The potential of Supplemental Instruction in engineering education

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INTRODUCTION

Engineering education is often considered demanding, leading to both drop-outs and students taking longer than stipulated 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 the 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, which is the focus of the present study.

So what is Supplemental Instruction (SI)? It 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 ([1]). 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 ([2]). SI is a complement to the 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 material you did not understand and did not dare to bring up during the scheduled classes (you don't want to look like a fool in

front of the professor), get alternative views of the material, and challenge your own understanding, etc. In order for the meeting to be structured 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 their work, and is supervised continuously thereafter.

Supplemental Instruction is used in all types of subjects and courses such as languages, literature, philosophy, political sciences, mathematics, physics, etc. 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 ([3], [4], [5]) and improved student retention ([6], [7], [8]). However, there are a number of question marks regarding the reported results on the benefits of SI.

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

- 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 and gender proportions 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?

1 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 minimizing 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.

2 DATA

Quantitative and qualitative data were collected during the academic years 2010/11 and 2011/12. The quantitative data consists 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 quantitative data presented here is restricted to one course in Linear algebra since data from all courses with SI at the faculty of engineering show similar results. The qualitative data was 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 and responses are presented in the text below.

3 RESULTS

3.1 SI-attendance vs. exam results with regard to prior academic ability

The exam results vs. SI attendance for the Linear algebra course is given in table 1. The results show that the percentage of students passing the courses is higher for students attending SI. The pass rates are significantly better for students attending SI at both average and high level. There is also 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 regarding students passing the course in table 1 are not surprising. Other studies have shown similar results ([9], [10]). However, in some studies ([11], [12]) there has not been an obvious on-going increase in student performance with an increase in SI attendance. This definitely raises the question of how effective SI is in different circumstances.

The exam scores are given in per cent with and without 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. 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. 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 scores are some 15 percentage-units higher for the group of students with high SI attendance compared to the group not attending SI. This means that the actual performance of the frequent SI attendees at the examinations is about 25 % higher compared to the students not attending SI. These are substantial and strongly statistically significant differences.

3.2 Is the impact of SI dependent on gender?

Does gender influence the obtained results on SI shown above? Do, for instance, female students attend SI at a higher rate, and do they also perform better? If this is the case it could at least partly explain why SI-attendees perform better. We will examine data from the same Linear Algebra courses as above. In the course 37 % (216 of 588) were female students. The SI attendance is higher for female students,

with 7.3 contact hours, as compared to 5.6 contact hours for male students. Thus female students attend SI at a 30 % higher rate than male students in the course. These results, with overrepresentation of female students at SI, agree well with those found by [4] for business courses at the University of Glamorgan in the UK and by [13] for engineering courses (including calculus) at San Francisco State University, USA. However, studies by [14] for engineering courses at University of North Carolina in the USA 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.

Table 1.

Exam results in the linear algebra course vs. SI attendance (in contact hours). The exam results are expressed in per cent and given both in original and corrected form (where prior academic ability in mathematics is accounted for). Results are for the final exams during the academic year 2010/11 and 2011/12. Statistically significant differences using the chi-square test and the 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 ***. A GPA of 10.0 corresponds to a passing grade, while a GPA of 20.0 corresponds to the grade excellent.

	SI-attendance			
	None (0)	Low (2-4)	Average (6-8)	High (≥ 10)
No of course registered students	168	119	158	203
GPA in mathematics in upper secondary school	17.3	17.8	17.3	17.9
Percentage of registered students passing course	49 % (83 of 168)	58 % (69 of 119)	72 %*** (113 of 158)	87 %*** (176 of 203)
Exam results (original), in % of maximum	51	55	61***	68***
Exam results (corrected), in % of maximum	53	54	63***	67***

In table 2 a comparison is made between female and male students regarding exam results in the course 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 do better on mathematics tests before compensation for previous academic ability. The exam results show a dependence on SI attendance for both female and male students. Students with high SI attendance have a significantly better exam score than students not attending SI. Also the group with average attendance appears to do better than the non-attendance group. Low SI attendance does not appear to give the male students any advantages in exams, while the female group show clearly better results compared to female students not attending SI. The reason this latter group did so well is not clear. Perhaps it has more to do with the relatively poor results for female not attending SI previously. But why the results are comparatively poor compared to the same male student group is hard to say. To summarize – both female and male students benefit from attending SI sessions regularly in approximately the same proportions. This result agrees well with those published by [15] for a first-year calculus course at the University of Northern British Columbia in Canada. However in contrast, [13] found that male students tend to benefit more from attending SI with respect to earned grades.

Table 2.

Exam results in the linear algebra course vs. SI attendance (in contact hours) and gender. The exam results are expressed in per cent and given both in original and corrected form (where prior academic ability is accounted for). Results are for the final exam during the academic year 2010/11 and 2011/12. 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 ***. A GPA of 10.0 corresponds to a passing grade, while a GPA of 20.0 corresponds to the grade excellent.

	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 (original), in % of maximum	44	54	58*	54	64***	60*	67***	69***
Exam results (corrected), in % of maximum	44	55	55*	54	62***	63*	63***	70***

3.3 Is the impact of SI dependent on students' prior academic ability?

Does SI benefit attendees in general, independent of prior academic ability, or is it just a certain group that benefits? In order to answer this question we split the students 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 3. The results show that all three groups of students benefit from attending SI in the Linear Algebra course. The 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 [11], for a variety of courses at the University of Missouri Kansas City, USA. A couple of other studies have come to other conclusions, however. [16] 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 [17] for an engineering course at the University of 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.

4 DISCUSSION

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 Fig. 1. 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.

Table 3.
Exam results (in % of maximum) in Linear Algebra vs. SI attendance for groups of different prior academic ability. Results are for the final exams during the academic year 2010/11 and 2011/12. 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 ***.

SI-attendance (Contact hours)	Number of students	Exam result
Low GPA in mathematics (10.0-15.0) in upper secondary school		
None (0)	31	37
Low (2-4)	19	36
Average (6-8)	38	48
High (≥ 10)	31	50*
Average GPA in mathematics (15.1-18.0) in upper secondary school		
None (0)	49	43
Low (2-4)	31	48
Average (6-8)	46	56**
High (≥ 10)	63	66***
High GPA in mathematics (18.1-20.0) in upper secondary school		
None (0)	58	66
Low (2-4)	54	66
Average (6-8)	65	73*
High (≥ 10)	103	75**

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 behaviour and attitudes. Such a comparison was not made here. However, an open question on the student survey on “what separates SI meetings from regular exercises in the course?” provided some insight into what SI can add, regarding the student learning environment, and thus what SI attendees might gain by attending SI. Three main themes emerged that set SI meetings apart from regular exercises:

1. Student-centred and adjusted study pace
2. Discussion and collaboration
3. Focus on understanding

Thus 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. Therefore it is not surprising that students attending SI performed better on exams compared to students not attending SI.

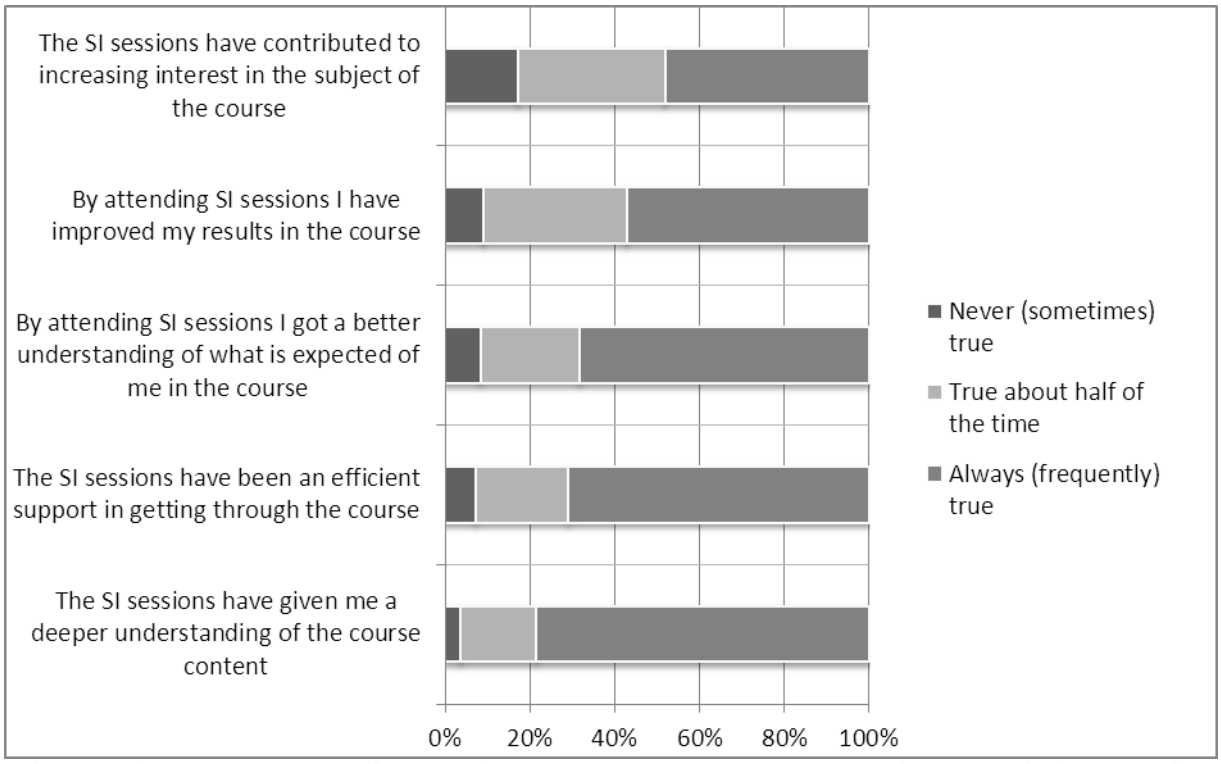

Fig. 1. Views from attending students on some aspects of SI that may influence first year student achievement in the course. The survey was handed out to students with an average to high SI attendance during the last SI session of the autumn semester 2010 and 2011. 769 of 1071 (72 %) of these students handed in completed surveys.

SUMMARY

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 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. 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.

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