The potential of Supplemental Instruction in engineering education – helping new students to adjust to and succeed in University studies

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Supplemental Instruction (SI) is a programme that is attached to difficult courses with the objective of increasing student performance and retention. However, an SI programme also has the potential to increase overall student performance and retention during the first critical year if applied to introductory courses. In this study the latter objective is investigated in an engineering educational environment. The study shows that an SI programme attached to difficult first semester courses for new engineering students has substantial positive effects on both first-year student performance and retention. Both male and female students appear to benefit from attending SI to the same extent. Some potential reasons for these improved first-year student performances are that attendance at SI sessions appears to lead to improved self-confidence, a broader network of study partners, improved study strategies and problem-solving skills and an increased ability to critically review material and work with others.

Keywords: peer learning; engineering education; active learning; Supplemental Instruction; study strategies

1. Introduction

Supplemental Instruction (SI) is a method of improving student performance in ‘difficult’ courses combining ‘how to learn’ with ‘what to learn’, using collaborative activities under the guidance of a ‘senior’ student. The collaborative activities can, for instance, be discussions and/or problem-solving in small groups or more structured activities such as ‘think/pair/share’ (group members work on an assignment or project individually and then share their results with a partner) or ‘jigsaw’ (group members are broken into subgroups – each subgroup works on some aspect of the same problem, question or issue – they then share their part of the ‘puzzle’ with the large group) as described in the SI Manual (2006). What differences then exist between SI and other collaborative learning methods used by teachers? It obviously depends on the method, but some of the most common are as follows:

- SI is a complement to regular education.
  - SI does not replace lectures, seminars, exercises, etc.
- The SI leader does not act as a teacher.
  - The SI leader does not present new material in the course.

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The SI leader acts solely as a facilitator of learning activities and helps the participants to structure and process difficult material covered by the teacher. The SI leader is not involved in assessing the participants’ work on the course in any way.

- The content of the SI session is determined by the participants together with the SI leader and is based on what the participants find difficult in the course.
- Study strategies (e.g. problem-solving, help-seeking and note-taking) are integrated into the processing of course material.

SI was created at the University of Missouri, Kansas City, in the early 70s in order to come to terms with declining retention numbers (Hurley, Jacobs, and Gilbert 2006). Since then, the use of SI has spread widely and staff at more than 1500 universities in some 30 countries have been trained in the method (Martin 2008).

Much of the use of SI has been geared towards improving results and retention of students in courses. Here, numerous studies have shown successful results (e.g. Coe, McDougall, and McKeown 1999; Congos and Schoeps 1993; Hensen and Shelley 2003; Kochenour et al. 1997; McCarthy, Smuts, and Cosser 1997; Ogden et al. 2003; Wright, Wright, and Lamb 2002). However, the method should also have a positive impact on the whole critical first-year experience for new students (Arendale and Martin 1993), when applied to introductory courses. SI combines, as mentioned earlier, how to learn with what to learn. These trained and developed study skills are transferrable to other courses the student may be taking, which do not have the benefit of SI. SI provides an opportunity for social integration by forming friendships and networks with fellow students in the academic environment. The SI leader, being an older student with the same study choices, can provide a link to studies in coming years and put the first basic courses in perspective. SI also prepares the student to see fellow students as learning resources and to combine self-study with group studies to make the study experience more enjoyable and fruitful. Thus SI addresses several of the reasons, as pointed out by Tinto (1993), for leaving higher education studies.

2. Research questions

The aforementioned observations suggest that SI has a high potential to contribute to better student performances overall during the first year, as well as increased student retention numbers. However, little attention has been paid to these aspects of SI and more information is needed to see how potent the method is regarding the enhancement of a student’s first-year experience.

A rare study focusing on the overall student performances during the first year in relation to participation in SI sessions was made by Malm, Bryngfors, and Mörner (2012), in an engineering education environment at Lund University, Sweden. They found that students with average and high SI attendance do significantly better in terms of overall first-year credit performance. Additionally, they found that students attending SI also do substantially better overall in the first-year courses without SI attached to them. However, since the study included data for one year only, it may be that these data are not representative for other years. Furthermore, the data regarding ‘spill-over’ effects to courses without SI for SI attendees were limited, and more data are needed to confirm the effects and their order of magnitude. Therefore, this study is partly a continuation of the work by Malm, Bryngfors, and Mörner where the first two research questions are as follows:

- What effect does SI have on overall student performance during the first year in terms of credits taken, and are there marked differences from year to year?
- Can it be confirmed that SI attendees consistently perform better than non-attendees over several years in first-year courses without SI?
A clear answer to the second question would be valuable since the few other earlier studies on transfer effects to other courses due to skills trained in SI have received mixed results. In a study by Gattis (2000), it was shown that students attending SI in a chemistry course during the autumn semester also had statistically better results in the chemistry course the following spring semester. This finding suggests that study skills and learning strategies practiced during the autumn SI sessions benefitted students in the later course. Parkinson (2009) found no significant transfer effects of learning strategies and study skills for Biotechnology students from courses with SI to courses without SI during the first year, as measured by student performance results. Price and Rust (1995) found that former SI participants in business modules earned mean final course grades that were higher in subsequent courses that did not have SI support provided, compared to non-SI participants.

The effect of SI on student retention has received slightly more attention. Blanc, DeBuhr, and Martin (1993) found that students attending SI supplementing seven arts and science courses at the University of Missouri, Kansas City, were more likely to re-enrol the following semester. Similar findings were made by Blat et al. (2001) in a second- and third-year engineering education environment at the University of North Carolina. Lin and Woolston (2008) found that students participating in SI at the College of Engineering at the University of Wisconsin-Madison dropped out to a much lesser extent than students not participating in SI. However, are these positive effects on retention also applicable to engineering education environments outside the USA? The third research question therefore is,

1. How does attendance at SI sessions at a European engineering education environment increase the chances of a student enrolling in the second year of engineering studies?

Besides the research questions stated earlier, we also focus on the following questions that have not received attention before and that are of interest to better understand the potential of SI:

- How are differences in overall first-year credit achievement/retention between male and female students related to SI attendance?
- How are differences in overall first-year credit achievement/retention between students of different prior academic abilities related to SI attendance?
- Are there differences between students attending SI and not attending SI in terms of initially different learning approaches which can affect student performance results?
- Are there differences between students attending SI and not attending SI in terms of initially different study strategies and time for self-study which can affect student performance results?

Another area, which has not received attention, is qualitative information on what the students feel they receive in the long term by attending SI, which can help explain potential ‘spill-over’ effects to courses without SI. This leads to the final research question of this study:

- What qualitative values does SI provide that might potentially help new students adjust to and succeed in engineering studies according to the SI attendees?

3. Description of the Supplemental Instruction programme at the Faculty of Engineering at Lund University

SI was introduced to the Faculty of Engineering at Lund University in 1994. The reasons were primarily to increase the performance in some initial difficult courses and, in a broader perspective, to improve the retention of students during the first critical year. Early evaluations were promising. SI participants performed better on examinations in the targeted difficult courses such
as calculus, algebra and mechanics. These evaluation results led to SI becoming a permanent complement to the regular education in initial difficult courses on two engineering programmes (civil engineering and surveying) in the late 90s. Since then, SI has expanded continuously and today encompasses all engineering programmes (mechanical, electrical, environmental, etc.) at the faculty. The interest from the engineering faculty in what SI gives students has also developed from potentially improving student results in difficult courses, to knowing how SI affects students’ results as a whole (e.g. credits taken during the first year, dropout rates and timely graduation). Furthermore, there is faculty interest in understanding SI’s potential to provide training in communication, presentation and critical review of course material as well as improving study strategies. In order to answer these and other questions from the faculty regarding SI, it has been necessary to improve the evaluation system and increase the types of data to be collected. During the last few years, the collected data have also included academic achievements from upper secondary school, credits taken during engineering studies, information on dropouts and study leaves, and qualitative data from several questionnaires. This study uses the new data to answer some of the questions from the faculty on the effectiveness of SI, stated earlier under the section research questions.

How is SI implemented at the faculty? Today, the SI programme is primarily attached to difficult courses for new students in the first semester. These courses have a traditional pedagogic approach, that is, lectures combined with exercises where students work with problems on their own with access to a teacher. On average, SI is attached to about one-quarter of the first-year course load, usually courses in mathematics. Each student has a two-hour SI meeting scheduled each week during the first semester. Attendance is optional and usually ranges from 5 to 15 students. A typical SI meeting consists of a short introductory phase reviewing what has happened in the previous week, where the participants decide what material to cover during the meeting. Thereafter the SI leader initiates different collaborative activities to process the material. In the last part of the meeting, participants present and summarise their results.

The SI leader does not act as a teacher but as a facilitator during the meetings. He/she organises the collaborative activities, guides students in their work, using probing questions or deflecting questions to other group members and organises the final presentations and summaries. The SI leaders (being second- or third-year students) receive a two-day training course before they start their work. Thereafter they are subject to ongoing supervision via meetings every second week, and hand in a short written reflective report after each meeting. They also receive feedback from observers (former SI leaders) who attend two of their meetings during the semester. The SI leaders themselves also attend one of their fellow SI leader’s meetings to gain perspective on their work. Feedback in the form of surveys, from both participants and SI leaders, is also collected at the end of the semester to see how the SI programme worked and what modifications could be made.

New SI leaders are selected through a rather rigorous process. First of all, potential SI leaders have to be recommended by their own SI leader during the first semester. This recommendation is made based on a good attendance record, as well as perceived communication, interpersonal and leadership skills. The recommended SI leaders are then invited to apply for the position, where they state reasons for wanting to be an SI leader. The new SI leaders are then selected based on the application, an interview and academic results in the course, and overall, during the first year.

4. Data

The data used in the present study are from the academic years 2010/2011, 2011/2012 and 2012/2013 for 2463 students from 12 engineering programmes. The quantitative data consist
of the following:

- SI attendance data collected by SI leaders;
- Data on grade point averages (GPA) in mathematics from upper secondary school (based on grades from the five courses in mathematics required to enter the faculty of engineering) for the new engineering students;
- Data on course and semester registrations, study leaves, dropouts and credits obtained in courses during the first year.

The qualitative data used in the study are based on three questionnaires. The first one was handed out to all active SI participants (students with an average to high SI attendance) at the end of the SI programme in the academic years 2010/2011 and 2011/2012. Of the 1071 students, 769 (72%) handed in completed surveys. The questionnaire covered areas such as reasons for attending SI meetings, views on core aspects of SI meetings and views on different general potential benefits of relevance for first-year study performance and student retention. The specific questions used are given in Figures 1, 2 and 5. To each question there were five response alternatives: never true, sometimes true, true about half of the time, frequently true and always true. In Figures 1, 2 and 5 the response alternatives have been grouped into three groups for transparency: never (sometimes) true, true about half of the time and always (frequently) true.

Table 1. Short version of the LASSI questionnaire used in this study.

**ANXIETY**
1. Even when I am well prepared for a test, I feel very anxious
2. When I am taking a test, worrying about doing poorly interferes with my concentration
3. When I am studying, worrying about doing poorly in a course interferes with my concentration
4. Courses in certain subjects such as maths or chemistry make me anxious

**ATTITUDE**
5. I am able to study subjects I do not find interesting
6. I only study the subjects I like
7. I have a positive attitude about attending my classes
8. In my opinion, what is taught in my courses is not worth learning

**CONCENTRATION**
9. I concentrate fully when studying
10. Because I do not listen carefully, I do not understand some course material
11. I am very easily distracted from my studies
12. I end up ‘cramming’ for every test

**MOTIVATION**
13. I set high standards for myself in school
14. When work is difficult, I either give up or study only the easy parts
15. I am up to date with my class assignments
16. Even when study materials are dull and uninteresting, I manage to keep working until I finish

**STUDY AID**
17. I try to find a study partner or study group for each of my classes
18. If I have trouble studying, I ask another student or an instructor for help
19. When studying for a course, I often try to explain the material to a classmate or a friend
20. When studying for this course, I often set aside time to discuss the course material with a group of students from the class
21. Even if I have trouble learning the material in a course, I try to do the work on my own, without help from anyone

**TIME MANAGEMENT**
22. I find it hard to stick to a study schedule
23. I put off studying more than I should
24. I spread out my study times so I do not have to ‘cram’ for a test
25. I set aside more time to study the subjects that are difficult for me

For each question/statement, there were five response alternatives: never true, sometimes true, true about half of the time, frequently true and always true.
The second questionnaire, Study Process Questionnaire R-SPQ-2F (Biggs 2001), was handed out to all new students at the start of the autumn semester in 2010 and 2011. Hereby, data could be obtained on the new students’ inclination towards a deep/surface learning approach and on whether SI attendees are initially more or less inclined to a deep learning approach compared to non-attendees.

The third questionnaire was a short version of Learning and Study Strategy Inventory (LASSI) developed at the University of Texas in Austin (Weinstein and Palmer 2002). The questionnaire consisted of 25 questions within the areas anxiety, attitude, concentration, motivation, study aid and time planning (see Table 1). (The last three questions in the study aids were adopted from the Motivated Strategies for Learning Questionnaire within the area of peer learning/help-seeking, as this is of special interest with regard to SI). The questionnaire was handed out to the new students before the start of studies in autumn 2012 to see what initial differences there were between different SI attendance groups. The questionnaire was handed out again after the first semester to see what changes had occurred and whether they were different dependent on how much a student attended SI. On this last questionnaire, there was also an additional question where the student was asked to estimate the weekly time for self-study during the autumn semester.

5. Results

5.1. Attendance

The attendance at SI sessions during the first and second quarters of the autumn semesters of 2010–2012 was on average 64% and 49%, respectively, of all students registered on courses with SI connected to them. Ninety per cent of all new students attended at least one SI session. The main reason for the decrease in SI attendance during the autumn is that most students after initially participating in all scheduled activities later start to prioritise. If they feel that the SI concept with collaborative activities is not for them, they will stop attending. On average each SI leader had 12 and 9 students, respectively, at each session during the first and second quarters. However, occasionally some SI leaders had sessions with some 20–30 students, especially in the very beginning of the autumn semester. The opposite also occasionally happened, where less than a handful of students attended.

Why did students choose to attend the SI meetings? Apparently they were quite attractive from an attendance point of view when one considers that SI meetings are extras – over and above regular education. Five different alternatives were suggested in a survey that was handed out to students at the end of the first semester. The results are shown in Figure 1. Almost all students attended SI with the meaning-oriented objective of understanding the course subject

![Figure 1. Answers from students on reasons why they attended SI meetings.](image-url)
better. However, four other strategy-oriented reasons were also suggested – to pass the course, to get a better grade in the course, because it is an efficient way of studying and because it is fun to study and discuss course content with fellow students – and applied to the majority of the students attending SI. The reasons for attending SI meetings being strategy based is natural, but it is gratifying that the main reason is apparently meaning oriented.

5.2. Characteristics of the SI sessions according to participants

Supervision meetings, observations of SI meetings as well as written weekly reports by SI leaders indicated that the SI programme was being run as intended. (The essential elements of SI are defined in the Supplemental Instruction Supervisor Manual 2003, 2006). These operative measures were supported by the SI leaders’ answers to a survey at the end of their term. However, the most important view on the SI meetings comes from the students who attended them. In Figure 2, the collective views of the attendees (based on the survey) are given on the fulfilment of some core aspects of an SI meeting. It seems that the participants’ views agree well with the other observations that the SI meetings were run as intended. The atmosphere was seen by almost all as easy-going, positive and supportive, one where it was easy to ask questions. In general the attendees did decide what difficulties they were to focus on during the meetings, together with the SI leader. The work in the meetings was done collaboratively, where the SI leader acted as a facilitator, guiding when needed by asking questions. A clear majority of the attendees felt they attained an insight from the SI leader into the nature of study in their engineering programme,
as well as on efficient study strategies. Thus it seems reasonable to conclude that the evaluation results presented later in the paper are the results from a programme being run according to SI principles.

5.3. The influence of prior academic achievement on credit acquisition

In order to see what influence the SI programme has on the students’ first-year study performance, we need to account for prior academic achievement. Malm (2008) showed that for students at the Faculty of Engineering at Lund University, the GPA for courses in mathematics in upper secondary school is a slightly better prognosticator for student credit achievement in the first year, compared to the total GPA from upper secondary school. Thus we will use the former GPA to account for prior academic achievement in the following analysis. This GPA is based on the five mathematics courses a student has to complete to be eligible to enter the Faculty of Engineering. The GPA is in the range 10.0 (passing grade) to 20.0 (excellent grade). The distribution of new students during the academic years 2010/2011–2012/2013 for different grades is given in Figure 3. It is apparent that most students entering an engineering course have a high GPA from upper secondary school. The credit achievement vs. GPA in mathematics in upper secondary school is shown in Figure 4. There is an obvious relation between the two, where students with the highest GPA in mathematics from upper secondary school obtain about 52 ECTS credits in the first year. The students with the lowest GPA, on the other hand, obtain considerably fewer – about 30 credits. The observed relation between mathematics grade in upper secondary school and the number of credits obtained by a student completing the first study year in Figure 4 can be parameterised using a linear regression. The resulting relation is that a 1.0 unit increase in GPA in mathematics leads to an increase of 2.3 credits obtained during the first study year. Thus there is a relatively strong dependence for student results during the first year on prior academic achievement, expressed in terms of GPA in mathematics from upper secondary school, which has to be accounted for.

5.4. Student credit achievement during the first year in relation to SI attendance

The credit achievement during the first year vs. SI attendance for new students at the Faculty of Engineering at Lund University is shown in Table 2. Only students completing the first year are taken into account. It is evident that SI attendance has a clear influence on how the students do
in their first year. As seen in Table 2, the difference in prior academic achievement between the groups of different SI attendance is marginal, and consequently has a marginal effect on the credit achievement results. All students who attended SI meetings performed better on average than students who did not attend. These differences are all strongly statistically significant. However, the more one attends SI meetings, the better one does on average. The difference between an average student with high SI attendance and an average student not attending SI is about 13 credits. Thus, students with high SI attendance rates outperform non-attendees with respect to first-year credit achievement, by almost a third. This result is very similar to the difference of 13–14 credits between students with high SI attendance and no SI attendance during the first year, as reported by Malm, Bryngfors, and Mörner (2012) for the academic year 2009/2010. The positive effect of SI on the students’ overall first-year performance therefore seems similar from year to year.

Are the effects of SI different for different engineering programmes? It is not possible to compare all 12 five-year M.Sc. engineering programmes, as several have a very high SI attendance, which means that there are too few students in groups not attending SI, or attending SI to a lesser
Table 3. Data on credit achievement during the first academic year as a function of SI attendance for three engineering programmes.

<table>
<thead>
<tr>
<th>Education programme</th>
<th>SI attendance (Number of contact hours in SI meetings)</th>
<th>None (0)</th>
<th>Low (2–10)</th>
<th>Average (12–20)</th>
<th>High (&gt; 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of new students completing the first study year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer engineering</td>
<td>58</td>
<td>82</td>
<td>89</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Chemical engineering</td>
<td>26</td>
<td>80</td>
<td>110</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td>Industrial engineering &amp; management</td>
<td>25</td>
<td>62</td>
<td>85</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>Average number of credits obtained by these students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer engineering</td>
<td>38.2</td>
<td>40.8</td>
<td>44.3*</td>
<td>50.9***</td>
<td></td>
</tr>
<tr>
<td>Chemical engineering</td>
<td>40.2</td>
<td>47.9*</td>
<td>50.7**</td>
<td>54.2***</td>
<td></td>
</tr>
<tr>
<td>Industrial engineering &amp; management</td>
<td>36.0</td>
<td>44.0</td>
<td>51.9**</td>
<td>55.6***</td>
<td></td>
</tr>
</tbody>
</table>

The data are from the academic years 2010/2011–2012/2013. Statistically significant differences between the groups (compared to the group that did not attend SI) are estimated using an independent t-test (two-sided distribution) with \( p < 0.05 \), \( p < 0.01 \) and \( p < 0.001 \), and are marked with *, ** and ***.

degree, to make a statistically meaningful comparison. In Table 3 however, a comparison is made between three programmes of similar size in terms of students. All the three programmes show variations in credit production vs. SI attendance that are similar to each other and consistent with Table 2. Therefore the efficiency of SI in helping new students to succeed during the first year appears to be independent of engineering programmes.

The student retention data given in Table 2 confirm observations from the USA that SI has a positive effect on limiting student dropout. The more one attends SI, the likelier one is to continue on one’s education programme after the first year. About a third of all students who did not attend SI did not re-enrol in year two. This can be compared to frequent SI visitors, where less than 10% did not continue into year two.

Is the higher first-year credit achievement for SI attendees solely a result of these students performing better in the course/courses with SI attached to them? Or is there a transfer effect of presumed improved study strategies (due to attending SI meetings) to other courses? In order to investigate this, we restrict ourselves to engineering programmes that have SI attached to one course only – a 15-credit calculus course – during the first year. The credit achievement results vs. SI attendance for students from these programmes are shown in Table 4. The first-year credit achievement vs. SI attendance shows the same picture as in Table 2 for 12 engineering programmes. It is clear that attending SI generally leads to better results in the course with SI attached to it. Students with high SI attendance outperform students not attending SI by 4.4 credits. This is indeed considerable in a course worth in total 15 credits. However, accounting for these differences by subtracting the credits obtained in the calculus course shows that transfer effects to the other non-SI courses are considerable during the first year. There is a clear tendency toward all SI attendance groups doing better in non-SI courses compared to students who did not attend SI during the first year. In the case of the average and high attendance groups, the differences are strongly significant. A student with high SI attendance takes about 10 credits more than a non-attendee in non-SI courses (with a total credit sum of 45), which indeed suggests that the benefits of attending SI extend far beyond the course to which SI is attached. These benefits for SI attendees also appear to be consistent from year to year when compared to data from Malm, Bryngfors, and Mörner (2012) for the academic year 2009/2010. However, in that year the credit difference between a student with high SI attendance and a student with no attendance was slightly smaller – about 7 credits.
Table 4. Data on total credit achievement and credit achievement in non-SI courses during the first academic year as a function of SI attendance.

<table>
<thead>
<tr>
<th>SI attendance (Number of contact hours in SI meetings)</th>
<th>None (0)</th>
<th>Low (2–10)</th>
<th>Average (12–20)</th>
<th>High (&gt; 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of new students</td>
<td>83</td>
<td>214</td>
<td>250</td>
<td>361</td>
</tr>
<tr>
<td>GPA in mathematics in upper secondary school for students</td>
<td>16.7</td>
<td>16.4</td>
<td>16.4</td>
<td>16.9</td>
</tr>
<tr>
<td>Average number of credits obtained during the first year by students</td>
<td>38.6</td>
<td>41.2</td>
<td>47.1***</td>
<td>53.3***</td>
</tr>
<tr>
<td>Average number of credits obtained in the calculus course by students (15-credit course)</td>
<td>7.9</td>
<td>8.8</td>
<td>10.0*</td>
<td>12.3***</td>
</tr>
<tr>
<td>Average number of credits obtained by students in first year non-SI courses</td>
<td>30.7</td>
<td>32.4</td>
<td>37.1***</td>
<td>41.0***</td>
</tr>
</tbody>
</table>

The data are from five engineering programmes for students who completed the first study year during the academic years 2010/2011–2012/2013. The programmes had SI in one course only (calculus) during the first study year. Statistically significant differences between the groups (compared to the group that did not attend SI) are estimated using an independent *t*-test (two-sided distribution) with \( p < 0.05 \), \( p < 0.01 \) and \( p < 0.001 \), and are marked with *, ** and ***.

Table 5. Student data on credits obtained during the first year (for academic years 2010/2011–2012/2013) as a function of supplemental instruction attendance and mathematics grades from secondary school.

<table>
<thead>
<tr>
<th>Supplemental instruction attendance (Contact hours)</th>
<th>Number of students</th>
<th>Average number of credits obtained during the first year</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Weak’ students (group with 10.0–15.0 GPA in mathematics in upper secondary school)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (0)</td>
<td>52</td>
<td>34.4</td>
</tr>
<tr>
<td>Low (2–10)</td>
<td>121</td>
<td>33.9</td>
</tr>
<tr>
<td>Average (12–20)</td>
<td>143</td>
<td>41.0*</td>
</tr>
<tr>
<td>High (&gt; 20)</td>
<td>200</td>
<td>47.1***</td>
</tr>
<tr>
<td>‘Average’ students (group with 15.1–18.0 GPA in mathematics in upper secondary school)</td>
<td>56</td>
<td>35.9</td>
</tr>
<tr>
<td>None (0)</td>
<td>134</td>
<td>41.1*</td>
</tr>
<tr>
<td>Low (2–10)</td>
<td>197</td>
<td>47.7***</td>
</tr>
<tr>
<td>Average (12–20)</td>
<td>300</td>
<td>52.4***</td>
</tr>
<tr>
<td>High (&gt; 20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Strong’ students (group with 18.1–20.0 GPA in mathematics in upper secondary school)</td>
<td>79</td>
<td>46.6</td>
</tr>
<tr>
<td>None (0)</td>
<td>167</td>
<td>49.8</td>
</tr>
<tr>
<td>Low (2–10)</td>
<td>210</td>
<td>53.6***</td>
</tr>
<tr>
<td>Average (12–20)</td>
<td>443</td>
<td>56.9***</td>
</tr>
</tbody>
</table>

The student data are only for students completing the first year. 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 ***. (The number of students is slightly less than that in Table 1, as not all students had mathematics grades obtained in the regular Swedish upper secondary school system).

5.5. First-year credit achievements for SI attendees vs. academic ability

Do all students benefit from attending SI or does it depend on the student’s academic ability? For instance, do only ‘weak’ students benefit from attending SI? To investigate this, we divided the students into three groups dependent on their prior academic ability. Students with a GPA in mathematics in upper secondary school from 10.0 to 15.0 were labelled as ‘weak’. Students with a GPA of 15.1–18.0 were labelled as ‘average’, and students with a GPA of 18.1–20.0 as ‘strong’. The reason for the uneven intervals was to have relatively similar numbers of students in each group, as many students entering the Faculty of Engineering have high grades. The first-year credit achievement vs. SI attendance for the three ‘ability’ groups is given in Table 5. It is apparent that all students benefit from attending SI, independent of academic ability. For students
Table 6. Data on credit achievement during the first academic year as a function of SI attendance and gender (M = male, F = female).

<table>
<thead>
<tr>
<th>SI attendance (Number of contact hours in SI meetings)</th>
<th>None (0)</th>
<th>Low (2–10)</th>
<th>Average (12–20)</th>
<th>High (&gt; 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Number of new students</td>
<td>59 (20%)</td>
<td>233 (80%)</td>
<td>149 (27%)</td>
<td>403 (73%)</td>
</tr>
<tr>
<td></td>
<td>195 (31%)</td>
<td>437 (69%)</td>
<td>413 (42%)</td>
<td>574 (58%)</td>
</tr>
<tr>
<td>GPA in mathematics in upper secondary school for students who completed the first study year</td>
<td>18.1</td>
<td>16.9</td>
<td>17.6</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
<td>17.8</td>
<td>16.8</td>
<td>18.2</td>
<td>17.1</td>
</tr>
<tr>
<td>Percentage of students who did not complete the first study year</td>
<td>39%</td>
<td>28%</td>
<td>20%***</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>8%***</td>
<td>10%***</td>
<td>2%***</td>
<td>2%***</td>
</tr>
<tr>
<td>Average number of credits obtained by students who completed the first study year</td>
<td>41.3</td>
<td>39.1</td>
<td>44.9</td>
<td>41.5</td>
</tr>
<tr>
<td></td>
<td>50.5**</td>
<td>47.1***</td>
<td>54.0***</td>
<td>52.7***</td>
</tr>
<tr>
<td>Modified average number of credits obtained by students who completed the first study year, accounting for differences in prior academic achievement</td>
<td>39.5</td>
<td>39.8</td>
<td>44.3*</td>
<td>42.3*</td>
</tr>
<tr>
<td></td>
<td>49.3**</td>
<td>48.1***</td>
<td>52.0***</td>
<td>53.0***</td>
</tr>
</tbody>
</table>

The data are from 12 engineering programmes with SI in two or three quarters in the academic years 2010/2011–2012/2013. Statistically significant differences between the groups (compared to the group with same gender that did not attend SI) are estimated using an independent t-test (two-sided distribution) or Chi-square test with \( p < 0.05 \), \( p < 0.01 \) and \( p < 0.001 \), and are marked with *, ** and ***.

With average or high SI attendance, the difference in first-year credit achievement compared to that of students not attending SI is strongly significant. It is interesting to note that a student with ‘low’ prior academic achievement but high SI attendance actually does better in obtaining first-year credits compared to a student with ‘high’ prior academic achievement who does not attend SI.

5.6. Gender aspects on benefits from attending SI meetings

A question that arises is whether both male and female students gain similar benefits from attending SI in terms of increased credit achievement during the first year. A summary of the results is shown in Table 6. First, it is interesting to note that female students are more frequent visitors to SI meetings than male students. In the high attendance group, 42% of all students are female. In the non-attendance group, 20% are female students. Thus SI seems to be more attractive to female students than male students. Without doing an in-depth analysis of study patterns for female and male engineering students it is hard to say why this is so. Possibly female students are, on average, more familiar with the concept of studying together. Also female students have, on average, higher GPA in mathematics in upper secondary school. This is reflected in a higher first-year credit achievement. Regarding results on first-year credit performance, however, both male and female students show similar benefits from attending SI. The most remarkable difference
5.7. Differences in learning approaches for new engineering students with respect to SI attendance

A possible explanation to observed differences between students with different SI attendance rates is that they have different learning approaches. For instance, one could suppose that students who become frequent SI attendees are more inclined to use a deep learning approach compared to students who do not attend SI sessions. To test if there were differences in learning approaches to studies prior to entering the Faculty of Engineering, between the groups with different SI attendance rates, we used the revised two-factor Study Process Questionnaire (R-SPQ-2F) developed by Biggs (2001). This questionnaire has the advantage of being relatively short (20 items), which makes it less time-consuming and more suitable for large-scale testing. The outcome of the questionnaire provides measurements on the use of deep and surface learning approaches as well as on the subscales – motive and strategy. The questionnaire was handed out to all new engineering students at the start of the academic years 2010/2011 and 2011/2012. They were asked to complete the questionnaire based on their experiences in the last study year before entering the Faculty of Engineering. In Table 7 the questionnaire outcome scores are given in relation to attendance at SI sessions.

The results show that the new engineering students had only a slight tendency towards the use of a surface learning approach before entering the Faculty of Engineering. They were more inclined towards a deep learning approach, without it being strongly pronounced. What is clear, however, is that there is basically no difference in approach or subscale scores between the different SI attendance groups. One can therefore conclude that new engineering students at Lund University did not differ in the prior use of learning approach between different SI attendance groups.

5.8. Differences in learning and study strategies and time for self-study for new engineering students with respect to SI attendance

Other factors that could explain the observed differences in study results between students with different SI attendance rates is that they have different learning strategies and spend different

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Table 7. Scores on R-SPQ-2F developed by Biggs (2001) for new engineering students during the academic years 2010/2011 and 2011/2012 vs. SI attendance.

<table>
<thead>
<tr>
<th>SI attendance (contact hours)</th>
<th>None (0)</th>
<th>Low (2–10)</th>
<th>Average (12–20)</th>
<th>High (&gt; 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of students</td>
<td>185</td>
<td>386</td>
<td>471</td>
<td>564</td>
</tr>
<tr>
<td>Surface learning approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Motive</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Strategy</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Deep learning approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>31</td>
<td>31</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Motive</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Strategy</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

The scores range from 10 (no tendency to use approach) to 50 (strong tendency to use approach) for deep and surface learning approaches. For the subscales motive/strategy, the scores range from 5 (no tendency) to 25 (strong tendency). The students were asked to complete the questionnaire at the start of their engineering studies based on their experiences in the last study year before entering the Faculty of Engineering.

between male and female students in Table 6 is that female students who do not attend SI tend to drop out at a considerably higher rate during the first year compared to male students with no SI attendance. However, because of the low number of female students who do not attend SI, one should be careful when drawing conclusions. But if true, it seems especially important to encourage female students to attend SI meetings in order to become integrated into academic life.
amounts of time in self-study. In order to investigate this, the short version of the LASSI questionnaire described earlier was used. The questionnaire was handed out to all new engineering students in August before the start of the academic year 2012/2013. The students were asked to complete the survey based on their experiences during their last year of studies before being admitted to the Faculty of Engineering. The questionnaire was handed out once more in January 2013. The students were then asked to answer the survey based on their experiences during the first semester of engineering studies. The results are given in Table 8.

There are no substantial initial differences in attitude, concentration, motivation and time planning for students with different attendance rates at SI meetings during the first semester. There is a weak tendency that students attending SI have more anxiety compared to students not attending SI. Students attending SI have a slightly higher score on study aids. However, this is primarily due to the fact that students attending SI have a higher preference towards study with fellow students, which is the main concept of SI.

After one semester of engineering studies it appears that students with no or low SI attendance get lower scores on attitude, concentration, motivation, time planning and study aids (enhanced compared to initial differences) compared to students with high SI attendance. It thus seems to indicate that the training of study strategies at SI meetings has an effect. The difference in weekly self-study time between the groups with no, low or average SI attendance is small. The group with high SI attendance appears to study about an hour more per week than the other groups. However, as shown by Malm et al. (2013), the relation between self-study time and student results in terms of credits taken is very weak (being considerably less than one credit per extra hour of weekly self-study time for the autumn semester) and cannot explain the differences in credits taken during the first year between the different SI attendance groups.

5.9. **Qualitative aspects of SI that may help new students adjust to, and succeed in, engineering studies**

From the aforementioned results, it appears that students attending SI perform better overall during the first year of studies, as well as dropping out to a lesser extent. What then are the features of SI that produce these positive effects? The potential positive elements are numerous, but here we chose to focus on a few using a survey that was conducted among those students who had an average or high SI attendance. The questions and results from the survey are shown in Figure 5. Substantial portions of students agree with the seven statements. Roughly half agree that SI helped them achieve better self-confidence in studies, developed their way of studying, created contacts with other students, trained their ability to critically review material as well as presenting material in front of others and developed problem-solving skills and the ability to work with others. These items are the factors most likely to help students perform better in their studies during the first year. And, with the exception of problem-solving, they are not usually practised or emphasised in regular education. An ability to quickly integrate into university life should be of importance, from the point of view of both retention and study performance. The fact that roughly a quarter of the respondents thought that SI helped them in that respect (and about a quarter partially agreed) is gratifying for the SI programme. Especially so, considering all the other initiatives (four-week social introduction programme organised by senior students, team-building exercises organised by the faculty, small group information sessions on academic issues by student councillors, etc.) that exist at the Faculty of Engineering during the beginning of the first year to make new students adjust to, and feel comfortable with, their studies and life at university.

The factors considered in Figure 5 and practised in SI should also have a positive influence on student retention. If we look at the three principles of effective retention presented by Tinto (1993, 145–148):
Table 8. Results from LASSI questionnaire vs. SI attendance during the autumn semester 2012.

<table>
<thead>
<tr>
<th>Time for survey</th>
<th>Attendance at SI meetings during autumn semester (hours)</th>
<th>Number of students</th>
<th>Anxiety</th>
<th>Attitude</th>
<th>Concentration</th>
<th>Motivation</th>
<th>Study aids</th>
<th>Time management</th>
<th>Weekly time spent in self-study (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 2012</td>
<td>0</td>
<td>38</td>
<td>4.2</td>
<td>4.0</td>
<td>3.7</td>
<td>4.0</td>
<td>3.1</td>
<td>3.5</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2–10</td>
<td>205</td>
<td>4.1</td>
<td>4.0</td>
<td>3.7</td>
<td>4.0</td>
<td>3.2</td>
<td>3.4</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>12–20</td>
<td>167</td>
<td>4.1</td>
<td>4.1</td>
<td>3.8</td>
<td>4.1</td>
<td>3.3</td>
<td>3.5</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>&gt; 20</td>
<td>256</td>
<td>4.0</td>
<td>4.1</td>
<td>3.7</td>
<td>4.0</td>
<td>3.5</td>
<td>3.6</td>
<td>–</td>
</tr>
<tr>
<td>Jan 2013</td>
<td>0</td>
<td>38</td>
<td>3.9</td>
<td>3.8</td>
<td>3.3</td>
<td>3.6</td>
<td>2.9</td>
<td>3.1</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td>2–10</td>
<td>205</td>
<td>3.9</td>
<td>3.9</td>
<td>3.5</td>
<td>3.6</td>
<td>3.1</td>
<td>3.1</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>12–20</td>
<td>167</td>
<td>3.9</td>
<td>3.9</td>
<td>3.6</td>
<td>3.7</td>
<td>3.4</td>
<td>3.3</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td>&gt; 20</td>
<td>256</td>
<td>3.7</td>
<td>4.0</td>
<td>3.6</td>
<td>3.8</td>
<td>3.6</td>
<td>3.4</td>
<td>11.6</td>
</tr>
</tbody>
</table>

The questionnaire was handed out to new students before the start of studies (August 2012) and after one semester of studies (January 2013). The results include only students who handed in both questionnaires.

Estimated average weekly time for self-study during the autumn semester 2012 was reported in the January questionnaire (no such data were collected in the August survey). For the factors anxiety, attitude, concentration, motivation, study aids and time planning, value 1 corresponds to it being not good at all and value 5 to there being no reason to worry.
Figure 5. Views from attending students on some aspects of SI that may influence first-year student performance and retention.

(1) ‘Effective retention programmes are committed to the students they serve. They put student welfare ahead of institutional goals’

(2) ‘Effective retention programmes are first and foremost committed to the education of all, not just some, of their students’

(3) ‘Effective retention programmes are committed to the development of supportive social and educational communities in which all students are integrated as competent members’

These are all cornerstones of the SI programme. Thus it is not surprising that SI has, as demonstrated earlier, a positive effect on student retention during the first year.

6. Conclusions

The answers to the posed research questions can be summarised as follows:

• Students with high SI attendance obtain, on average, about a third more credits during the first year compared to students not attending SI meetings. This benefit appears to be consistent year to year.
The improved student performance during the first year for SI attendees is not only limited to the courses with SI attached to them, but is also clearly seen in other courses during the first year and is consistent year to year.

Student re-enrolment to the second year is considerably higher for students with high SI attendance during the first year compared to students with no SI attendance.

Both male and female students appear to benefit from attending SI with respect to first-year performance, and to the same extent.

The benefits in first-year performance resulting from attending SI are also of similar magnitude, independent of whether the students are ‘weak’, ‘average’ or ‘strong’ with respect to prior academic ability.

The observed differences between SI attendees and non-attendees in first-year performance could not be explained by differences in prior academic achievement or in different learning approaches. Both these factors were similar for students, independent of the extent of SI attendance.

There are no substantial initial differences between students attending SI at different rates with respect to anxiety, attitude, concentration, motivation and time planning. However, students who frequently attend SI seem to score higher on these factors (except anxiety) after one semester of studies. This suggests that the training of study strategies in SI has effect.

Students with high SI attendance use slightly more time for self-study compared to students not attending SI. However, this does not explain that the former students perform better during the first year since the relation between self-study time and student results is very weak.

A qualitative study indicated some potential reasons for the improved first-year student performances and higher retention for students attending SI. Factors such as improved self-confidence, increased network of study partners, developed study strategies, problem-solving skills and ability to critically review material and work with others were reported by a large portion of students attending SI.

7. Final remarks

The aforementioned results suggest that Supplemental Instruction can be a powerful method to improve student results and retention during the first critical year. Furthermore, the qualitative results seem to indicate that students attending SI receive other positive elements such as improved study skills, self-confidence and ability to work with others as well as training in making presentations to others. This should be a great help to the students in their later studies.

But are these results just valid for Lund University, or can they be replicated in other engineering education environments? The components of an SI programme are general and simple and it should be possible to set it up at any university. However, the particular environment in a particular education programme may be more or less suited for the implementation of an SI programme. For instance, the engineering courses at Lund University are largely based on traditional educational methods (lectures, tutorials and laboratories) with little student-to-student interaction. Thus SI can be expected to be particularly effective from a learning point of view, since the method is based on student interactivity that complements the regular education. If the education at a university is largely based on interactive educational methods, such as problem-based learning, cooperative learning or projects, one may expect SI to be less efficient.

Another point of importance for the SI programme to run efficiently is that SI is applied only to courses that are considered ‘difficult’, in the sense that a considerable portion of students fail
or withdraw from the course. This provides interest and motivation for students to participate in SI sessions in order to increase their chances of passing the course.

References


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