Experiences with use of Various Pedagogical Methods Utilizing a Student Response System – Motivation and Learning Outcome

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Abstract: This paper describes use of an online Student Response System (SRS) in a pre-qualification course for engineering studies in Norway. The SRS in use, where students answer quizzes using handheld mobile devices like Smartphones, PADs, iPods etc., has been developed at Sør-Trøndelag University College. The development of the SRS was co-funded by the Lifelong Learning Program KA3-ICT in 2009-2010. SRS has been designed to help teachers effortlessly i) break the monotony of a lecture and allow the students to actively take part in the lecture, ii) increase teacher-student interaction, and iii) give teacher and students immediate anonymous feedback on learning outcome. The response system was used in mathematics in two groups with different lecturers during two semesters in 2009-2010. The pedagogical methods in use will be referred to as "Peer Instruction" and "Classic". In each method the students will answer a multiple choice quiz using their mobile devices. In both cases the result of the quiz will immediately appear as a histogram on a screen in the classroom. The closing parts will also be identical. The lecturer then highlights the correct option in the histogram and explains why this option actually is the correct one. In the Peer Instruction method there will be an additional element. The first poll will be followed by a discussion in student groups, where the students are urged to defend their choice and convince their fellow students that their chosen option is the correct one. The discussion is then followed by a new individual voting session before the final results are shown and the closing part takes place. The paper will compare this method with the peer instruction method as described in existing literature. The learning outcome will be discussed according to interviews with students and the lecturers' experiences from the classroom. In addition we will analyze students' grades and test results in mathematics with respect to their expected level, based on previous achievements. We will present results showing that when students are arguing their point of view, they will have a stronger tendency to convince their fellow students when they themselves already have found the correct option in the quiz. Finally we will suggest pedagogical improvements for future use of response systems in mathematics. Input from lecturers and from students has already been used in the process of developing a new version of SRS, finished in January 2013.

Keywords: student response systems, mobile learning, smartphones, peer instruction and learning, peer learning assessment systems, learning outcome

1. Student response system (SRS)

1.1 Technical equipment

The SRS in use was developed at Sør-Trøndelag University College (HiST), cofounded by the European Commission (EduMecca 2009). In the current version the lecturer must be equipped with a computer, preferably connected to a projector. Each student needs a device capable of accessing a web page, for example a smartphone, iPod, iPad, laptop etc. In addition there must be a wireless network present.

The major advantages with this system compared to traditional clickers are independence of software and flexibility in use of voting device. A quiz might be presented through any kind of computer application. The quiz might also be written on the fly, even on paper or a traditional blackboard. In the testing phase described in this paper we handed out iPods for a one year loan to all students, although some of the students preferred to use their own devices. In the following semester the students could choose between borrowing an iPod or using their own smartphone. As a result more than 80 % preferred to use their own equipment. The advantages of a system using equipment the students already own and are familiar with are obvious. The students' mobile phones are in this way transformed from an unwanted source of distraction into a powerful learning tool.

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1.2 Voting procedure

We will differentiate between two methods, Classic and Peer Instruction (PI). Figure 1 shows a flowchart for the two different variants of the SRS session.

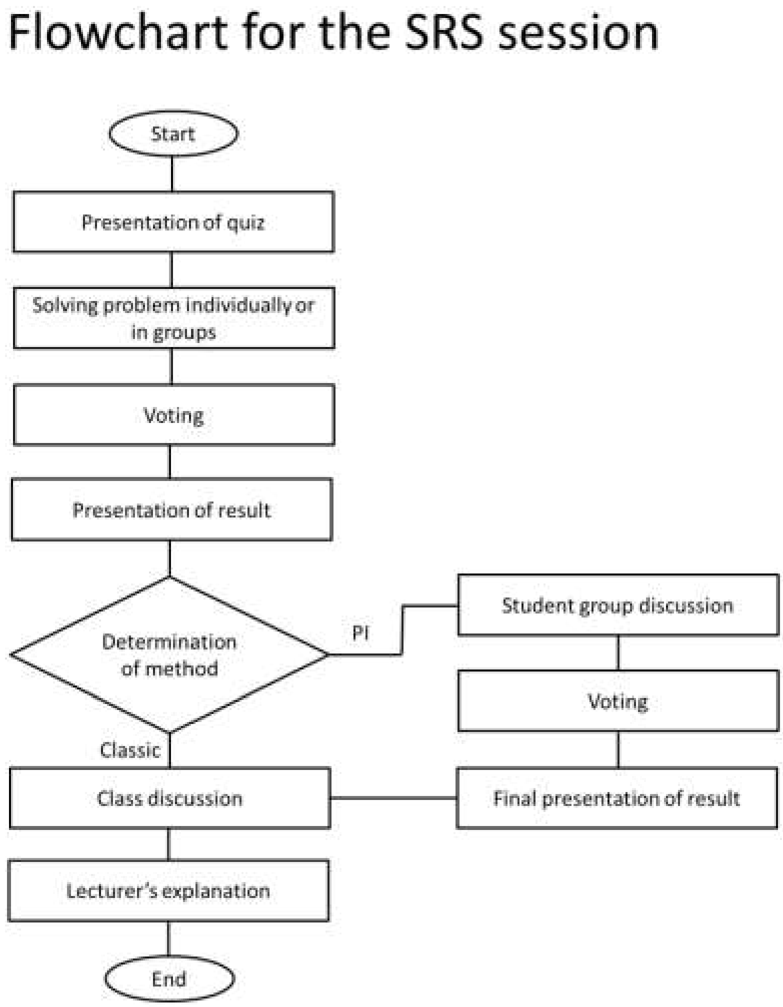

Figure 1: Illustration of the SRS session

In both methods the students were given a quiz, usually at the start at the lecture. They were given a couple of minutes to make up their opinion and optionally discuss the problem before casting individual votes. The result of the voting session would then appear as a histogram on the lecturer's computer and be projected onto the screen. The closing session is also similar in the two methods. The lecturer opens for a class discussion where the students are urged to defend their own choices. Finally the lecturer highlights the correct option in the histogram and explains why this is the correct one why the others are not.

The lecturer can choose to arrange a second voting session involving a student discussion in groups consisting of three to five students. This option can be decided upon in advance or on the fly depending on the result of the first vote.

The peer instruction method used here is a slight modification of the original method described by Mazur (Mazur 1997). Originally, it is seen as important that the students make individual decision before the discussions, where they are supposed to defend their own choice for solution and convince their fellow students of its validity.

Our reason for suggestion a different approach is mainly to add flexibility. It is usually not necessary to open for student discussion when most of the students agree on the correct solution.

A similar method is suggested by Dufresne et al (Dufresne 1996), but without the lecturer's explanation before closure.

1.3 Categories of quizzes

We will differentiate between three categories of using SRS:

- Repetition: Testing the students' skills in a previous lecture's theme.
- Wake up: Testing the students' skills in the present lecture's theme.
- Introduction: Preparation for a new learning session.

1.3.1 Repetition

The majority of events have been in this category. A voting session in this category is usually held at the start of a new lecture. The basic idea is that if most of the students give the correct answer, it will not be necessary to give any further explanation, but rather move on to the next theme. If the result of the quiz shows that a significant part of the students does not choose the correct solution, this will be a strong incentive for the lecturer to return to the previous lecture and give a new explanation. This may be important particularly in subjects where the learning material is of a sequential nature, as in mathematics. This method will allow the lecturer to vary the lecture according to the students' response according to Draper's contingent teaching (Draper 2004).

1.3.2 Wake-up

The question of whether the students really are following the lecture should be the concern of any lecturer. The most common method is plainly to ask a question and wait for the students to raise their hands and answer the question. This will not usually give a good indication of the students' understanding, since only a few students will raise their hands, while the majority will remain inactive. Use of SRS provides a method to get answers from the entire group of students, since everyone is guaranteed anonymity. This feedback allows the lecturer to decide whether the lecture should continue as planned or if it is necessary, for instance give one more example or look at the theme from a different angle.

1.3.3 Introduction

In the third category student activity will be more important than the actual feedback. The desired feedback is that a new concept will be introduced to the students either through some sort of open question or a problem that can be solved combining existing knowledge in new ways. One example that we used was the question "The weight of one brick is one kilogram plus the weight of a half brick. What is the weight of one and a half brick?" as an introduction to equations. The solution can be found the hard way by trial and error, but is found with less effort for the ones capable of using mathematic language and set up the equation for the problem. It is interesting to note that only 12 % managed to find the correct solution before they were introduced to the theory of equations, which should give a strong motivation to learn a systematic method for solving the problem.

2. SRS and mathematics

From autumn 2011 the SRS has been in systematic use at the pre-qualification course at the Faculty of Technology at Sør-Trøndelag University College. The course is aimed at students from vocational schools who need this one year course to be allowed to study for a bachelor or master degree in technology. The annual acceptance of students has been 240 and the students are divided into four groups with approximately 60 students in each group. This study covers the subject mathematics in two groups during the testing period for 2010-11. The two lecturers involved were responsible for one group each, and had the responsibility for developing the quizzes in mathematics and physics respectively. This led to the establishment of a database consisting of 276 quizzes in mathematics and 89 quizzes in physics.

All data presented are from one of the groups, while the lecturers' experiences and the result from student interviews are collected from both groups. The subject lasted for two semesters, and the students were given one lecture each day, consisting of 2x45 minutes. Usually the students were given one to three SRS quizzes in each lecture.

Two thirds of the quizzes were held as Repetition, while the last third was almost equally divided into the Wake-up and the Introduction categories. Many of the quizzes were not consisting of conceptual problems, instead focusing on calculation techniques.

2.1 Classic versus peer instruction

There were a total number of 123 quizzes in the course, most of them using the Classic method as can be seen in figure 2. In most cases of Peer Instruction this method was decided upon after the result of the first voting. An unsatisfactory result gives the lecturer the opportunity to choose a student discussion and a new voting. Figure 3 shows the relative distribution of correct answers from each quiz. All quizzes that were expanded to PI have a result in the lower part of the distribution. When the method is decided upon according to the first voting, the students will see the result of the first voting, which is not recommended in earlier literature (Mazur 1997). It is important to notice that the SRS is compatible with traditional Peer Instruction. This method can be chosen in advance to ensure that the result of the first voting sessions will not be shown until the last voting is finished. Then both results will be sequentially displayed.

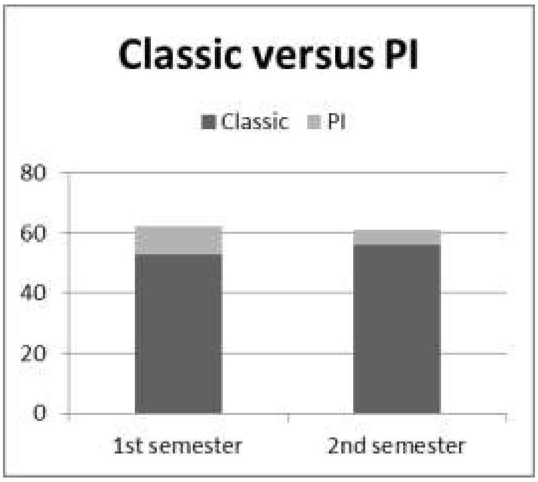

Figure 2: Different types of quizzes

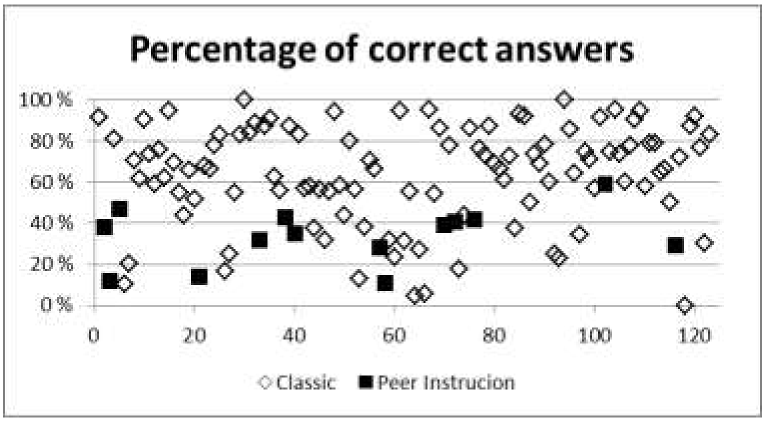

Figure 3: Correct answers in classic versus peer instruction

2.2 Improvement after peer instruction

Figure 4 shows the number of correct answers before and after the discussion for the 14 cases where Peer Instruction was used. The percentage of correct answers did improve in all quizzes except in one. The average percentage of correct answers in the first voting session was 34 %, while the number increased to 61 % in the second session. These results strongly support our hypothesis that the students with the correct solution are more likely to convince fellow students to agree with their point of view than the other way around. Earlier research on Peer Instruction in physics teaching for college students (Crouch 2001) also gives similar results.
The student interviews suggest a preference for peer instruction. "You have the time to make up your own opinion before the discussion. Then you compare your own answer with the student sitting next by. You compare your answers and then you agree on a final answer together." "And it might happen that if you have a theory, it will be proven to be false. And then it perhaps is easier to remember when you do the tests."

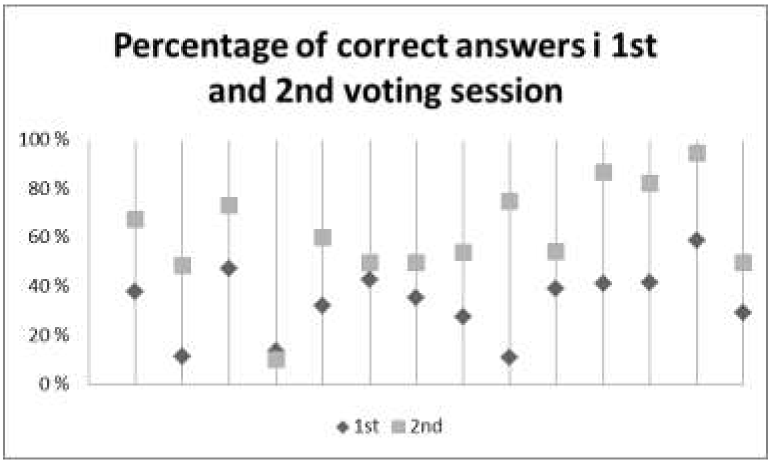

Figure 4: Increase in correct answers in 2nd voting session

Even though PI is a very effective teaching method, we will still emphasize the importance of the lecturer's explanation before closing the session. The students identify the explanation as the most important part of the session in interviews (Hansen-Nygård 2011). A research among biology students actually shows that the combination between discussion in student groups and the lecturer's explanation will produce maximum learning outcome (Smith 2011).

3. Experiences from use of SRS

The students' opinions of SRS are collected from a poll involving all students and from group interviews. Three groups consisting of four students in each were interviewed.

We have registered a positive attitude towards SRS from the students. A significant majority of the students are of the opinion that SRS increases both engagement and learning.

Figure 5 shows the distribution of students' evaluation of SRS' contribution to increasing engagement in classes. More than 70 % of the students claim increased engagement in classes where SRS was used.

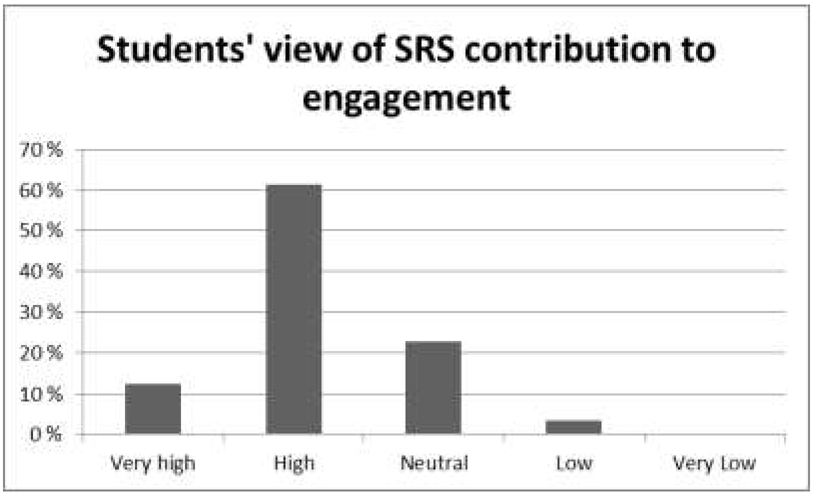

Figure 5: Results from student poll on engagement

This is also confirmed in the student interviews. Student quotes: "It feels a bit like a small exam… Yes, I will pass it. So, I try to do my best.", "…And you suddenly wake up instead of just waiting for the lecture to end. So it definitely helps in raising my spirit".

The lecturers also report increased student activity. Starting the lecture with a SRS session is found to provide engagement and participation throughout the entire lecture, not only the SRS session.

Figure 6 shows student responses to the hypothesis "SRS increases my learning". Almost 90 % agree, while none of the students disagree.

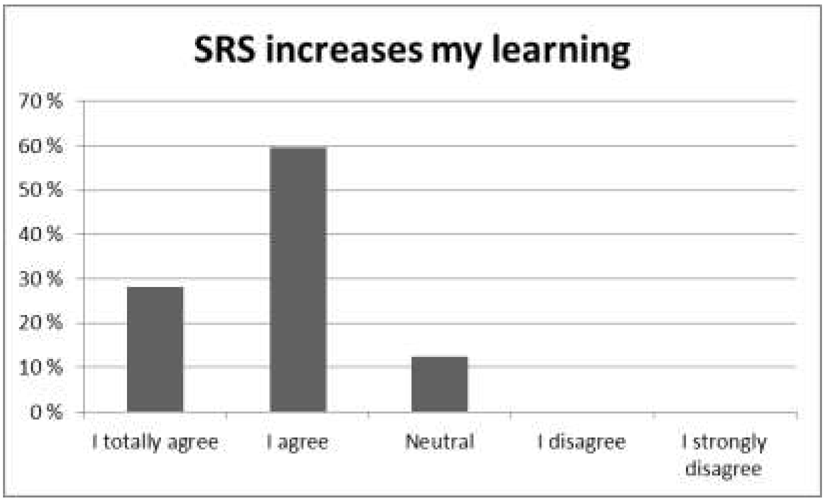

Figure 6: Results from student poll on learning

The fact that students claim higher learning outcome in polls does of course not guarantee that this really takes place. There have been many studies on the effect of response system on learning outcome measured by tests and exams.

Mazur reports significant improvements in learning outcome. This is supported by other studies (Caldwell 2007), while others show small improvements (Chen 2010). Some studies still show a neutral effect (James 2012). The variations in learning outcome suggest that the result is dependent on other factors than just use of response systems. Factors to be considered are lecturer's choice of methods and relevant quiz questions and ability to motivate the students' participation and engagement. We find support for this in the student interviews:

"It is like in mathematics, when almost everyone gets the right answer, there will not be much of a discussion afterwards. On the other hand, if only half of the class or even less are wrong there will be engagement and peer discussion." "In my opinion variation is the key. The A students have found their way in the old system with blackboard, lecturer and students. It is working for them. Variation in the classroom is the key." "Superficial questions don't do much for us. We already have too many of them."

This study has focused on different level of the students based on their acceptance points, and we have found support for this hypothesis.
According to the lecturers there seem to be an improvement in the students' calculation techniques leading to fewer primitive errors in assessments, even if there are no statistical evidence so far to confirm this assumption. An analysis of the final student grades including a control group not using SRS (Arnesen 2012) seem to indicate that students with lower grades from vocational school have a lesser tendency to fail the course in the SRS groups than in the control group. Since those students generally suffer most from lack of calculation technique, this result might be interpreted as a support for the assumption on improved skill in performing simple arithmetic operations
In this study we had two groups with different lecturers using SRS and a third control group that did not use SRS. The two SRS groups differed in use of methods. The group analyzed in this paper differed from the second by more frequent use of Peer Instruction (16 quizzes) and more variation between Repetition, Wake up and Introduction. The other group had a more limited number of Peer Instruction (5 quizzes) where almost all quizzes were given as Repetition. The first group will be labeled SRS-P, and the second SRS-C. We also note that there were more quizzes given in SRS-P (126) than in SRS-P (87).

The grading for the subject follows the ICTS standard, A being the highest grade and F representing a failed course. The average grading is obtained by giving 5 points for each A, 4 for each B and so on.

An inspection of the final grades for the three groups as shown in table 1 does not strongly support any progress in student performance in the SRS groups.

Table 1. Final grades in mathematics

Group	*A*	*B*	*C*	*D*	*E*	*F*	*Total*	*Percentage failed*	*Average score*
Control	*7*	*7*	*10*	*12*	*1*	*7*	*44*	*15,9*	*2,7*
SRS-P	*2*	*6*	*11*	*12*	*1*	*7*	*44*	*15,9*	*2,2*
SRS-C	*7*	*8*	*8*	*11*	*7*	*5*	*46*	*10,9*	*2,6*

We observe that the control group actually has the best average grade score, while the number of failed students is lowest in one of the two SRS groups.

There are of course a number of factors affecting the grades, examples being performance of the lecturer, student effort and educational level in advance to the course. The most important and available factor is the earlier grading score from vocational school. This is converted to a number between 0 and 60, the acceptance points, when the students apply to Sør-Trøndelag University College. Figure 7 shows the distribution of the performance of the students in the pre-qualification course of 2008-2009 depending on acceptance points. As expected higher acceptance points seem to increase expected grades. The Pearson correlation between acceptance points and grade is 0.33.

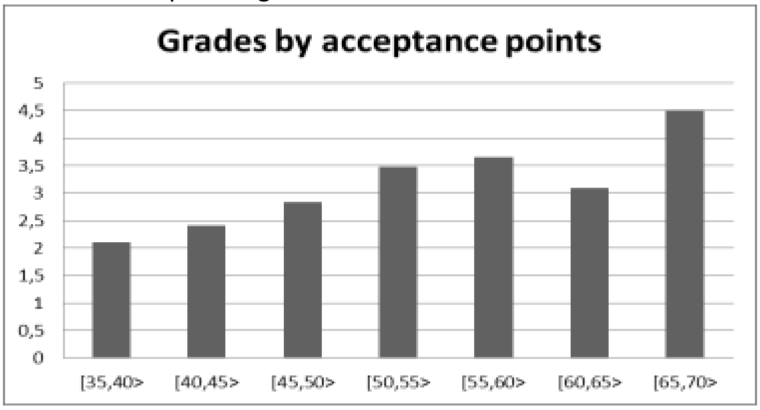

Figure 7: Grading depending on acceptance points

The importance of acceptance points is even more significant for students' tendency to pass the course. Of the 268 students in 2008-2009 180 passed the course, 88 did not finish the course and 60 did not pass the final exam. Figure 8 shows the distribution of students who did pass the course sorted by acceptance points.

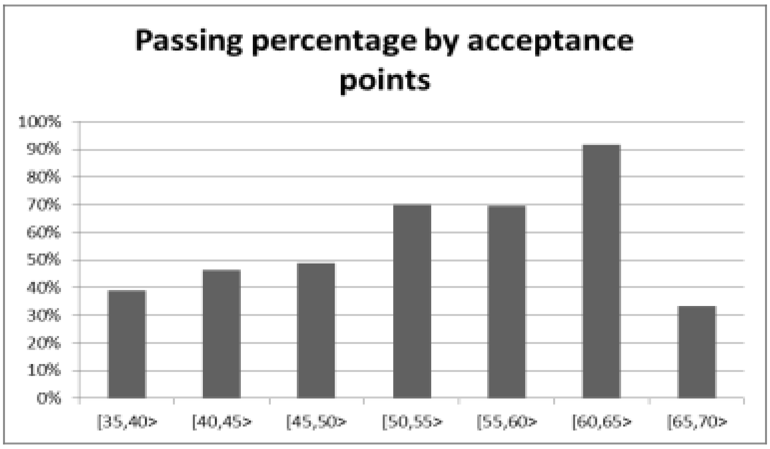

Figure 8: Passing ratio based on acceptance points

We observe that the passing ratio increases considerably when the students' acceptance points exceed 50. When we compare the three groups we should also take the acceptance points into consideration. As can be seen from table 2 the students in the control group have a higher average level than the two SRS groups.

Table 2: Average acceptance points

Student group	Average acceptance points
Control	42.3
SRS-P	40.2
SRS-C	40.0

The acceptance points become even more important when we consider the distribution shown in figure 9.

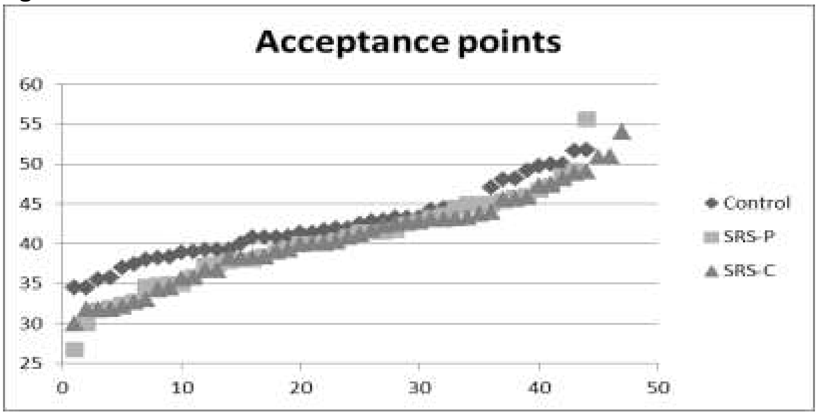

Figure 9: Distribution of acceptance points

The control group is the only group without a fair share of students in the critical area below 35 points where academic achievements tend to drop drastically (Arnesen 2012). We should then expect better results in this group, both in better grades and higher passing ratio.

The student polls indicate that the students are of the opinion that SRS increases their learning outcome. In the student interviews there are some suggestions that students whose performances usually lies in the lower half, will benefit more from SRS than the better students.

It is therefore of interest to examine the results for the students with the lowest acceptance points in the three groups. We restrict the sample to students with acceptance points below 40.The reason for this is that due to a minor change in the calculation procedure from 2008, points from 2011will be from 5 to 10 points higher than earlier. The students from 2011 with points below 40 would then be expected to be similar to the students from 2008 with points below 50. Those are the students we want to examine with increased learning outcome as SRS effect in mind. The results can be seen in table 3.

Table 3: Results for students with acceptance points below 40

Group	Average acceptance points	Average grades	Relative failure
Control	37.5	2.2	0.21
SRS-P	35.1	2.2	0.11
SRS-C	34.5	1.7	0.33

As can be seen from the average acceptance points and figure 9, the control group still has the “best” students, but the SRS group with the most frequent and most varying use of SRS has better performance. The last SRS group comes out with the lowest performance, but does also contain the students with the lowest acceptance points and therefore arguably the lowest potential for success. As a final inspection of which kind of students that benefits from use of SRS, we will look into three tests given throughout the semester. The students were graded on a percentage scale, which can give more information than the crude scale of ECTS grades. Table 4 shows the Pearson correlation between and acceptance points and percentage score on each test.

Table 4: Correlation between acceptance points and results

Group	Test 1	Test 2	Test 2
Control	0.56	0.55	0.35
SRS-P	0.05	0.15	0.11
SRS-C	0.31	0.31	0.29

These results strongly support the theory that SRS helped improving results among the students with the lower acceptance points. All groups have a positive correlation, but it is considerably lower in the SRS groups, especially in the SRS-P with the most frequent use of SRS.

The final class discussion before the lecturer's explanation is a version of the original peer instruction method (Mazur 1997). We have found that while few students usually will contribute to a discussion involving the entire class, these inhibitions seem to lessen when they are urged to defend their answer in a SRS session. We also have the impression that starting the lecture with the use of SRS will more easily get the students into a learning mode and to participate more actively in the entire lecture.

Another important reason for having the class discussion is the opportunity to reveal the possibility that the correct solution is reached based upon erroneous reasoning or conceptual misunderstandings. Recent research (Nielsen 2012) shows that in some cases the majority of students will reach the correct answer based on a misconception of fundamental theories. The class discussion can then be an opportunity for the lecturer to address and correct these misconceptions. One specific challenge is when the presented problem consists of performing basic mathematical operations, as for instance solving an equation or an integral. In these cases it will often be easier to find the correct answer by testing all the options in the quiz by "backward" calculations rather than solving the problem independent of presented options. One way to avoid this is to hold back the options until the students are casting their votes. In this case the students will have to rely upon their calculated answer instead of testing the different options. When this procedure is used, many students will reach a solution not listed among the given options. Therefore, we suggest adding "None of the above" as the last option in these cases. Some of these quizzes then need to have this option as the correct answer for the students to be able to trust their answer even if it is not listed as a possible solution.

Unfortunately we do register a decrease in the number of participating students during the two semesters. Figure 10 shows the development of participants from the first to the last quiz.

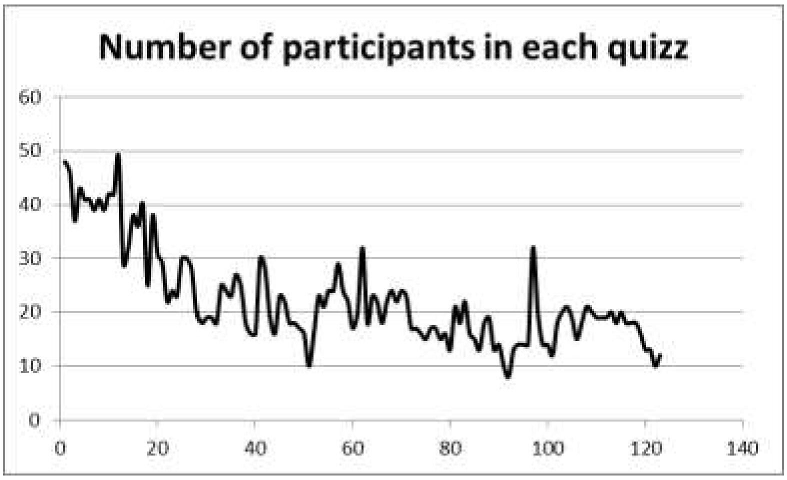

Figure 10: Development in number of voting students

This can partly be explained by a decreasing number of students. While 61 students started, only 43 finished the subject. In addition the students' tendency to skip lectures will increase throughout the semester. In some of the quizzes the number of present students was recorded, and figure 11 shows the percentage of participating students in these cases.

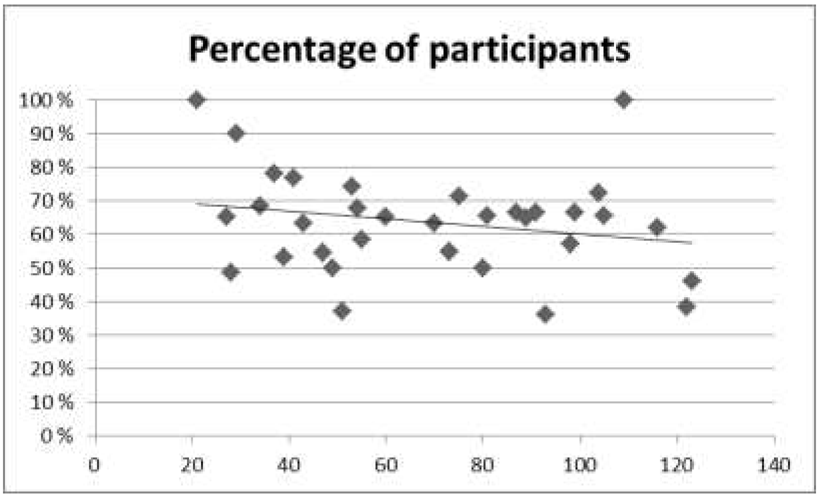

Figure 11: Development in percentage of voting students

The 95 % confidence interval for the slope of the regression line is given by (-1.15 ± 1.77) %. The probability for a negative valued slope is 80 %, meaning that the hypothesis of a possible decline in the percentage of participation is not statistically verified. The statistics for the regression line are shown in table 5.

Table 5: Regression for development of participation

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0,71544556	0,06564733	10,8983186	3,9501E-12	0,58155694	0,84933418
Slope	-0,00114511	0,0008703	-1,31576487	0,19790098	-0,0029201	0,00062988

Another interesting angle is to compare the amount of participation during the two semesters. The data show a decrease from 66 % to 62 %. There is no statistical evidence for a difference between the two samples, This is seen in the statistics in table 6,

Table 6: t-test on difference in participation by semesters

	1st semester	2nd semester
Mean	0,65726382	0,61642325
Variance	0,02547268	0,02146644
Observations	16	17
Hypothesized Mean Difference	0	
df	30	
t Stat	0,76437401	
P(T<=t) one-tail	0,2253076	
t Critical one-tail	1,69726089	

Still there is a fact that a significant part of the group is not participating. Explanations may be technical problems or lack of interest from the students. One of the interviewed students suggested a combination of these factors: "*Some time you can blame it on technical problems. You might get an error message or you don't have any battery power left or you just have left the iPod at home. But sometimes you are just not up to it. You just don't feel motivated*". Another possible explanation given in the interviews is that they often will choose not to answer if they do not have any preferred options: "*I think they don't answer because there are no "Don't know" option. People just don't want to make a wild guess, because if they are lucky and get the correct answer, the lecturer will get the impression that everyone has learned the stuff and just carry on*"

This last factor can be examined statistically. When the option "Don't know" is present, the mean participation increases from 60 % to 68 %. The hypothesis that inclusion of "Don't know" increases participation is still not statistically valid within a significance level of 0.05. As can be seen from table 7, the actual significance level is 0.08

Table 7: Relevance of "Don't know" option

	With «Don't know»	Whithout «Don't know»
Mean	0,678662254	0,603140112
Variance	0,0223179	0,022523249
Observations	14	19
Hypothesized Mean Difference	0	
df	28	
t Stat	1,432469891	
P(T<=t) one-tail	0,081540007	
t Critical one-tail	1,312526782	

4. Emerging technologies

A new version of the SRS is finished in january 2012. The most notable changes are a new and improved user interface, allowance for more multiple users and access to earlier voting results.

The Done-IT project, cofounded by the European Commission, aims at developing an assessment system based on the described response technology using smartphones or pods (Done-IT 2011). The pedagogical idea is to change the assessment into an area for learning as well as evaluation. This can be achieved by using SRS technique for immediate feedback on student scores to individual questions. If one or more of the questions are unsatisfactory, the lecturer may then give a short lecture, allow group discussion etc. followed by a new voting session giving the students a second chance to improve their assessment (Thorseth 2012). The assessment system will be tested in the pre-qualification course during the autumn semester 2012.

5. Conclusion

Studies have shown that SRS either has benign or neutral effect on learning outcome. We have suggested three methods for use of SRS in mathematics, Repetition, Introduction, and Wake up. All methods depend on the method introduced by Mazur. We have focused on what type of students will benefit from SRS, and our findings support the theory that SRS will increase learning outcome among students who usually have academic achievements in the lower part of the group. We still emphasize that this may not be true in other subjects and for other student groups. The varying results from different studies indicate that more research is needed to find and systemize the factors of success for use of clickers in education.

6. Acknowledgements

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