Incorporating Student Response Systems in Mathematics Classes

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In the past decade, Student Response Systems (SRS) have been used more widely in higher education as advancement in technology makes them more affordable, easier to use and of compact design. This technology shows potential in enhancing the student experience, especially in traditionally hard subjects like mathematics. Major reasons for introducing the technology into classrooms include positive student perception, anonymity, active teaching and learning and providing a natural break from straight content delivery. There remain issues related to the integration of the technology within mathematics courses - in particular related to the time required during lectures to successfully embed SRS without impinging too greatly on the delivery of the syllabus. In this study the appropriate number of questions that should be posed during a lecture is investigated, as is the time interval that should be permitted per question and when each question is posed. It has been suggested that SRS are not utilized effectively unless questions used provoke deep learning but this can be problematic and impact on endemic math anxiety regardless of anonymity. It is proposed that questions involving higher order thinking may be better explored within a tutorial environment using a Team Base Learning approach.

Keywords: SRS, technology, clickers,

Introduction

Student response systems (also called audience or personal response systems) involve use by most or all students responding directly in class to short questions posed to determine conceptual understanding. These allow the lecturer or tutor to gauge the effectiveness of learning transfer in a class. Commonly students use small input keypad devices (‘clickers’; ‘zappers’) to signal support for an option among those presented to them with a question stem. Multi-choice and true false questions are usually posed – sometimes mixed together – and displayed by prepared slide. The responses are automatically collected and the results analysed in spreadsheet and displayed for further discussion by the class.

The idea has been around for many years (Horowitz, 2006) but only recently have systems been sufficiently affordable and reliable to be widely used. Changes to technology also made systems compact, portable, wireless and easy to use. Even the wireless systems have undergone changes from infrared use to radio frequencies to increase efficiency and reduce collection errors. The explosion in their use in general over the past decade is charted in survey papers such as those by Kay and LeSage (2009) and Caldwell (2007). Retkute (2009) examines their use in mathematical

[1] Part of this work was done while this author was on leave at the School of Arts and Sciences (Vic), Australian Catholic University

sciences in particular. Titman and Lancaster (2011) report that one expert claimed some use of SRS existed in almost every university in the USA by 2006. The principal use has been in the science disciplines but there has been use in almost every type of course. The use varies from large lectures to small tutorials. It is used where class styles reflect classical instruction with interposed questions used to check student progress or attempts to run classes more as dialogues on material that students are expected to read in advance.

In this work we will briefly review the nature of and the reasons for using student response systems and examine some of the issues affecting its use, both technical and pedagogical. We will then analyse the outcome of using the SRS over a period of 3 semesters in classrooms where mathematics was taught in three different subjects to pre-service teachers in first and third year of their undergraduate course, and discuss the results in terms of prevailing theory and practice. The same questions used in two subjects provide for an analysis of response times and surveys on students in all three semesters provide information on attitudes and use.

Motivation for Using a Student Response System

Some educators claim the most common and traditional didactic delivery method in mathematics education is often seen as too disengaging, ineffective and therefore inefficient for large student numbers (Larsen, 2006). Whether we agree with this completely, it is clear that students are frequently absent physically from classes for many reasons including false perception of ability, excess outside social life and work and the tendency for mass education to funnel people into courses they may not be suited to or really seek. Students can readily feel isolated in large classes. This would be serious enough for subjects which are central to student interests but mathematics classes at university are often taken as service subjects, a major component of a course but not central to the student interest. A student's need for mathematics may then not be naturally coupled to high ability in the subject which can lead to student negative perception that mathematics is too hard and boring – reinforced by mathematics anxiety and phobia.

A number of benefits are claimed by advocates of these student response systems. We consider these in turn. The systems are automated and provide immediate compiling of responses. Response frequency data can be displayed to the class for discussion so that the various choices can be explored further including the opportunity to correct widely held misconceptions if this is needed. One common criticism observed in classes over time is the issue of poor feedback for students and this can be overcome by this process as each student gets a chance to vote and receive some feedback on their own opinion. Moreover this vote can be anonymous – a major issue in favour of the systems. Asking students to raise hands or comment on an issue directly does not allow effective and efficient data collection and display and it invites poor response rates or responses affected by student perception of their peers' opinions (conformity). This issue is well documented by Stowell et al. (2010) where a comparison of traditional approaches with clicker systems was outlined. The student response systems improved validity of responses by increasing variety and reducing conformity and boosted participation as anonymity ensured reluctance to be noticed at all or seen to be wrong was overcome. This feature is highlighted in most papers discussing the use of clickers and remarked on in survey papers (Caldwell, 2007; Kay and LeSage, 2009).

Favourable student reaction (which we see is admittedly not universal – see figure 2) to use of the response systems has been identified as a cause of improving student engagement with the class (on an individual basis) and for improving classroom attendance overall with the prospect that time on task will be improved – a key feature in the learning process. The prospect of improving engagement in class is remarked by Titman and Lancaster (2011) where this is believed to link directly to good pedagogy. This automatic link is questioned by Dangel and Wang (2008) who caution about the quality of engagement being a determinant on good learning. This issue of classroom attendance is also reported by Titman and Lancaster (2011) where they note poor attendance in class is discussed in several papers as a motive for introducing the clicker systems. It is addressed in both major surveys (Caldwell, 2007; Kay and LeSage, 2009). In some cases, this increased participation may be dependent on related variables. In a large engineering mathematics class, use of the clicker technology by d'Inverno et al. (2003) was accompanied by a use of 'skeletal notes' where students received partially completed notes which they needed to finish in class. The ostensible reason for this was to speed the flow of class presentation and allow time for clicker use without the commonly reported reduction in coverage of material. However students are more likely to attend regardless, if the subject notes sold contain gaps to complete in class, in contrast with courses where notes supplied are complete. The effects confound one another at this level.

An additional advantage is reported in promotion of team-based learning (Haeusler and Lozanovski, 2010). In this application the formation of small groups after an initial question session allows students to reflect on the results and review their opinions. This may address concerns by Dangel and Wang (2008) about the style of teaching which is reinforced by common clicker usage but it may seem to obviate advantages emphasised by Stowell et al. (2010) on the benefits of anonymity in suppressing conformity. In this case however a preliminary use ensures the legitimate response and the small group discussion forms part of the proper learning process. In any subject like mathematics where there is a true answer, the aim is for all students to conform to that opinion finally!

Methodology, Implementation and Practicalities

Three mathematics education courses were selected for this study which covered a period when mathematics education subjects at USQ [Faculty of Education] were re-vamped. The first course, in semester 1 of 2010, was the fourth year[2] mathematics course named Becoming Numerate that covered all the five strands of mathematics education. This was the last semester the course was delivered in favour of two re-vamped courses, namely the first year course Introduction to Numeracy, in semester 2 of 2010, and Mathematics Pedagogy and Curriculum in semester 1 of 2011. Broadly speaking, the sum of the content of these two re-vamped courses was equivalent to the former course, Becoming Numerate. Attendance is not assessed in itself. Approximately half the students attended in the clicker classes. In two subjects the material was also supplied online which can affect attendance. This attendance rate is in line with proportions reported in the literature and the increasing of this attendance and engagement of students is one motive for incorporating SRS in a course.

In all courses in the study, students had a traditional lecture and a two hour tutorial. Upon entering the lecture or tutorial room's students were instructed to pick up their "clicker" for use in class – each student was assigned a clicker number for the entire semesters work. A clicker is a radio transmitter with an electronic key-pad

[2] Please Note that "fourth year" here does not imply fourth year level content but merely that the course was available only to fourth years students enrolled in education courses.

(resembling the key-pad on a mobile phone) where the signal is received by a (compact) USB Dongle. No other hardware component is needed and the system can be used on any PC or Laptop where the proprietary software is installed. The software is an add-on within Microsoft PowerPoint. In lectures and tutorials students would be asked a series of multiple-choice and/or true-false questions. The lecturer would first read the question to the class and the possible answers (in the case of multiple-choice questions). Students would then respond to the question by depressing a number on their key-pad corresponding to the choice they assumed was correct. Then the overall response to a question was displayed on a bar-chart for the entire class to review. Finally, a classroom discussion would then address any misconceptions. The rate of giving questions was three per class-hour. A sample set used for analysis here are given in the Appendix.

In the event that close proximity of classes using the clickers should lead to interference it is easy to set the frequency in each room to a different level. Otherwise, the novice user may be surprised to see data arrive on the unit before they gather it which is merely a technical error!

In the first course that the clickers were introduced all questions were posed after the delivery of the course content. In this case, the clickers effectively facilitated an end-of-lecture/tutorial formative quiz. However, this approach clearly did not take full advantage of the technology being used. The clickers offer a chance to break lecture flow at natural concentration walls and may be better used this way. The time used in running the SRS comes from teaching time. This raises a number of fundamental questions – what is the optimal number of questions that should be posed during a lecture, what time interval should be permitted per question and when should each question be posed? Moreover, the types of questions posed are of critical importance as higher order questions (questions that required high order thinking), although needed, proved a stumbling block as far as the practical application of the program.

Table 1. Means and Medians for Survival (Response) Time

Question No	Mean[a]				Median			
	Estimate	Std. Error	95% Confidence Interval		Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound
1	4.729	0.373	3.998	5.460	4.454	0.106	4.246	4.661
2	11.266	0.612	10.066	12.465	11.275	0.231	10.823	11.727
3	64.923	3.816	57.443	72.403	49.327	5.542	38.464	60.190
Overall	26.973	2.363	22.341	31.604	11.275	1.450	8.433	14.117

a. Estimation is limited to the largest survival time if it is censored.

The student response times were studied in order to address the issue of the optimal number of questions and the time dedicated to each question. This was only applied to two of the courses as a sub-set of students from the latter went onto the third course, and this removed repeated exposure. The probability that a student will take longer than a specified time to respond produces an empirical distribution. Maximum likelihood estimators for this yield the Kaplan-Meier estimates from classical survival data analysis. These were produced for the response times with the analysis conducted using SPSS (see eg. Titman and Lancaster, 2011). This generates confidence intervals on 'response' times' – the time to final response or allows censored data to be used where the response was timed out. The estimates generate a step graph as shown in figure 1 and also give measures of location for response times as shown in table 1.

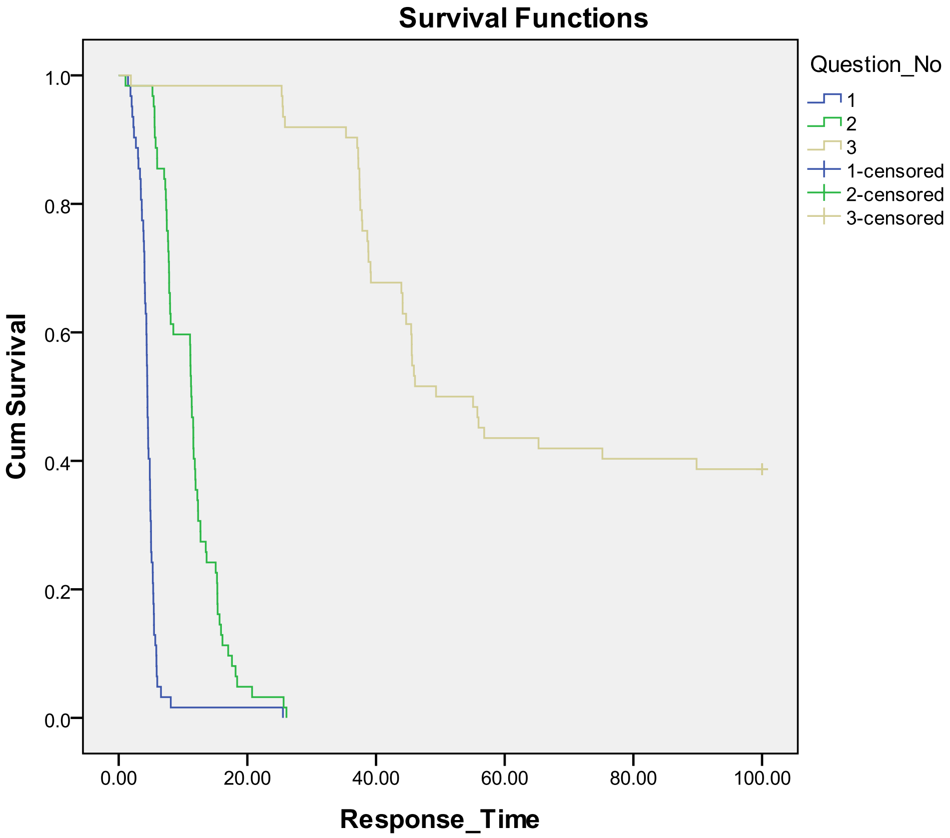


Figure 1. Graph of cumulative response times.

A comparison of the response time data between questions is interesting and instructive, as the graph in figure 1 shows. The first question was of no issue at all with over 95% of students responding within 10 seconds (after the question and possible responses was read out load). This was reinforced with a 90% correct response to Question 1 (see appendix). It is interesting to note that a few students either responded immediately or took considerably longer to respond relative to their peers. Several reasons may explain this common phenomenon – a technical or human error, or perhaps a manifestation due to student's objection to the use of the technology (D'Inverno et al, 2003). The second question proved more of a challenge as 95% of students responded within 20 seconds, but only 50% with a correct response. This question required more classroom discussion than the first. Again, some students either responded immediately or took considerably longer. The last question was the most problematic as 39% of student could not respond within a reasonable time (100 seconds) and of the 61% that did reply within a reasonable time only 37% responded correctly. It is evident that Question 3 requires substantially more computation than Question 2 which the students could not deal with in the lecture environment. Although a classroom discussion was then initiated, this problem was a good candidate for further and more detailed consideration in a tutorial setting. This information is still useful to the lecturer as it shows that more time on the idea is needed for learning to occur.

The output in table 2 shows that the response times could not reasonably come from a single distribution pattern which is also strongly suggested by figure 1. Although the students only receive 5 options and can press a clicker in the same time regardless of question level, they clearly choose to reflect on a response and not merely give a random or first guess. This is despite the total anonymity involved. Response time patterns will differ with level of difficulty even though the correct response is always a selection of a listed option.

Table 2. Statistics on Response Time Pattern

Overall Comparisons

	Chi-Square	df	Sig.
Log Rank (Mantel-Cox)	284.668	2	0.000
Breslow (Generalized Wilcoxon)	227.920	2	0.000

Test of equality of survival distributions for the different levels of Question_No.

Student Perception and Benefits

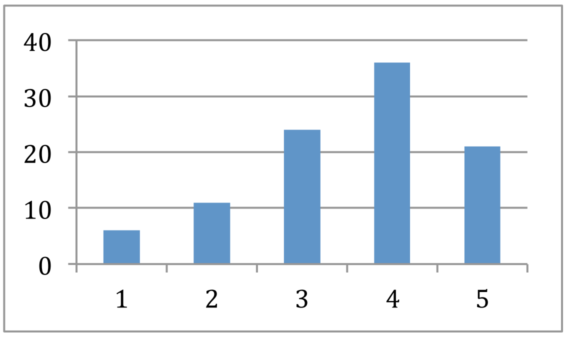
Student perception of SRS use has been commonly found to be very positive as noted by Kay and LeSage (2009). This is confirmed by a survey carried out on subjects over 3 semesters at USQ. Students were surveyed on seven items and the 5 point Likert scale of agreement was analysed to show the accompanying bar-charts in figure 2.

The mathematics education students reveal the method is generally popular but as noted in other institutions there are detractors and here they form up to 20% of the cohort. The negative responses were most marked on the issues of whether the clickers assisted learning, made the class more engaging or clarified the student how they stood with regard to their peers. It is interesting to note that some students who claimed it did not assist learning clearly still believed it helped them identify areas of strengths and weakness. This may imply they still were unable to decide how to get help to rectify the weaknesses or capitalise on their strengths and this in turn means it may be the post- SRS discussions that need examination.

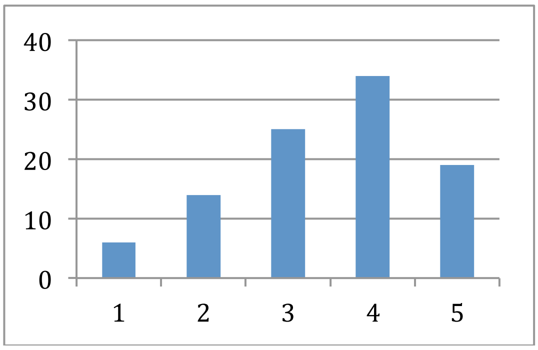
Discussion

Rapid change to secondary level delivery of mathematics, incorporating use of technology, can promote high expectations in students entering tertiary education (d'Inverno et al, 2003). It would be folly to use technology for its own sake or misuse it but students are now clients and expect universities to invest in constant improvement in course development and delivery and the university system is a free market. If more students like using clicker technology than not, and feel more engaged regardless of final performance it creates pressure to provide this. Many authors argue this fact and our results confirm it as seen in figure 2.

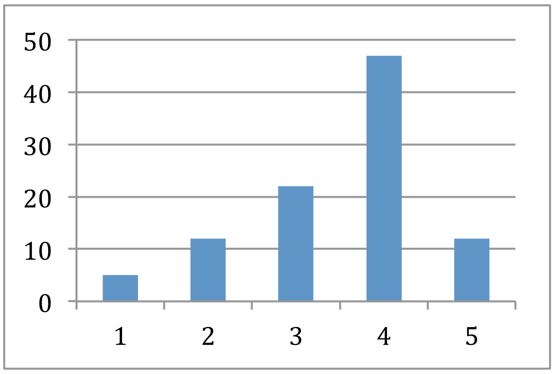
If we are to use an SRS it is important it be used wisely as noted by Beatty (2004) and emphasised by Dangel and Wang (2008). Beatty (2004) talks of transforming student learning with clicker technology but remarks that the form of questions used need to have a clear and defendable pedagogic goal, and he lists seven examples of these which draw out understanding, highlight and remove common misconceptions and do more than probe memory or call on facts or computation. Dangel and Wang (2008) suggest that their survey reveals little of this in the visible literature painting a depressing view that the clicker technology is not definitely associated with any measurable improvement in overall performance which they attribute to its use in surface learning.



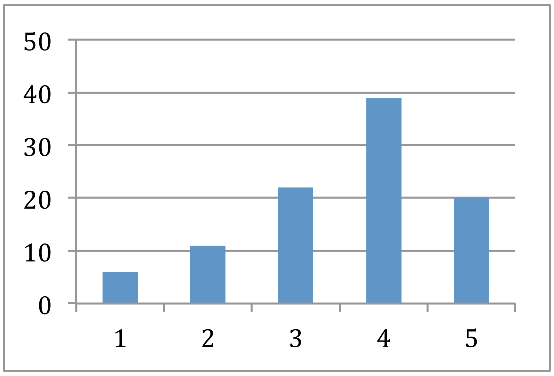
Was not a waste of time



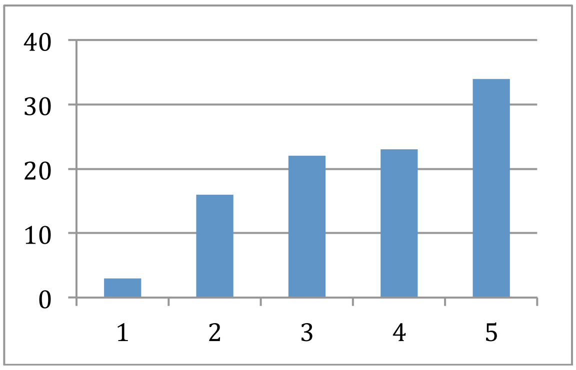
Did assist my learning



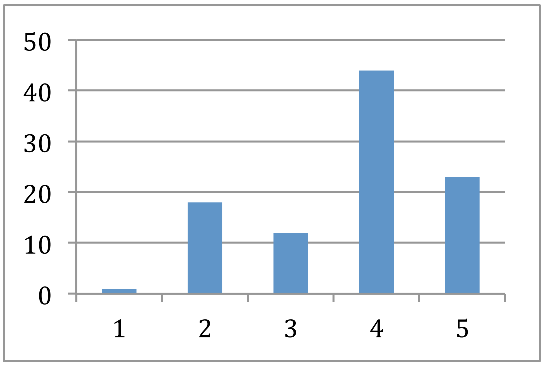
Assisted understanding of concepts discussed



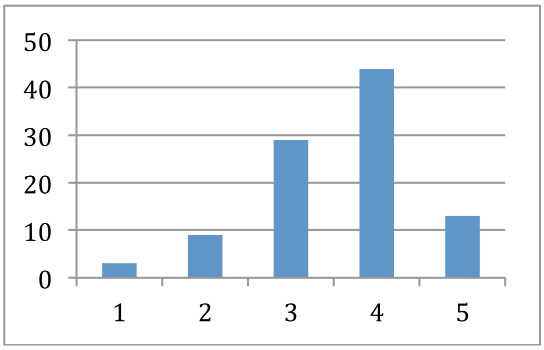
Prompted discussions in my group



Made the classes interesting and engaging



Showed me where I stood in relation to the rest of class



Helped me identify areas of strength and weakness in content knowledge

Figure 2. Bar charts on student attitudes (1 = strongly disagree 5 = strongly agree).

We have seen that students generally do not provide answers indifferently, and this has implications for the recommendation of Dangel and Wang (2008) that only deep learning questions, which take longer to reply, should to be used. They rightly urge that the SRS be married to good pedagogy to enhance deep learning rather than decry the technology however. This data on student response times does argue against questions that need any serious calculation, which may be merely time consuming but not insightful in pedagogical terms.

In the first question which was used in the sample discussed in this study the aim was to use the SRS to assist in engaging student attention and reducing math anxiety which was endemic to the cohort. Where this is the aim, the question needs to be posed at an easy level. The issue of pedagogy is strained further when we see that the third question used had many non-respondents as students could not answer it, and declined to 'guess'. This could signal more time needed to be allocated but it also brings up one significant issue with the clicker systems.

One serious problem identified in the literature is that use of an SRS removes teaching time. The time taken includes reading out questions, waiting for longest response time (or choosing a cut-off) and clarifying any misconceptions found. The time sacrificed in this sample was about 3 minutes of waiting time , about 1 minute of reading time and perhaps 4 minutes of discussion in a 50 minute class totalling about 16% and this reduction is reported to be of the order of 15% to 30% in different studies. As d'Inverno et al. (2003) note, this is an unacceptable loss of coverage for providers of a service mathematics course – even if we could demonstrate that students were learning better and retaining more. Courses are already under twin pressures of coping with entry students of reducing background and course management pressure on time allocated to service subjects. This is certainly the case in engineering mathematics for example. Other disadvantages can be identified to use of an SRS. The technology itself carries a cost and whether this is borne entirely by the institution as at USQ or partly by students as reported in some US universities, it has implications for use. Some students are not engaged by the SRS and have negative reaction to it, as seen in our survey in figure2. This may be exacerbated if universities elect to make students pay fort heir own clicker as occurs commonly overseas.

In summary, the use of an SRS comes down to balance in a gain/loss case. The gains include frequent nonthreatening feedback for students on learning and for lecturers on student understanding. This in turn offers a chance for better learning transfer. The overall student favourable perception of SRS shown here and in the literature offers a prospect of better engagement by those attending and higher attendance in classes. The losses include a need to reduce class coverage of material through time used in the SRS and the initial cost of implementing the process.

This issue of time used on the SRS needs to be addressed. Either more time in the syllabus needs to be made by using other devices like skeletal notes and/or technology to assist coverage like use of CAS or we need to find an acceptable loss level at which to operate. The amount of time we could sacrifice will dictate how many questions can be used and how long they may take. In practice the number of questions set here also assists in breaking up an hour into more manageable periods of concentration for students. The level of questions should vary and the final question here showed that anxiety may remain even with anonymity which may argue against using each question to probe deep learning; some may be chosen to just inspire participation. There is no clear answer on how many questions can be used in a class although more than 3 or 4 seems unnecessary, and the time loss would be too high. However the issue on how to gain more effective learning transfer as identified by Dangel and Wang (2008) remains unresolved and so we need to examine cases where the technology was used and it lead to improved results. The items students traditionally have trouble with are always a good start for building suitable questions.

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Appendix

The multiple choice questions chosen for the analysis:

Question 1: How many Tens are there in 13201...?

1. Zero
2. 20
3. Three hundred and twenty
4. 1320
5. 132

Question 2: 1/(5 × 5) has the equivalent decimal form of...?

1. 0.5
2. 0.05
3. 0.2
4. 0.4
5. 0.04

Question 3: The Base 10 value of 444_5 *is...?*

1. 124
2. 444
3. 421
4. 123
5. 4440