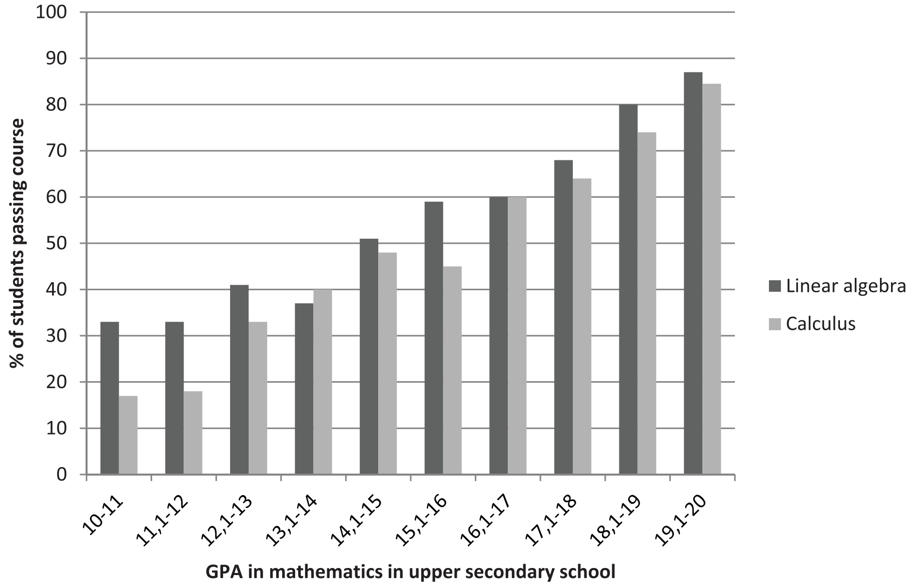

Figure 1. Percentage of students who passed the calculus and linear algebra courses vs. GPA in mathematics in upper secondary school. A GPA of 10.0 corresponds to a passing grade, while a GPA of 20.0 corresponds to grade excellence.

Table 5. Exam results for the academic year 2010/2011 and 2011/2012 in the calculus, part 1 (C1) and linear algebra (LA) courses vs. SI attendance (in contact hours). The exam results are expressed in percent and given in corrected form (where prior academic ability is accounted for).

	SI attendance							
	None (0)		Low (2–4)		Average (6–8)		High (≥10)	
C1	LA	C1	LA	C1	LA	C1	LA	
No of students	123	138	175	104	259	149	823	197
GPA in mathematics in upper secondary school	17.2	17.3	17.1	17.8	17.0	17.3	17.2	17.9
Exam results (corrected), in % of maximum	51	53	52	54	54	63***	60***	67***

Note: Statistically significant differences using an independent *t*-test (two-sided distribution) with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the group of students not attending supplemental instruction, are marked with *, ** and ***.

course in the first quarter of the year. The number of SI sessions available was also about the same as for the linear algebra course, which simplifies comparisons. One difference is, however, that the linear algebra course was given either in quarter two or three; thus, the students may have had experience from SI previously, which theoretically might make it easier for them to adjust and take advantage of a different learning environment. This was not the case for the calculus course, possibly leading to some differences in the results.

As seen in the table the difference in prior academic ability between groups of students with no, low, average and high SI attendance is marginal and actually represents a good spread between students with low, average and high academic ability in all attendance groups. This result agrees well with several other studies as presented above. Thus, SI does not appear to be seen as an extra learning opportunity for 'weak' students or something that is just for the 'strong' students. This is good information, since SI is intended for all, and a good mix between abilities is seen as an advantage for producing good sessions. The small differences in academic ability between the attendance groups mean that the corrections of the examination marks are minor. The examination marks are on average some 10–15 percentage-units higher for the group of students with high SI attendance compared to that of the group not attending SI. This means that the actual performance of the frequent SI attendees at the examinations is about 20–25% higher compared to that of the students not attending SI. These are substantial and strongly statistically significant differences. In the calculus course there are weak tendencies, showing the group with average students tending to have better results on the exam compared to the non-attendance group. However, this tendency is not statistically significant. There does not seem to be any difference between the exam results of the groups with low and no SI attendance in the calculus course. In the linear algebra course, the picture is slightly different. The group with average SI attendance clearly performs better (statistically significant), and the group with low SI attendance tends to perform better than the group with no SI attendance. As mentioned above, these result differences when compared to the calculus course may potentially be explained by the fact that students following linear algebra most likely had some experience of SI from the previous quarter, and therefore presumably found it easier to take advantage of the different types of learning opportunity that SI provides.

4.3. *Is the impact of SI dependent on gender?*

We will examine data from the same two mathematics courses as above – calculus (part 1) and linear algebra. In the data from the calculus and linear algebra courses, 32% (435 of 1380) and 37% (216 of 588), respectively, were female students. The SI attendance is in both courses higher for female students, with 10.4 and 7.3 contact hours in calculus (part 1) and linear algebra, respectively, as compared to 9.1 and 5.6 contact hours for male students. Thus, female students attend SI at a 14% and 30% higher rate, respectively, than male students in the two courses. These results, with overrepresentation of female students at SI, agree well with those found by Packham and Miller (2000) for business courses at the University of Glamorgan in the UK and Peterfreund et al. (2008) for engineering courses (including calculus) at San Francisco State University, USA. However, studies by Blat et al. (2001) for engineering courses at University of North Carolina in the USA and Parkinson (2009) in mathematics and chemistry courses at Dublin City University in Ireland showed no differences in gender proportions within groups of SI attendees and non-attendees. Thus, it is hard to draw any general conclusions as to whether female students tend to use SI to a higher degree.

In Tables 6 and 7 a comparison is made between female and male students regarding exam results in the two mathematics courses vs. their SI attendance. The previous academic ability in mathematics, as measured by the GPA in upper secondary school, favours the female students. The difference is strongly significant, which suggests that female students will perform better (and actually do) on mathematics tests before compensation for previous academic ability. The exam results show a dependence on SI attendance for both female and male students, with similar results for both genders. Students with high SI attendance have a significantly better exam score, about 20–40% higher, than students not attending SI. Also, the group with average attendance appears to perform better than the non-attendance group. Low SI attendance does not appear to give any advantages in exams, excluding the female group on the linear algebra course. The reason this group did so well is not clear. Perhaps they benefitted from attending SI previously, but then one might wonder why the corresponding male group did not show similar benefits. To summarise,

Table 6. Exam results for the academic year 2010/2011 and 2011/2012 in the calculus course (part 1) vs. SI attendance (in contact hours) and gender. The exam results are expressed in percent and given in corrected form (where prior academic ability is accounted for).

	SI attendance/gender (F = Female, M = Male)							
	None (0)		Low (2–4)		Average (6–8)		High (≥ 10)	
F	M	F	M	F	M	F	M	
No of students	23	100	52	123	82	177	278	545
GPA in mathematics in upper secondary school	17.7	17.1	17.5	16.9	17.5	16.7	18.0	16.9
Exam results (corrected), in % of maximum	49	51	51	52	57	52	60*	61***

Note: Statistically significant differences using an independent t-test (two-sided distribution) with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the group of students not attending supplemental instruction, are marked with *, ** and ***.

Table 7. Exam results for the academic year 2010/2011 and 2011/2012 in the linear algebra course vs. SI attendance (in contact hours) and gender. The exam results are expressed in percent and given in corrected form (where prior academic ability is accounted for).

	SI attendance/gender (F = Female, M = Male)							
	None (0)		Low (2–4)		Average (6–8)		High (≥10)	
F	M	F	M	F	M	F	M	
No of students	31	107	35	69	59	90	91	106
GPA in mathematics in upper secondary school	17.6	17.2	18.3	17.5	17.9	16.9	18.4	17.5
Exam results (corrected), in % of maximum	44	55	55*	54	62***	63*	63***	70***

Note: Statistically significant differences using an independent *t*-test (two-sided distribution) with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the group of students not attending supplemental instruction, are marked with *, ** and ***.

both female and male students benefit from attending SI sessions regularly in approximately the same proportions. This result agrees well with those published by Fayowski and MacMillan (2008) for a first-year calculus course at the University of Northern British Columbia in Canada. However in contrast, Peterfreund et al. (2008) found that male students tend to benefit more from attending SI with respect to earned grades.

4.4. *Is the impact of SI dependent on students' prior academic ability?*

The students were split into three groups: one with low upper secondary school GPA in mathematics (10–15), one with average GPA (15–18) and one with high GPA (18–20). The reason for the uneven intervals is in order to have more or less equal numbers of students in the groups. The exam results for these three groups, related to SI attendance, are shown in Table 8. The results show that all three groups of students benefit from attending SI in both courses. The substantially better exam results for the high attendance group compared to the non-attendance group are statistically significant in all cases. Thus, students seem to benefit from attending SI, independent of whether they were high, average or low achievers in mathematics in upper secondary school. These results agree well with those presented by Arendale (1997), for a variety of courses at the University of Missouri-Kansas City, USA. A couple of other studies have come to other conclusions, however. Kenney and Kallison (1994) concluded that low-ability students attending SI benefitted disproportionally more in two calculus courses at the University of Texas, compared to high-ability students. In a study by McCarthy, Smuts, and Cosser (1997) for an engineering course at the University of

Table 8. Exam results 2010/2011 and 2011/2012 (in % of maximum) in the courses calculus, part 1 (C1) and linear algebra (LA). The results are given vs. SI attendance for groups of different prior academic ability.

	Number of students		Exam result	
SI attendance (contact hours)	C1	LA	C1	LA
Low GPA in mathematics (10.0–15.0) in upper secondary school				
None (0)	33	31	33	37
Low (2–4)	46	19	36	36
Average (6–8)	72	38	39	48
High (≥ 10)	210	31	48***	50*
Average GPA in mathematics (15.1–18.0) in upper secondary school				
None (0)	35	49	49	43
Low (2–4)	62	31	48	48
Average (6–8)	92	46	50	56**
High (≥ 10)	278	63	56*	66***
High GPA in mathematics (18.1–20.0) in upper secondary school				
None (0)	55	58	64	66
Low (2–4)	67	54	64	66
Average (6–8)	95	65	66	73*
High (≥ 10)	334	103	72**	75**

Note: Statistically significant differences using an independent *t*-test (two-sided distribution) with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the group of students not attending supplemental instruction, are marked with *, ** and ***.

Witwatersrand, Johannesburg, South Africa, they found that only students with low prior academic ability achieved statistically significantly better marks compared to their non-attendee counterparts. For students of average or high prior academic achievement, no significant difference in marks between SI attendees and non-attendees was found. The results from the latter studies are rather surprising since theoretically SI sessions should benefit all students independent of ability. A possible explanation could be the way the SI programme was set up. However, such data were not available in the different studies.

4.5. *Are course results related to time of scheduled subject exposure? Comparison of regular exercises and SI sessions*

We used attendance data that were available for two engineering programmes, from regular exercises and SI sessions during the first quarter of 2010/2011. The relation, between exercise attendance (grouped as low, average or high) and exam results on the first part of the calculus course, is given in Table 9. A similar comparison, but using SI attendance data, is given in Table 10. The exam results are similar for different attendance groups for regular exercises. The group with high attendance achieves a few percent higher exam results. The same comparison with respect to SI attendance shows greater differences in exam results between the groups. Both the average and high attendance groups have markedly higher exam results compared to the low attendance group, being in the range 10–20% higher. The difference in exam results between the group of students with low and high SI attendance is strongly statistically significant. Thus, one can conclude that the positive effect of SI on exam results can hardly be just an effect of more scheduled exposure to the subject. This agrees well with the findings of Kenney and Kallison (1994), using different methodology and students subject to the same amount of scheduled course time but following different disciplines – either with conventional tutorials or SI meetings.

4.6. *Qualitative results from questionnaire*

It is apparent from the results above that students who attend SI meetings perform better on course examinations. But what are the views from students themselves on what SI provides? Student answers on some questions related to this are given in Figure 2. It is evident that SI provided help in several different regards. A clear majority of the students attending SI felt that they got a better understanding of what is expected of them in the course, that SI was an efficient support in getting through the course and most importantly that SI gave the students a deeper understanding of course content. Roughly half of the students answering the survey felt that SI contributed to an increase in their interest for the subject in the course. Obviously, all of these are factors that should influence student performance and help explain why the exam results were better for SI attendees. Almost 60% of the students answering the survey also thought that attending SI improved their course results.

The results from the questionnaire suggest some potential reasons why SI participants performed better in the investigated courses. However, it is not possible to ascertain this without a comparison with students not attending SI on, for instance, change in understanding of course content, study

Table 9. Scores on the first calculus exam as a function of attendance (in contact hours) at regular exercises during the first quarter. The exam results are expressed in percent and given in corrected form (where prior academic ability is accounted for).

	Attendance at regular exercises (contact hours)		
Low (0–12)	Average (14–20)	High (22–28)	
No of students	40	39	70
Exam results (corrected), in % of maximum	52	52	55

Note: Statistically significant differences using an independent t-test (two-sided distribution) with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the group of students with low attendance, are marked with *, ** and ***.

Table 10. Scores on the first calculus exam as a function of attendance (in contact hours) at SI sessions during the first quarter. The exam results are expressed in percent and given in corrected form (where prior academic ability is accounted for).

	Attendance at SI sessions (contact hours)		
	Low (0–4)	Average (6–8)	High (≥10)
No of students	66	35	48
Exam results (corrected), in % of maximum	49	53	60***

Note: Statistically significant differences using an independent *t*-test (two-sided distribution) with $p < 0.05$, $p < 0.01$ and $p < 0.001$ compared to the group of students with low attendance, are marked with *, ** and ***.

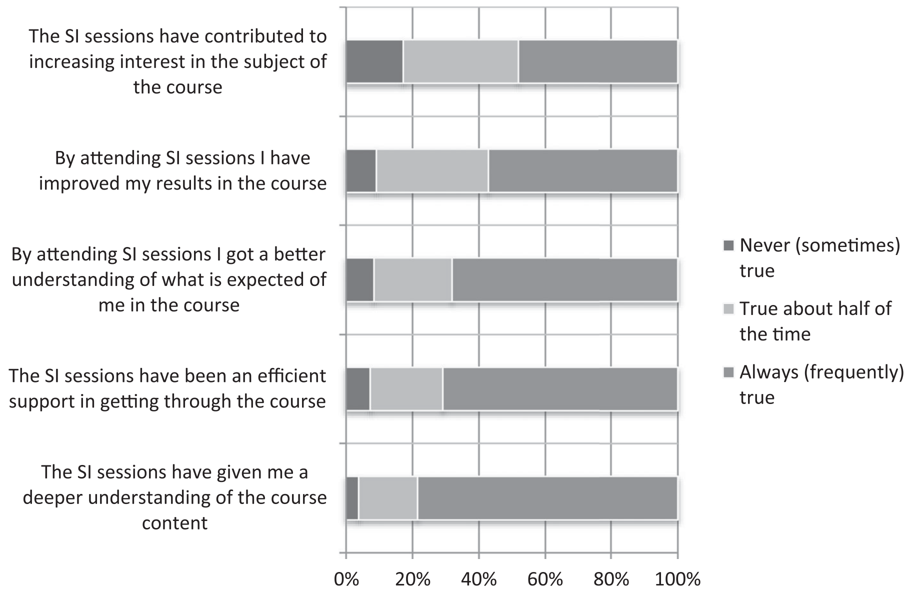

Figure 2. Views from attending students on some aspects of SI that may influence first-year student achievement in the course. The survey was handed out to students with an average to high SI attendance during the last SI session of the autumn semester 2010 and 2011. Of 1071 (72%) of these students, 769 handed in completed surveys.

behaviour and attitudes. Such a comparison was not performed here. However, the open question on the student survey on ‘what separates SI meetings from regular exercises in the course?’ can provide some insight into what SI can add, regarding the student learning environment, and thus what SI attendees might gain by attending SI. Given below are a few examples of answers, divided into three main themes (underlined) based on content analysis, echoing the sentiments from many others:

Student-centred and adjusted study pace

- “SI meetings are on our terms and we decide what we should focus on.”
- “You can ask questions you don’t dare to/will not/cannot otherwise.”
- “You work at a slower pace and in depth on issues you don’t understand.”
- “At SI meetings you discuss more – quality before quantity. In regular exercises, I often feel stressed and don’t spend enough time understanding a problem. I often feel satisfied if I get the right answer.”

Discussion and collaboration

- “The possibility of a completely open discussion and thorough repetition. That we can explain for each other, and get encouragement solving the problem more than obtaining the answer.”

- "You discuss and help each other more. In regular exercises you make calculations on your own, while in SI meetings you solve problems together and cooperate."
- "SI is more exciting and instructive as you get a chance to discuss solutions and hear other students' train of thought."

Understanding

- "In regular exercises it's just calculations, while on SI you ask yourself the questions 'why?', 'what will happen if I change these values?', etc."
- "The comfort of discussing problems in the course with fellow students, which develops understanding as well as confidence."
- "In SI meetings I reflect much more on what I do. In regular exercises I just do and 'get through' calculation problems from the book without understanding what I really did; that is, deeper understanding on SI."
- "We learn things in SI. Lectures provide the information, but it is in SI we understand what it is about."

From these answers we can see that SI meetings differ from regular exercises in the sense that it is a scheduled learning opportunity where the students themselves decide what material they want to cover. The processing of course material is also different, as it is based on exchange of thoughts and collaboration between students. Further, according to the students, SI meetings seem more geared towards the objective of understanding course material as compared to the regular exercises. The fact that SI meetings are focused on the understanding of course material also shines through in many of the answers to the open-ended survey question 'What did you get from attending SI meetings (for instance, in terms of skills, knowledge, etc.)?' This can be illustrated by the following answer:

- "I understood how important it is for understanding, to discuss and reason in a group (of students) and how much you learn by having to explain in your own words."

Based on the answers to these open-ended questions, we can conclude that SI seems to provide a different learning environment, which promotes a deeper understanding of course material – at least according to some students. Thus, it is not surprising that students attending SI performed better on exams compared to students not attending SI.

5. Conclusions

The results from this study show that both the percentage of students passing a difficult first-year engineering course, and scores on the course exams are considerably higher for students attending SI compared to students not attending. There is also a clear relation between SI attendance and student performance, with higher attendance leading to higher student performances. The study also shows that female students are attending SI at a higher rate than male students. However, both genders seem to benefit to the same degree by attending SI meetings. Also all students, independent of prior academic ability, benefit from attending SI. Furthermore, the study shows that the reasons why students attending SI are more successful cannot be explained purely by an increase in scheduled 'exposure' time for course material. Instead, a qualitative study based on a questionnaire to students attending SI suggests that SI meetings provide elements missing in other scheduled learning opportunities in the courses, which are important for understanding course material.

The results of the study show that SI can be a useful complement to regular teaching in an engineering course, leading to improved student results. SI provides an opportunity to study and discuss course content in depth in a safe environment and at a student-adjusted pace. Furthermore, SI combines what to learn with how to learn under the guidance of an older successful student who guides the meetings and acts as a role model. Thus, SI can be especially beneficial when implemented in the first courses in an engineering education.

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No potential conflict of interest was reported by the authors.

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