Implementing Supplemental Instruction (SI) for a large group in mathematics

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The Supplement Instruction (SI) programme is well established world wide and the resulting success of the programme is indisputable. The University of Pretoria has decided on SI as the model to be used for addressing the under preparedness of students entering the university, largely brought about by the changes in the curricula at secondary school level. The SI model was piloted in two courses, one in mathematics and another in chemistry, each consisting of more than a thousand students. This paper addresses implementation issues of SI for such a large group of students in mathematics. It cautions would-be implementers to pitfalls and shortcomings of the SI model and suggests how the model could be adapted to answer in current needs. The paper also shows that despite problems in strictly adhering to SI principles in the implementation of the programme, participants showed increased performance.

Keywords: supplemental instruction, mathematics, large groups

1. Background

The past two decades have been notable for change in South Africa. Not only has the country undergone significant political changes but it has also implemented a new education system. The diversity in backgrounds of students entering university after the political changes is prominent. This diversity includes culture, language, and academic preparedness. Lecturers of first-year modules and planners of foundation programmes often lack insight into the academic backgrounds of first-year students towards whom the university curriculum is directed [1]. The full effect of the new outcomes based education approach became evident when the first students to have completed their schooling in the new system entered universities in 2009. These students experienced the gap between secondary school and tertiary mathematics more severely than before and were under prepared with regards to both general mathematical skills as well as content related skills [2].

The phenomenon of under preparedness for university mathematics is by no means limited to South Africa. In a study in Ireland in which students' inability to cope with the transition between secondary and tertiary mathematics was investigated, Hourigan and O'Donoghue [3] found that there was a large difference between the

nature of students' mathematics experiences at pre tertiary level and those experienced at university in mathematics intensive courses. Hoyles, Newman and Noss [4] reported on a number of studies dealing with the difference between university expectations and the wide spectrum of mathematical abilities of the new students. De La Paz [5] and Hoyles et al. [4] named changing school curricula as one of the reasons for these changes.

Changes in school curricula bring challenges for university lecturers and can result in the development and implementation of bridging courses, the need for change of university curricula and assessment strategies and for carefully designed supplemental programmes. In an effort to meet the demands presented by the under preparedness of students, the University of Pretoria (UP) has identified so-called High Impact Modules (HIMs) in the Faculty of Natural and Agricultural Sciences. These courses have large student numbers, are taken by students across faculties and should a student fail any of these courses, it has serious implications for his/her studies. For example, failure of a first semester calculus module not only prevents a student from progressing to the follow-up calculus module but also hinders progression to other subsequent modules, such as physics, for which it is a prerequisite. Failure of such a module often results in a student extending his study period by at least a year.

As supplemental instruction for the HIMs the SI (Supplemental Instruction) programme was chosen, a model that originated in the USA and is in use world wide. This model was piloted at the University of Pretoria in 2011 in two courses – one a mathematics course and the other a chemistry course. The thinking was to learn from the successes and problems experienced through conservative implementation before expanding across the university.

The success of the SI model has been reported on extensively ([6], [7], [8], [9], [10]). It seems to have been established beyond reasonable doubt that SI can enhance student performance and could effectively answer in a need for instruction beyond the formal teaching programme. Reports have been written about issues surrounding the initial implementation of the SI model [11] that provide valuable guidelines. Implementation of such a system for a large group of students offers a challenge – in the case under discussion the group consists of more than a thousand students, and little has been written about large group implementation in particular. This paper documents the implementation process, discusses pitfalls experienced and gives a critical evaluation of why some of the key elements of the SI system are questionable for large group implementation. This paper thus aims to provide guidance and insight to first time implementers of the SI model for large groups of students in mathematics.

2. What is SI?

Supplemental Instruction (SI) is a student academic assistance programme that increases student performance and retention. SI is the intellectual property of the University of Missouri at Kansas City, developed by Martin in 1973. A license may be granted to registered, certified trainers to use the term Supplemental Instruction in association with educational programmatic approaches to enhance student academic development.

The programme attempts to address students' needs in a holistic approach. Less emphasis is placed on transmission of information and more on developing students' skills. Fundamental features of SI are that it is voluntary, student-driven, cost effective, and focuses on high-risk courses rather than high-risk students. Timely identification of students who are at risk is difficult in the traditional model and students can often only be referred for correctional instruction after scoring of the first examination [12].

Delivery of SI begins in the first week of lectures, it integrates study skills with content and it encourages peer collaborative learning. SI sessions are open to all students – irrespective of academic capability. Central to the activities of the SI programme are the SI coordinator and the SI leaders. The former coordinates the SI activities for a particular course and guides the SI leaders who conduct the SI sessions.

The SI leaders are senior students themselves, who have successfully completed the course concerned and have received intensive training in the principles of non-directive facilitation of small groups. They offer regular out-of-class, peer facilitated sessions after attending the lectures, thereby integrating content with learning skills and study strategies. SI leaders are trained to think about how they themselves achieved content-competency. Training includes process and methodology applicable to the subject and ways in which that knowledge can best be transmitted to students. SI leaders function as model students rather than authority figures.

In addition to dealing with the content, SI sessions include information on note-taking, anticipating test questions, vocabulary development, and memory aids, not normally found in other types of study/review sessions. Students develop the thinking and reasoning skills that characterise intellectual maturity. One of SI's goals is to help students formulate and answer questions and so develop a more sophisticated mode of enquiry. When successful, the SI groups show a statistically significant lower rate of drop-outs, failures and withdrawals and higher average course grades [13].

3. Implementation of the Mathematics SI programme

The course for which the SI programme was deployed and that we report on is the first year engineering calculus course, coded WTW 158. Approximately 1200 students are registered for the course. Presenting the SI programme for such a large group of

students is costly and in this case special funding was provided by the University Executive through the intervention of the management of the Faculty of Natural and Agricultural Sciences. The initiative for embarking on SI came from the Department of Education Innovation (EI) at the university and all SI programmes run under the auspices of this department. The departments Chemistry and Mathematics, both in the Faculty of Natural and Agricultural Sciences, were identified for piloting SI. The academic staff who would be directly involved in the pilot courses as well as the proposed SI coordinators attended a two day workshop before commencement of the academic year.

4. Finding time slots for SI sessions

Students in the WTW 158 course attend four lectures per week presented by experienced lecturers. In addition to these lectures there are 20 three hour slots allocated per week, called tutorial sessions, of which every student has to attend one, giving an average of 60 students per three hour tutorial session. These sessions are mostly presented by lecturers, with carefully selected post graduate students presenting the odd session. Although three hours are allocated per tutorial session, traditionally only two hours are used for the tutorial work, considered enough time for performing the planned activities. During the tutorial sessions students are expected to work on assigned problems with a short assessment concluding the session most of the time. That leaves one hour unaccounted for and it is precisely this hour that provided opportunity for hosting the SI sessions. In so doing the problems of finding venues for so many SI sessions and of fitting extra sessions into the already overfull timetables of students were automatically resolved. The original intention was for the SI sessions to be presented in the final hour of the three hour session but, instead, the decision was taken

to present the SI sessions in the first hour of the three hour slot. The reason for this decision was that the tutorial sessions were mostly presented in the afternoon and the SI leaders, all post graduate students, had their own classes scheduled for late afternoon. So the first hour of the tutorial class was used for presenting the SI sessions. The SI programme was marketed under the acronym SMILE (Supplemental Mathematics Instruction for Learning Enhancement), a positive sounding name that soon caught on.

5. Appointing SI leaders

Funding made it possible to appoint six SI leaders, each presenting two SI sessions. There were twelve SI sessions available in which to accommodate a group of over a thousand students. The SMILE leaders were selected on grounds of their experience and ability to teach and handle groups of students. SMILE leaders were appointed for 12 hours per week and attended a two day workshop before the lectures commenced, presented by EI.

6. Data collected

The SI programme design requires that record should be kept of class attendance and that SMILE leaders should report weekly on the content of their sessions, on attendance as well as on their experiences. In addition three questionnaires were issued to attendees of SMILE sessions – one at the onset, another after the first of two major semester tests and the final one after the second semester test. The questionnaires aimed to give a voice to students in order to monitor their experiences for future improvement. Questionnaires probed students as to their enjoyment of SI sessions, perceived benefits, perceptions of group sizes and also gave opportunity for students to freely express their feelings in general regarding the SMILE programme. In addition, informal interviews

were conducted with the SMILE leaders to determine their experiences as first time presenters of these sessions. Data was also available on performance in mathematics in the final secondary school examination as well as marks obtained in the run of the WTW 158 course. We will refer to the data where necessary to support claims.

7. Implementation issues

We discuss issues of implementation that will be of value to anyone who considers instituting an SI programme for a large group of students in mathematics.

7.1 Student selection and group size

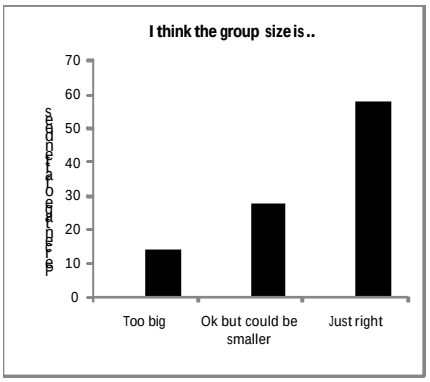
One of the key features of SI is that it is voluntary, which means that there can be no selection of students for attending sessions and from week to week students can choose whether they want to attend or not. The thinking behind this principle is that if SI is promoted as an option for struggling students, students will perceive it as remedial and they will not come to the sessions [13]. The general idea is that students will benefit so much from the programme that they will return week after week and that numbers will therefore not dwindle. The danger of sparse attendance is counteracted by the assumption that students who find it difficult to succeed in the course will responsibly decide to attend SMILE sessions. Surprisingly, we found that the reverse problem of over attendance is one that can indeed occur when working with a large group of students. This situation creates problems of its own and it is an issue that is not adequately addressed in literature. Because of the "first hour" structure of the SMILE programme it was convenient for students to attend the SMILE sessions as an introduction to the subsequent tutorial session. In addition, many of the high achieving students attended the SMILE sessions, concerned that they may miss out. It needs to be pointed out that because of the university's experience of the widening gap between

school and university, students underwent a two week orientation period before the beginning of lectures. During this period repeated emphasis was placed on diligence and hard work and so students became ultimately aware of the importance of bringing their side, taking responsibility for their own learning and time management. Instead of the ideal SI session size of 20 – 30 the SMILE sessions hosted on average approximately 60 students with up to 100 students attending a single session. The SMILE leaders were by no means experienced teachers and certainly not prepared for dealing with such large groups. The training only prepared them for a smaller, more intimate environment. The SMILE leaders lamented the situation, as became clear from comments extracted from their weekly reports:

> "More SMILE sessions are needed to fully utilise the techniques learned."
>
> "My plan to make them work in groups failed, the groups were too big. Will try it next week."
>
> "Students tended to get noisy from time to time and disruptive."
>
> "Big groups tend to make it difficult to answer or get to discuss all the questions."

Yet, despite their misgiving and to their credit the SI leaders seemed to come to a working solution by adapting their presentation style and coping reasonably well. Witness to this comes from the enlightening finding that the majority of students did not seem to experience the problem of functioning within such large groups quite as severely as expected (Figure 1(a)). This opinion could be attributed to the fact that all first year lecturing groups are large (>150) and that the SMILE sessions were comparatively small. The finding that the majority of students claimed to attend SMILE sessions every week (Figure 1 (b)) further supports their acceptance of the session size. In addition, the average group size for the duration of the course did not dwindle

notably (Figure 1(c)). It should be noted that week 4 was a short week following a long weekend and Week 7 was also shortened for the start of the second test period. Attendance for these weeks was understandably lower than usual.



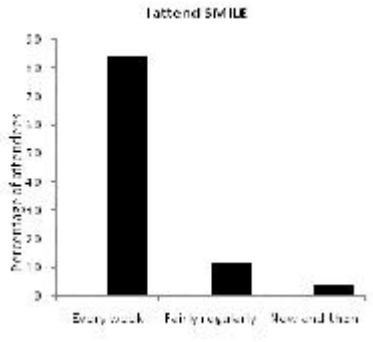


Figure 1(a) Figure 1(b)

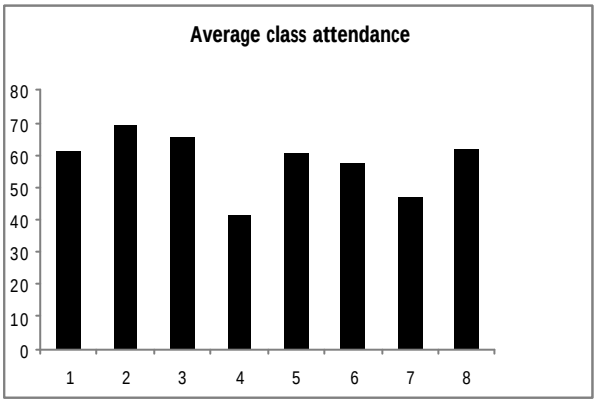


Figure 1 (c)

Figure 1(a): Student opinion on Group size (Questionnaire midway in the semester).

Figure 1(b): Student attendance (Questionnaire midway in the semester)

Figure 1(c): Average SMILE session attendance

The fortuity of being able to link the SMILE session slots onto the tutorial class slots became evident when it became apparent that for the Chemistry pilot course it was indeed problematic to maintain high student attendance numbers. They allocated a number of time slots per week that fitted into the student timetables (a difficult task) and found that it was not convenient enough for students to attend these isolated sessions, disjoint from other chemistry activities. As for Mathematics, in follow-up courses the

"first hour" convenience for hosting SMILE sessions will not be available, but it is hoped that the benefits of SMILE attendance will have become apparent and that a culture of attendance will have been cultivated.

7.2 SI leader selection

The importance of careful selection of SI leaders became apparent. The expertise and enthusiasm of the SMILE leaders are paramount for the success of such a programme. Appointing the SMILE leaders proved to be more problematic than first anticipated. Firstly, because of the strongly pyramidal structure of student ranks in mathematics, it was not so easy to find six post graduate students with the necessary demeanour, commitment and available time. Mathematics offers service courses to a vast number of students, yet students who are available as SI leaders are those that major in mathematics, a very small number, too small to feed such an extensive supplemental programme. In addition, the demand for student assistants is wider than the SI programme – assistants are needed for grading and for other supplemental programmes within an academic department. It would therefore have been arrogant to simply demand the best for the SMILE programme. Senior engineering students could be considered as SMILE leaders but their workload and overfull timetables are also prohibiting. Although a somewhat higher remuneration was offered to the SI leaders than for other student assistants, it was still not comparable to what they could earn for part-time employment outside the university, an issue that needs to be addressed at a university wide level. SI leaders need to be rewarded for their commitment and skills. Instead they are expected to work for the experience gained and the satisfaction of success which may be a noble outlook but not conducive for employing quality manpower. Budget constraints also prohibited employment of more leaders.

The named pyramidal structure of most mathematics departments is a worldwide phenomenon [14]. Mathematics majors are becoming a scarce commodity and the postgraduate pool of potential SI leaders is disappointingly small. In addition, at the university instruction takes place in one of two languages – English or Afrikaans – with each group taught in one of the two languages. In South Africa a large contingency of post graduate students are from African countries and these students mostly only have a command of English and often have accents that are difficult to follow.

The SMILE leaders are commendable and impressed with their positive attitudes. The SI training did, however, not prepare them exactly for the reality and it was important that they were able to show initiative and be able to improvise to create a workable environment. The SMILE leaders often coped under difficult circumstances and they mentioned the valuable growth that they experienced. They also mentioned how some groups were easier to handle than others, for no apparent reason, and how some students were more committed than others. A problem with the "first hour" structure of the SI sessions was that some students used the SMILE sessions as a "waiting room" for the subsequent tutorial class and did not contribute to the session at all. One leader described how his sessions evolved into peer collaborative learning sessions and how successful interaction was within these smaller groups. Unfortunately most venues were not conducive to convenient seating for groups, consisting of rows of fixed seats and often steeply slanted. It is recommended that the university invests in venues with movable chairs and tables if it wants to expand the SI programme . Comments of SI leaders included:

"Seating very formal, could not create an informal environment initially."

"Lots of disorder. It is a bit difficult to create the SI-environment."

"Awesome!" (Commenting on the experience of being an SI leader.)

7.3 Administrative centre of gravity

The number of administrative tasks in conducting SI sessions for such a large group is formidable. Apart from getting the course off the ground with respect to budgeting, funding, venues and promotion as well as identifying, appointing and training the leaders, there is the weekly administration of attendance lists, leader feedback on session content, experiences etc. Although the initiative came from IE and the intention was for the administration to be handled from there, this proved not to be the case because of manpower issues. The SMILE coordinator, who was appointed in the Mathematics Department to guide SMILE leaders academically, in reality dealt with the administration as well, leaving little time for performing other duties during working hours. The SMILE leaders were required to report at EI on programme progress but obviously also to the Mathematics Department. The dual reporting was unnecessarily time consuming and it would have been preferable to have all administration centralised. It should be determined at the onset of such a programme where the administrative centre of gravity lies and how administration can be effectively minimised.

8. Programme progress

Having discussed concerns and points of importance regarding implementation of the SI programme for a large group of students, it is of interest to monitor student progress. The question to be addressed is how successful the SMILE programme was with such large session groups, with voluntary attendance of students and with relatively inexperienced leaders guiding them. It became clear that the SI principles could not be strictly adhered to. In this regard it is advisable to customise the name of the programme in order to have slight freedom of deviating from the strict requirements of SI

programme. Whereas our programme was marketed under the name of SMILE, the other pilot course named their programme CSI (Chemistry Supplemental Instruction). There are more cases of coining customised names such as PASS, short for Peer assisted study sessions [9] and PAL, short for Peer Assisted Learning [15].

There were 600 students attending SMILE sessions (having attended at least three sessions) and 651 students not attending. We used the final Grade 12 mathematics marks of these students to determine whether the groups were academically on par. The average Grade 12 mark in mathematics mark for the SMILE group was 81.3% compared to 81.1% for the non-SMILE group. There was no statistically significant difference between the two groups with respect to the performance in Grade 12 mathematics as determined by using a statistical t-test ($p = 0.3706$). It was concluded that the two groups were academically on par. This finding in itself is of interest as it verifies that the SMILE programme is not perceived to be just for weaker students.

Students underwent two major assessments during the semester of 13 weeks, Semester Test 1 and Semester Test 2, before taking the final examination. Due to the structure of the academic year of 2011 the first of these assessments was done exceptionally early on, after three weeks, with the second one following after another six weeks, leaving another four weeks to the examination. We investigated the progress of the two groups between Semester Tests 1 and 2. In Table 1 the average performance of the two groups are compared for the two major assessments. For Semester Test 1 there is no statistically significant difference in performance between the two groups, as determined by a statistical t-test ($p = 0.08216$ indicating that the means are the same on both a 1% and a 5% significance level)). This finding is not unexpected because the SMILE sessions only started in the second week of lectures (deviating from the prescribed first week start of the SI model). It seems an impossibility to start in the first

week as students need to be alerted to the option of SMILE sessions and no content had been covered yet.

There is a statistical significant difference between the performance of the two groups in Semester Test 2, verified by a t-test ($p = 0.02447$ indicating that the means are the same on a 5% significance level but not on a 1% significance level). It was also, and most importantly, statistically verified that the SMILE group improved more than the non-SMILE group by a t-test. The average increase in performance of 13.38% for the SMILE group differed significantly from the average increase in performance of 10.19% of the non-SMILE group) ($p = 0.0002$ indicating that the means differ at both a 1% and 5% significance level). It needs to be pointed out that the performance in Semester Test 1 of the two groups is low, but not unexpectedly so, considering the recognised gap between secondary school and university. It is pleasing that students seem to adapt well in general after an initial difficult start.

	SMILE group	Non-SMILE group
Semester Test 1	49.25%	50.63%
Semester Test 2	62.63%	60.83%

Table 1: Average performance of SMILE and non-SMILE groups in the two Semester Tests.

Another indicator for success is pass rate. For the SMILE group the pass rate (number of students scoring 50% or more) increased from Semester Test1 to Semester Test 2 from 46.24% to 79.46% whereas for the non-SMILE group the pass rate increased from 50.61% to 73.69%. The increase in pass rate of 33.22% for the SMILE group compared to 23.08% supports the claim that attendance of the SMILE sessions could lead to improved performance.

9. Conclusion

The SI model has a proven track record and the value thereof cannot be disputed ([6}, [7], [8], [9]). However, the model was developed in the 1970s and since then universities have grown so that large groups are at the order of the day, almost everywhere. Large group implementation of this programme has issues of its own as the paper has pointed out. Funding is limited and the ideal SI session size of below thirty is hardly attainable. Because of the large session sizes more responsibility is placed on the SI leaders and therefore selection is crucial. Yet the selection pool is limited and the demand outweighs the supply. During training sessions conducted before the onset attention should be paid to this vital issue and leaders should be prepared for adapting techniques to accommodate large groups. The conclusion also is that it is hardly possible to strictly adhere to the principles of the SI programme. These principles should be adapted for the current university demographics and particularly for accommodating large groups. This view supports the findings of Wright, Wright and Lamb [16] who also advised to follow an adapted SI model. It is not surprising then that there are many examples of how the principles of the programme are adapted to suit the needs of the particular course and of how the programme is then marketed under a customised name.

The strength of the SI programme lies in the educational principles followed. The peer directed, voluntary sessions with non-directive facilitation, integrating content with learning skills and study strategies as well as interaction within small groups are integral to SI instruction. Applying these principles have proven to improve performance of students attending the SMILE sessions, despite misgivings about session sizes and venues that are not conducive to peer collaborative learning.

Finally, the administrative component of such a programme needs special consideration. The scope of this activity should not be underestimated and the responsibility of the administrative component needs to be clarified before embarking on such an SI programme.

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