Journal of Peer Learning

Volume 3 Article 5

November 2010

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Recommended Citation
Malm, Joakim; Bryngfors, Leif E. Mr; and Mörner, Lise-Lotte, Supplemental Instruction (SI) at the Faculty of Engineering (LTH), Lund University, Sweden. An evaluation of the SI-program at five LTH engineering programs autumn 2008., *Journal of Peer Learning*, 3, 2010, 38-50.
Available at:https://ro.uow.edu.au/ajpl/vol3/iss1/5

Australasian Journal of Peer Learning (2010) 3: 38-50

Supplemental Instruction (SI) at the Faculty of Engineering (LTH), Lund University, Sweden: An evaluation of the SI program at five LTH engineering programs, autumn 2008

Joakim Malm, Leif Bryngfors and Lise-Lotte Mörner

ABSTRACT

The study presents an evaluation of the SI program in five engineering programs within the Faculty of Engineering (LTH) based on data from questionnaires to SI participants and SI-Leaders, credits taken by the students during the first year, and average grade data from high school for the first year students. The results show that participation in SI sessions markedly improves the chances of student success in studies during the first year. Furthermore, there are clear indications that the SI program creates a positive social introduction to engineering studies. The SI sessions also improve the participants' study techniques and develop common skills important for the engineer, such as problem solving, group work, and presenting/discussing results.

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, and 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). (Other names for SI exist, like PASS - Peer Assisted Study Sessions, and PAL – Peer Assisted Learning, but the basics of the method are the same.)

What then is SI? First and foremost it is not just a method but an attitude to learning where inner motivation and curiosity are the driving forces and where the main emphasis is on self-governing and collective learning (Olstedt, 2005). SI is, as understood from the name, 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 between 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 senior student should not be a teacher but help in clarifying tough questions within the subject by asking questions, initiating work in small groups, and coordinating presentations of conclusions. The senior student receives a preparatory education of how to be a SI-Leader, and gets tools to use during his or her SI-sessions.

What are the objectives of the SI program at LTH? The main purposes are to bridge the gap between secondary school and university and to help the students learn skills needed to succeed at the university level. That academic support programs like SI are indeed very important for student retention has been pointed out by Tinto (2010)[1]. The

[1] The need for a strong student support system to face the growing heterogeneity among students has also been emphasised by the National Agency for Higher Education in Sweden, see

Published by the University of Wollongong
ISSN 1835-856X (print)/1836-4306 (online)

aim is to maximise the student's performance in the already critical first year of study by training them in the necessary study skills through the SI program. The goals set by the Board of the Faculty are that 75% of the incoming freshmen should pass at least 2/3 of the credits given at the first year of study (LTH, 2007). The SI program could be one way to help reaching this target. Students need to take more responsibility for their own studies at the university level, to learn to spend more time on their own, and to develop new skills needed for their studies. Such skills are problem solving, learning to get help from and ask questions of peers, working in groups, and learning to present and discuss the task and the result. In the SI sessions students learn early on, in a relaxed but structured atmosphere, how to integrate course content and study skills while working together. The sessions are facilitated by "SI Leaders", students who are not involved in the assessment of the course, who have previously done well in it, and now act as role models.

In this study we will examine the extent to which:

- the SI sessions positively affect the students' performance in the first year of study;
- the SI sessions help in reaching the LTH goal (75% of the incoming freshmen should pass at least 2/3 of the credits for the first study year);
- the SI sessions improve student performance in the first exam in the mathematics course; and
- the students feel that they improved their study skills in the SI sessions.

METHOD, DATA AND LIMITS OF SCOPE

In the study we have chosen to examine five-year engineering programs at the School of Engineering at Lund University (LTH) that have SI in one common subject – mathematics: more specifically, in the course common for all engineering first-year students, Calculus in one Variable. This is to simplify comparisons. Furthermore, we have limited ourselves to the autumn of 2008 for the five engineering programs (Information and Communication Technology, Computer Engineering, Industrial Economy, Surveying, Civil Engineering) where the authors were supervisors.

Attendance data from the SI sessions during the first half of the autumn semester (8 of 16 weeks) have been used to separate SI participants from those not attending SI.[2] At all five engineering programs the students can attend one two-hour SI session per week. To be defined as a SI participant, a student must attend 50% or more of the sessions.

For the quantitative part of the study we have used data for the credits taken by each student during the first year in the engineering program to compare student success for SI participants and those not attending SI. Regarding credits, Sweden follows the European ECTS system. The ECTS system gives 60 ECTS credits for a full year of completed studies. The engineering programs at LTH typically have a study year comprising 8 courses worth 7.5 ECTS credits each on average. Here, we determined the sum of all credits taken by a new student during the first year. This credit sum determines whether the studies were successful or not (as laid out in the strategic goal formulated by the governing board at LTH, described above).

Högskoleverket, 2009. Small-group learning, like SI, used in an engineering context may have particularly large effects on the academic achievement of underrepresented groups; see Springer, Stanne, and Donovan, 1999.

[2] The autumn semester is divided into two parts, with exams in the end of each part. The SI sessions run over the entire autumn, but are most effective in the early stages regarding bridging the gap between high school and university studies. This is also reflected in the attendance data that decrease slightly during the second half of the autumn semester when students feel more comfortable with their studies.

We have also used examination data from the exam in the first part of the mathematics course, worth 5 ECTS credits, as one of our objectives stated above was to determine whether attendance at SI sessions improves the results on the exam. This exam takes place after the first half of the autumn semester.

In order to examine whether there are differences in previous knowledge between SI and non-SI participants that must be accounted for in the quantitative analysis, we have used the grades from high school, both the total grade average and the grade average for the five mathematics courses in Swedish secondary school. For this to be understandable 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 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 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. This value for each student included in this study is used as a measure of his or her previous knowledge. Besides this full grade average in high school, we have also used the average grade in the five math courses as a measure of previous knowledge of special importance for engineering students.

For the last objective of the study – to what degree the students feel that their study skills (like problem-solving ability, ability to ask questions, discuss and cooperate, etc.) that are part of the SI-sessions have developed, we used a qualitative method - a questionnaire to SI participants and SI-Leaders at LTH. The form consisted of statements regarding their skills (and how they perceived the SI sessions in general). These statements were to be answered in one of five steps between true and false. Furthermore there were open questions both for SI participants and SI-Leaders to get some depth in their views towards the SI sessions (questions like “What is the best thing about the SI sessions?”, “What needs to be improved with the SI sessions?”, “Describe briefly what an SI session is according to you?”). The questionnaire was handed out and collected after the first half of the autumn semester.

RESULTS

Student Performance

We start by analysing whether SI participation leads to an improved student performance both on a course level and for the first year as a whole. In Table 1, student performance during the academic year 2008/09 is compared between SI and non-SI-participants. The two groups are equal in numbers with 209 students being SI-participants and 209 not attending SI. The number of students not completing the first year is higher for those not attending SI: 23 individuals compared to 11 in the SI-participant category. The difference between the groups in average high-school grades is small (especially compared to the span between the lowest and highest grade that is 10 units). Thus it does not seem like there is a considerable difference in previous knowledge between the groups, see also below. The difference in result regarding the percentage who passed the first exam in Calculus in one Variable is 15% higher for the SI-participant group, thus a notable difference. The largest difference in student performance between SI and non-SI participants is in the number of credits taken as a whole during the first year. The average ECTS credit for those who completed the first year is 51.2 of 60 for SI participants and 44.5 for those who did not attend SI - a difference of 6.7 ECTS credits. Regarding the strategic goal for LTH that at least 75% of the students should take a minimum of 40 ECTS credits during the first year: 79% in the SI group passed this goal compared to 55% in the other group, thus a considerable difference.

Table 1

	SI participant	Non-SI- participant
Number of students	209	209
Average grade from secondary school	17.1	16.8
Average grade in mathematics in sec. school	17.0	16.7
Number of students who did not complete the first year	11	23
Percentage of course-registered students who passed the first mathematics exam	70% (147 of 209)	55% (114 of 209)
Student average of ECTS credits taken during the first year as a whole	51.2	44.5
Percentage of all new students with an ECTS credit total of at least 40 during the first year (the LTH strategic goal limit)	79% (165 of 209)	55% (115 of 209)

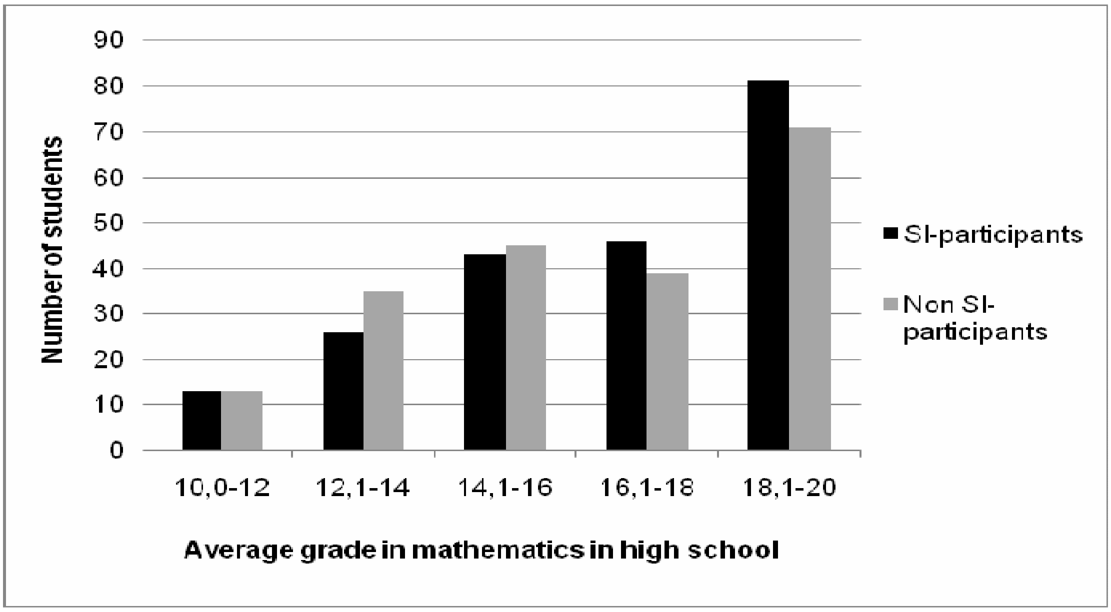
Comparison of student performance during the first year between SI participants and non-SI participants. The data is from five engineering programs at LTH.

Does the difference in student performance between SI and non-SI students vary with low, average and high grades from high school? And does the difference in the high school grade average of 0.3 between SI- and non SI-participants have a significant influence on the numbers presented above?

To seek the answers to these two questions we start this part of the investigation by comparing examination numbers in the first exam in the Calculus in one Variable course. A division of the students registered in the course into five groups with regard to their average grade in mathematics in high school shows a relatively even number of SI and non-SI participants in each of the five grade groupings, see Figure 1. There are, however, a slightly higher number of SI participants with higher grades – a reflection that SI participants on average have a slightly higher grade in mathematics from high school. It should be noted that there are relatively few students with an average mathematics grade ranging from 10 to 12. Some caution should therefore be used in evaluating students with low grades. By making this division in five grade groups we neutralise the difference in previous knowledge in mathematics as expressed by the high school grades. If participation in SI does not affect the results in the examination, the SI and non-SI participants should have the same results for each of the grading groups. This is, however, not the case, which is shown in Figure 2. The difference in the percentage who passed the exam (to the advantage of SI participants) is about 10-15% in four of the five grading groups. In the fifth grading group – 10-12 – there are just five (two SI participants and three non-SI participants) who passed the exam: the population is too small to say anything about the SI effect. Thus there are clear differences in student performance in the first mathematics exam between SI and non-SI students independent of grades from high school.

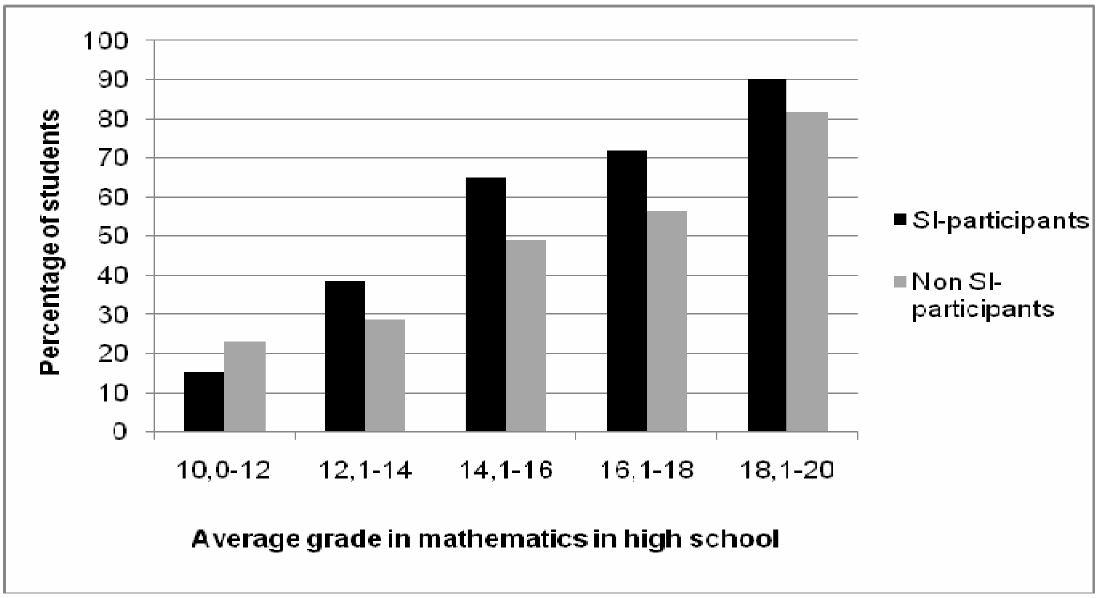
The next step in the investigation is to compare student performance over the first year as a whole taken in relation to high school grades. The process is exactly as above: dividing the results into five high school-grade groups. Here we used the average mathematic grade in high school as a measure of previous knowledge (the total average grade in high school was shown to yield similar results). In order to compare the number of credits taken per student during the first year, we first have to show the distribution of students who completed year one in relation to their average mathematics grade in high school, see Figure 3. The distribution is essentially the same as in Figure 1, but with a slightly lower number of students. There is a notable difference in average ECTS credits taken per student for SI and non-SI participants for each grade interval see Figure 4. Excluding the grade interval 10-12 with few students, the ECTS credit difference per student is between 5-8 in favor of SI-participants for the different grade groups.

Figure 1



Number of students (SI-participants and non SI-participants) in relation to their mathematics grade in high school. (The number of students with complete mathematic grade from high school was slightly less than 418).

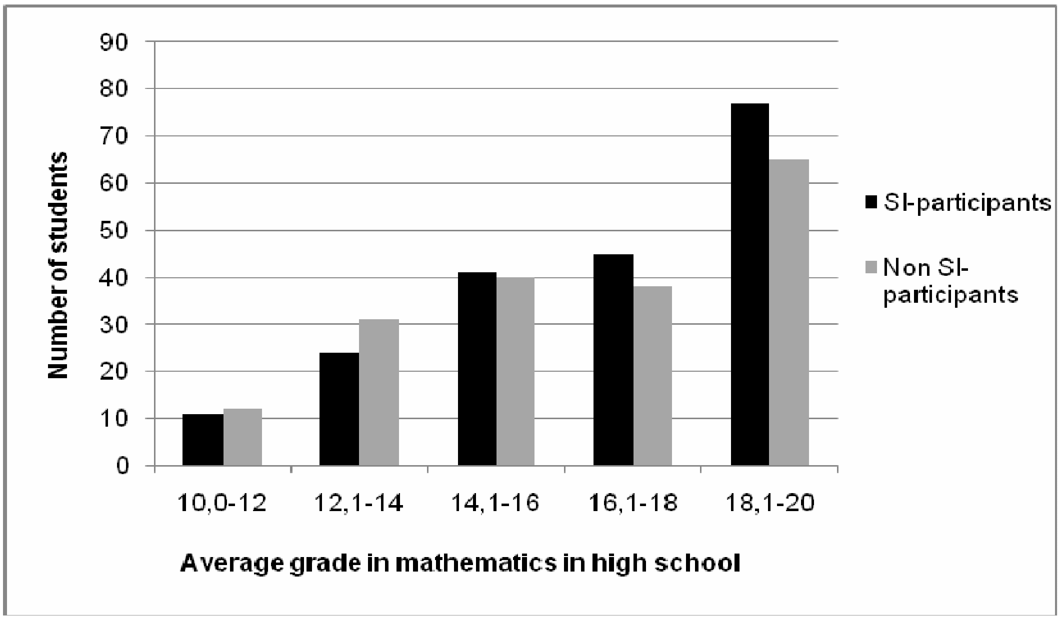
Figure 2



Percentage of students (SI-participants and non SI-participants) who passed the first mathematics exam at university in relation to their mathematics grade in high school.

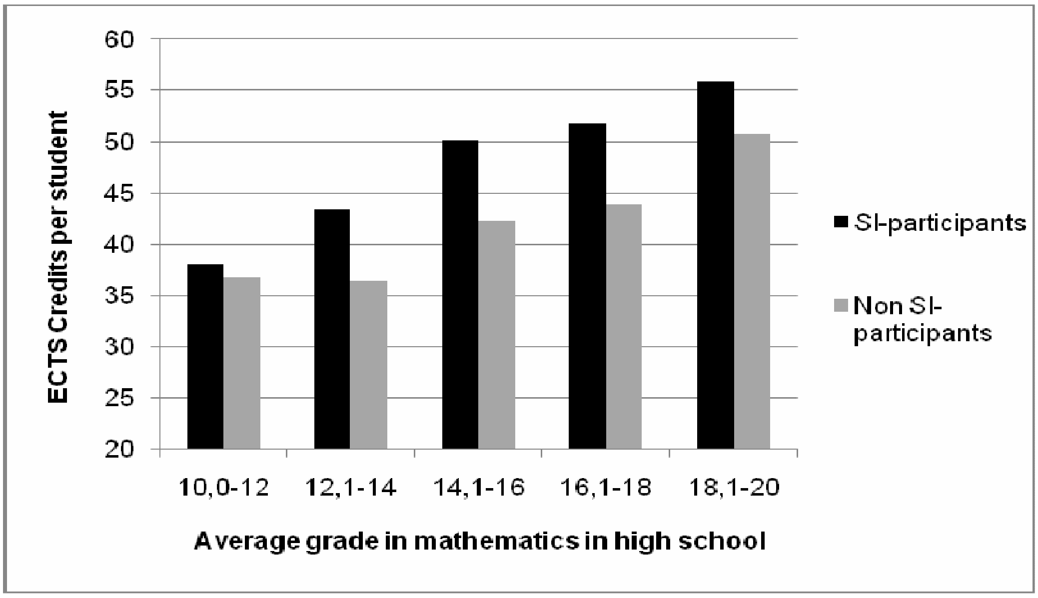
These differences can be compared with the average difference with all students included, being 6.7 ECTS credits as given in Table 1. Therefore it can be concluded that the difference in average high-school grade of 0.3 units between the whole groups of SI- and non SI-participants do not have a significant influence on the numbers presented in Table 1.

Figure 3



Number of students (SI participants and non-SI participants) who completed the first year in relation to their mathematics grade in high school.

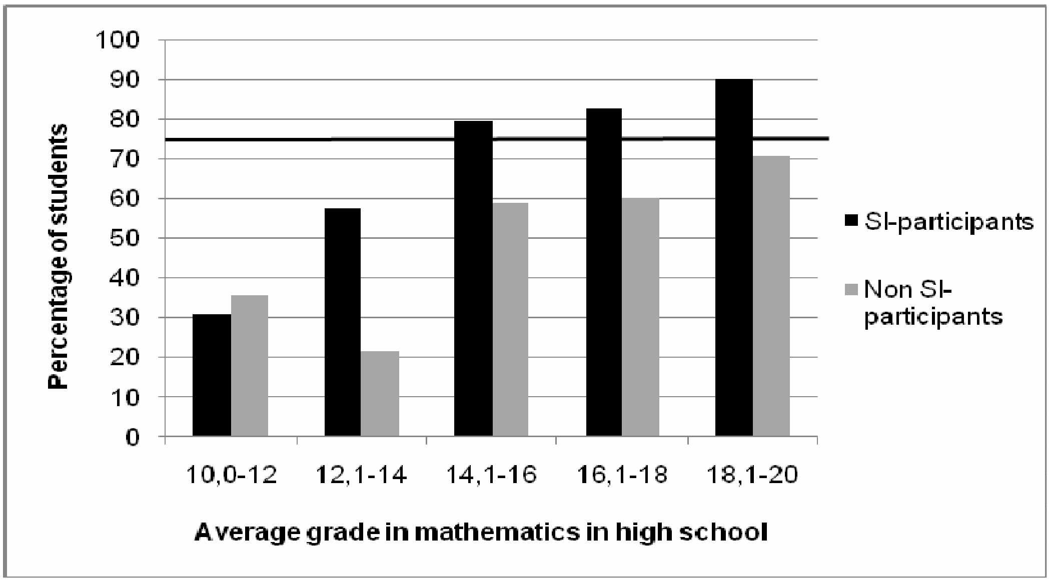
Figure 4



Average ECTS credits taken per student (SI participants and non-SI-participants) who completed the first year in relation to their mathematics grade in high school.

The success in reaching the LTH goal for first-year student performance (that at least 75% of all students should get a minimum of 40 ECTS credits during the first year) in relation to the average grade in mathematics in high school is shown in Figure 5. SI-participants clearly top the goal for the three highest grade intervals (as well as in total as shown in Table 1 above). None of the non-SI participant grading groups reaches the LTH-target. This clearly indicates the potential of the SI-program as being one major means of reaching the LTH strategic goal.

Figure 5



Percentage of all new students (SI participants and non-SI -participants) with an ECTS credit total of at least 40 during the first year (the LTH strategic goal limit) in relation to their mathematics grade in high school. The LTH goal of a minimum 75% of students reaching a minimum of 40 ECTS credits is shown as a horizontal line.

Student/SI Leader Views on SI Sessions and Development of Study Skills

In order to obtain a general view of the SI sessions and the development of study skills in particular, we used, as mentioned above, a qualitative method with a questionnaire to students and SI-Leaders. One hundred and fifty-eight of 209 (76%) SI participants returned the questionnaire, sufficient to provide a representative picture for the entire group of participants. For the SI-Leaders 19 of 21 (90%) answered the questionnaire. The answers to some of the questions are given in Table 2. A complete report of all answers is given in (Malm, Bryngfors, and Mörner, 2009). Overall the participants and SI-Leaders are satisfied with the SI sessions, which is quite similar to the results from a similar study by Kieran and O'Neill (2009). Much worked well – the goal of the sessions was clear, the students felt that they had the opportunity to focus on the difficult parts in the course, and they felt that they worked as a group in solving problems in the subject. About two-thirds of the participants thought that the sessions had contributed to a deeper understanding of the subject, while 30% were not sure. All but one of the SI-Leaders supported the idea that the SI-sessions had given the students a deeper understanding of the subject.

It is also clear from Table 2 that the students thought they had improved their study skills in the SI sessions. This is supported by the answers of the SI-Leaders as well. It is shown most clearly in the students' problem-solving skills, which, according to 2/3 of the students, improved thanks to the SI-sessions; most of the others were not sure. Seventeen of 19 SI-Leaders also agreed that the students' problem-solving abilities had improved during the SI-sessions, the other two being unsure. The ability to work in a group and to discuss problems in the subject also improved due to the SI sessions, according to the majority of the students and SI-Leaders. The questionnaire did not have a direct question regarding the ability to ask questions and if it had improved. Instead an indirect question was used to ascertain whether the training environment for this skill was optimised – "It has been easy to ask questions during sessions". Here 94% of the students concurred. Thus it is quite likely that the ability to ask questions in the subject developed as well. One can therefore conclude that a majority of the students experienced a development of crucial study skills due to the SI-sessions, which in turn should lead to better results in their studies.

Table 2

Questions (statements) to student/Leaders	Answers to questions (statements) from students/Leaders		
	True (%)	Neutral (%)	False (%)
General view on SI-sessions			
Overall I am satisfied with the SI sessions (students)	93	6	1
Overall I am satisfied with my SI sessions (Leaders)	100	0	0
SI sessions have given me a deeper understanding of the subject (students)	68	29	3
The SI sessions have given the students a deeper understanding of the subject (Leaders)	94	6	0
Development of study skills			
SI sessions have developed my skills in problem solving (students)	67	29	4
SI sessions have developed the students' skills in problem solving (Leaders)	89	11	0
SI sessions have developed my ability to work in a group (students)	57	33	10
SI sessions have developed the students' ability to work in a group (Leaders)	79	21	0
SI sessions SI-sessions have trained my ability to discuss tasks in the subject (students)	54	36	10
SI sessions have trained the students' skills in discussing problems in the subject (Leaders)	72	22	6
It was easy to ask questions during sessions (students)	91	6	3
Development of leadership ability			
I feel much more confident in leading a group (Leaders)	95	5	0
I have improved my ability to meet and inspire different individuals (Leaders)	84	16	0
I have developed my ability to inspire a group of individuals to do a task (Leaders)	84	16	0
I am much more confident in leading a discussion (Leaders)	63	37	0
It was easy for me to get the students to help each other with the subject (Leaders)	58	42	0

Responses to questionnaire questions to students/SI-Leaders from five engineering programs at LTH about the general view of SI-sessions, development of study skills, and development of leadership ability

Similar results were found by Tariq (2005) in a study of first-year undergraduate bioscience. Therefore, it is not surprising that the student success during the first year is more pronounced for SI-participants than for non SI-participants.

In Table 2, some questions regarding leadership ability for the SI-Leaders are included. From these it can be concluded that the majority develop their leadership abilities, which is indeed a bonus for the SI-program.

DISCUSSION

It is rewarding to conclude that the SI-program yields pronounced positive effects on both examinations in the related course and for student performance as a whole during the first year. Furthermore, these positive effects remain when previous knowledge (as indicated by grades from high school) is taken into account in the comparison of SI and non SI participants. That a SI program leads to increased student performance in the related course is not anything new – this has been shown in several investigations (see for example Zaritsky and Toce, 2006; Murray, 2006; Martin and Arendale (Eds.), 1994; Bruzell-Nilsson and Bryngfors, 1996). However, new data that confirm this for different subjects and for different academic environments is always valuable. The most important finding here, however, is the influence of the SI programs on student performance as a whole during the first year. Only a few studies on SI have been concerned with student success beyond the course it is applied to. Then the focus has been mainly on student retention (see for instance Webster and Dee, 1998, for an example in an engineering education context) or reenrollment/graduation (see Arendale, 1998; Topping, 1996; Peterfreund et al., 2008). Price and Rust (1995) showed that SI was not only beneficial for introductory business courses supported by SI, but also for subsequent business courses without SI. However, quantitative investigations on student accomplishments during the critical first year have not been made, to the authors' knowledge.

A certain amount of caution should be used when interpreting differences in student performance. First of all, there are the criteria for defining an SI participant as opposed to a student who does not follow SI. Here we thought it quite natural to use attendance at least half of the SI-sessions available (corresponding to 3-4 sessions depending on the engineering program) to define an SI-participant, as some sessions are needed to develop the appropriate study skills. In our experience, if students attend only one or two sessions, they are there mainly out of curiosity and/or for social reasons before they decide that the concept is not for them. However, the subject of defining when a student is a SI participant, from when he or she is not, is not obvious, as pointed out by McCarthy, Smuts, and Cosser (1997). That student success depends on the attendance record has, for instance, been shown by Cheng and Walters (2009). Thus more research on appropriate dividers between SI attendees and non-attendees is needed. Another problem is that SI participants consist of self-selected groups, which is why comparisons between SI and non-SI participants can be affected by other parameters such as, for instance, differences in motivation between the groups (Etter, Burmeister, and Elder, 2001). However, the parameter motivation can be considered in part by accounting for differences in attendance at SI sessions between engineering programs in the study. Should for instance, civil engineering students be more motivated than students in the industrial economy program since civil engineering students have much higher attendance numbers at SI sessions? This is hard to believe considering that industrial economy students have the highest grades from high school of any engineering program at LTH and are known for being very ambitious regarding their studies. Thus, there are good reasons to acknowledge the results above, although some caution should be used when considering the absolute values of the differences.

The effect of the SI program on student performance during the first year differs between the different engineering programs. The small programs – the Information and Communication Technology program with approximately 30 students and the Surveying program with approx. 60 students – show comparatively smaller effects when compared to larger programs – Computer Engineering, Industrial Economy, and Civil Engineering programs with approx. 100-120 students per program. For example, the ECTS credits taken per student during the first year are 4-6 credits higher for average SI participants (compared to non-SI participants) in the two small programs. This can be compared with the difference in ECTS credits taken per student in larger programs where the average SI participant takes 7-8 more credits than the non-SI participant. Perhaps it is the case that the effects of the social introduction to studies are smaller in a smaller program, since it is easier to get to know one another there. Another factor might be that the larger programs have comparatively more technical/natural science courses with problem solving as a general feature during the first year. Training in how to solve such problems is the main focus of the SI sessions.

Have the qualitative objectives stated above for the SI program at LTH been fulfilled? It is hard to give an absolute answer based on the survey. However, the answers from SI-participants and SI-Leaders above provide strong indications that both study techniques and some common skills important for an engineer have developed for the majority of the participants thanks to the SI sessions. Regarding the objective of giving upper classmen an academic leadership experience, we can conclude that almost all of the SI-Leaders feel that they have developed in their role as Leaders. This agrees with the results presented by Stout and McDaniel (2006), where SI-Leaders are reported to have gained multiple abilities such as leadership skills, teamwork strategies, improved communication and personal relationship-building skills. The leadership development in the present study is confirmed by the answers to the open question: "Describe how you have changed in your role as a SI-Leader during the semester". One example of such an answer:

> "Initially I was tense regarding what to expect, what problems might arise, and if I would be able to bounce questions back, etc. Now I am much more confident in my role and have as a result become better in listening and 'feeling' the group. Everything feels natural and this makes it easier to assume the type of role that is suitable. I also seem to notice that the students know what the SI sessions are about and are doing great on their own".

We can conclude that the SI-Leaders received good practical experience in leadership and the learning processes. It is also gratifying that the SI-Leaders had fun doing their work – as illustrated by the following comment:

> "I am really positively surprised at how much fun and how rewarding it is to be a SI-Leader. Hopefully I have been able to help the group also. The group and the different persons in it have given me a profound learning experience!"

The social dimension in SI sessions, to create an environment where you help each other and stimulate study work outside scheduled class time, is present in many comments by the SI participants. Some examples are (from the open question "What is the best thing about SI?"):

> *"I get inspired to study and learn more through collaboration!"*
>
> *"The feeling of unity within the group makes problem solving fun".*
>
> *"A chance to discuss and help each other understand difficult things".*
>
> *"That you sit together in a group and discuss your way to solutions and see to it that everybody understands. If you don't understand you get help and if somebody else doesn't understand, you explain to them".*
>
> *"That you can be together and learn from each other in a natural way".*

This is also confirmed by the SI-Leaders in their answers to the open question "How do you feel that the SI-sessions you have had have affected your students?" Some examples:

> *"They have fun and enjoy solving math problems together".*
>
> *"Become more comfortable in discussing problems. Engaged in the subject. Wanting to learn from each other and to some extent getting to know each other socially, which also is important!"*
>
> *"They understood the importance of helping each other".*

This indicates that the objective of a good social introduction to studies by SI sessions is fulfilled for many of the new students. That the SI sessions have provided a good environment to ask questions in is evident in the answers to the open question of what was best about the SI-sessions. Some examples:

> *"An opportunity to ask, discuss and practice on different difficult questions".*

> *"That it is relaxed and everybody dares to ask about things they don't understand".*

> *"That you can ask questions in a relaxed environment and get understandable answers back".*

Responses to the open questions to SI participants and SI-Leaders, give a stronger sense of having met the objectives for study techniques and skills important for an engineer. Some examples of such answers from SI-participants to the open question "What does a SI session mean to you?" are given below:

> *"Feelings of solidarity, discussion in a group. That you develop your ability to speak in front of a group".*

> *"That you solve problems together and discuss the results. It really helps one to understand the problems".*

> *"That you help each other to understand and that you can approach a problem from different angles".*

This is also confirmed in the SI-Leaders' comments. One such example:

> *"Improved the ability to work together and solve problems. Also improved their understanding by presenting the solutions to problems before the group".*

CONCLUSION

To what extent have the objectives of the study been fulfilled? First of all, the objective of the SI sessions is to develop some crucial study skills. A clear majority of the students and SI-Leaders confirmed that this had been achieved. Skills like problem solving, ability to work in a group, ability to discuss problems in the subject, and learning to ask questions were all improved. Consequently, it is not surprising that the other objectives of the study - whether the SI sessions contribute to increasing the student performance in the first exam in the mathematics course and for the first year as a whole – were answered affirmatively. Seventy percent of the SI participants passed the first mathematics exam compared to 55% of the non-SI participants. The average number of ECTS credits for those who completed the first year was 51.2 for SI-participants and 44.5 for those who did not attend SI - a considerable difference. Seventy-nine percent of the students actively attending SI sessions passed the strategic goal for LTH (that at least 75% of the students should have a minimum of 40 ECTS credits at the end of the first year), which can be compared to 55% of the non-SI students reaching the same goal. This clearly indicates that the SI-program applied at the start of the engineering programs has a pronounced positive effect on student success during the first year.

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