Can Clickers Enhance Team Based Learning? Findings From A Computer Science Module

Phil Maguire[†]

Rebecca Maguire[‡]

[†]NUI Maynooth

[‡]National College of Ireland

Abstract

In this study we describe a novel use of clickers in a second year computer science module. In recent years instructors in higher education have begun introducing classroom technology so that students can anonymously respond to questions during lectures. Studies have shown considerable benefits in terms of attendance, classroom engagement and instructor feedback (Caldwell, 2007; Kay & LeSage, 2009). In this study students were partitioned into self-selected groups of three. 20% of the final module grade was earned by answering clicker questions during lectures in competition with other teams. We found that the use of clickers had a dramatic effect on both attendance and engagement in class compared to analogous modules where clickers were not employed. Students were far more likely to ask questions and defend their points of view, both before and after lectures. At the end of the semester the majority of students rated the clickers positively. However, the final module grade was lower than previous years. An anonymous survey suggested that although students enjoyed working in groups, they were less likely to take personal responsibility for their own learning when there were others on the team that could do the work. In light of this, we recommend allowing students to discuss clicker questions together during lectures, but awarding marks individually.

Keywords: Clickers, computer science, data structures, algorithms, group work, programming, class engagement, assessment

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1. Introduction.

Many students taking introductory computer science (CS) find programming very challenging, with the result that up to a quarter of students drop out and many others perform poorly (Fowler & Yamada, 2009; Peters & Pears, 2012; Williams & Upchurch, 2001). One problem is that introductory CS modules often involve large classes with minimal interaction between lecturers and students. Textbooks and lecture material are often heavy on declarative knowledge, with particular emphasis on the features of a programming language (Robins, Rountree & Rountree, 2003). However, given that the skill of programming requires procedural knowledge, it is best learned through practice, experience and engagement with peers and instructors (Traynor & Gibson, 2004).

Research has shown that students must be active participants in the learning process in order for deep learning to occur (Mayer et al., 2009). Knowledge must be put into practice in order for misunderstandings to rise to the surface where they can be challenged and corrected (McKeachie, 1999). The ideal learning environment should involve mastery-oriented feedback, choice-making opportunities, interpersonal involvement and opportunities for students to evaluate their own and others' learning (Trees & Jackson, 2007). Unfortunately, the traditional lecture limits students' opportunities to practice activities that encourage higher-order learning (Trees & Jackson, 2007). In large classes it is simply not feasible for the lecturer to interact with each student. Perceived anonymity makes students more reluctant to participate in class (Wulff et al., 1987), with the result that many become passive recipients, as opposed to active participants in the learning process (Mayer et al., 2009). While large lectures can be effective in presenting new material, passive transmission fails to engage students in application, analysis, synthesis or problem-solving, all of which are essential for any CS graduate. What is required for teaching large CS classes is an instructional method that can motivate learners to process conceptual knowledge deeply, as well as supporting interaction with the instructor and other students.

1.1 Overview of Clickers.

The last decade has seen a rise in popularity of classroom technology that allows students to respond to questions via a small hand-held device. These devices, often known as 'clickers', typically have several buttons which allow students to reply to multiple choice questions in the style of game shows such as "Who Wants to be A Millionaire". The answers can be immediately aggregated, analysed, displayed and subsequently discussed in lectures. Clickers were first introduced at Stanford and Cornell in the 1960s, but only became commercially available in 1992 (Abrahamson, 2006). In 1999 a new generation of more affordable clickers was launched, with widespread use emerging in 2003 (Kay & LeSage, 2009). The most recent models have a 10-digit numeric keypad and keys for permitting text entry (Caldwell, 2007).

Clickers have been used in classes ranging from just 11 students (Smith, Trujillo & Su, 2010) up to 300 and beyond (Draper & Brown, 2004), and have been used to teach courses ranging from nursing to engineering to philosophy. They have also been employed in a variety of settings from optional tutorials to co-operative learning through peer-instruction (Caldwell, 2007). Clickers can successfully compensate for the passive, one-way communication that is inherent in large classes. They can motivate students to learn by focusing attention, facilitating feedback, providing challenges and encouraging active involvement (Blasco-Arcas, Buil, HernáNdez-Ortega, & Javier Sese, 2012; Trees & Jackson, 2007).

Students in larger classes are often reluctant to respond to questions because of fear of embarrassment, public speaking or peer disapproval (Caldwell, 2007). Solutions such as calling on student volunteers, or selecting students randomly from a list are not popular strategies, and typically only elicit responses from a small fraction of the class. This small vocal minority can give the false impression that the larger silent majority understands a topic (Caldwell, 2007). These issues are directly addressed by clicker systems, which allow students to respond anonymously and provide lecturers with instant feedback which can be used to clarify misunderstandings. Clickers can also change the atmosphere of lectures, with students more likely to become visibly active participants (Beekes, 2006). The act of committing to an answer causes students to become emotionally invested in the question, focusing their attention on the discussion that follows, and motivating them to defend their viewpoint (Beatty, 2004). The use of clickers can thus enhance metacognitive skills in students, allowing for deeper reflection on core conceptual issues (Brady, Seli & Rosehtal, 2013).

Studies have shown that the longest an uninterrupted lecture can be comfortably endured is only 20 minutes (MacManaway, 1970). Clicker questions serve to break up a lecture, allowing students to refocus their attention and improve their concentration. Students generally report a positive attitude towards the use of clickers, citing the benefits of anonymous contribution and the possibility of comparing answers immediately with the rest of the class as positive aspects (Bunce et al., 2006; Vaterlaus, Beckert & Fauth, 2012). Martyn (2007) investigated whether students' appreciation of clickers was due to the technology itself or due to the active learning pedagogy. In a direct comparison of clickers with class discussion, clickers were consistently rated more positively, suggesting that it is the dynamics of clicker use per se that students enjoy.

The use of clickers has also been found to lead to dramatic increases in attendance. For example, Burnstein and Lederman (2001) found that when clicker scores accounted for 15% or more of the course grade, attendance levels rose to 80-90%, with students noticeably more alert during lectures. Caldwell (2007) reports that attendance can be increased by assigning only 10% of the overall grade to clicker participation, though when this is reduced below 5%, the effect on attendance remains negligible. Clickers also appear to reduce student attrition, more than halving the number of students dropping out in some studies (Caldwell, 2007).

1.2 Peer Learning.

Another advantage of clickers is that they can be used to facilitate peer learning by encouraging students to discuss questions (Levesque, 2011). For example, one strategy is to ask students for an initial individual response, display the results, and then get them to discuss the question among themselves before voting again (Caldwell, 2007). When students make a mistake and see that many others voted for it, there is less stigma discussing what made that answer seem plausible (Simon et al., 2010).

Previous studies have shown that peer learning can result in superior learning gains and exam scores than the more traditional content based approaches to course material (MacManaway, 1970; Pollock, 2006). In surveys on peer learning, Nichol and Boyle (2003) found that 92% of students felt that discussing with others helped them to learn, with 82% agreeing that hearing other students' explanations helped them to develop their own understanding. Because of their common ages, language and mastery of the subject, students can be better than the lecturer at clarifying each other's mistakes and misconceptions (Caldwell, 2007). Communication can occur on an equal level, and information can be presented in a format which more closely matches the learner's immediate experience, leading to deeper processing (Assiter, 1995). In addition, when a student explains a concept to other students, it serves to reinforce their own understanding (Coleman, 1998).

In our study, we expand on this idea by examining how clickers can be used in a team-based scenario. Several studies have noted positive effects of team competition in a classroom setting. Lasserre (2009) found that team-based learning resulted in a significant change of ambiance in the class, with increased participation leading to enhanced student confidence and lower dropping rates. Jones et al. (2001) also noted that students became more involved with clickers when they were used in groups as opposed to individually. We hypothesised that using clickers competitively in teams would enhance both engagement and peer learning in the class.

2. Method.

2.1 Participants

This study was carried out with 120 students taking two consecutive modules in data structures and algorithms at NUI Maynooth. While all students were taking computer science, they came from a wide range of disciplines with some undertaking this as a minor subject as part of an Arts or Science degree, and others taking it is a single honours course. With the exception of a handful of students completing a Higher Diploma in computer science, the majority of students were in their second year of the course.

2.2 Design.

Clickers were used in the first semester module (data structures and algorithms 1) but not the second semester module (data structures and algorithms 2). This allowed for a within-participants design to be employed whereby student attendance, engagement and performance could be compared across the two semesters (with and without clickers). In addition, a quasi-experimental design was employed to compare exam performance on the semester 1 clicker module with performance on the identical module in previous years.

2.3 Procedure.

Each student was provided with a clicker, which they were told they would have to hand back at the end of the semester. Students marked down the code on the back of their clicker so that their responses could be identified. A total of 20% of the module grade was awarded for participation. Since such a large portion of marks went towards clicker questions, we were concerned about lectures becoming too much like exams, raising the possibility of student anxiety and also cheating. For example, Caldwell (2007) found that up to 58% of students had observed their peers bringing multiple remote devices to class to record marks for missing classmates. Given the high stakes, students might end up focusing on communicating the right answers to each other rather than on trying to think about the question themselves. For example, CS students with laptops could potentially devise a system for broadcasting answers to the whole class, ensuring maximum marks for everyone while also misleading the lecturer on the class's mastery of the material. In light of these possibilities, it was decided to assign students to groups and have all of the groups compete against each other for marks.

We hypothesised that dividing marks among teams in a zero sum game would eliminate the motivation for broadcasting answers between teams, while promoting constructive collaboration within teams. Teams were awarded marks based on their ranking of correct answers relative to the rest of the class. For cases involving a tie in the number of questions answered correctly, response times were used to decide the ranking. No matter how many or how few questions were answered correctly, the same amount of CA marks was always distributed among the class. Caldwell (2007) recommends giving partial credit for any answer to keep the pressure off students during lectures and reduce anxiety. In light of this, we awarded 50% to the weakest team each week and 100% to the strongest, with graded levels in between. An individual on an average team, attending all lectures, could therefore expect to earn 75% of the CA marks available for clicker participation.

Based on our previous experience with team-based programming it was decided that the optimal size for a team was three students. Students were invited to select their own groups, though some remaining students without groups had to be matched randomly. Inevitably this resulted in some students expressing dissatisfaction with the commitment and ability of the people on their team. Some students had poor attendance during the semester and others dropped out, leaving their teams short of members. The scoring system was thus designed so that teams missing members would not be penalised. This was achieved by always selecting one answer at random from all responses provided by team members for a particular clicker question. Given that it would be unfair for all members of the team to gain equal marks regardless of contribution, individual marks were adjusted by taking the team mark and multiplying it by the proportion of questions answered by the individual. For example, if a team earned 80% overall, a team member responding to only half of the clicker questions for that week would earn 40%. It was hoped that the system would encourage team members to sit together in lectures so as to ensure consistency of responses and avoid losing marks.

The goal of the intervention was explained to the class and they were told that they could contact the lecturer at any time to discuss potential problems. In addition, they were informed that all data would be anonymised and used for research purposes only. As the use of clickers and team-based assignments is standard practice in many third level institutions (Caldwell, 2007), students were not asked to provide ethical approval for participation. Although occasional problems arose involving disagreements with other group members, these issues were resolved by reassigning teams.

2.4 Question development.

There are many guidelines in the literature surrounding how to design good clicker questions. Beatty et al. (2006) state that the critical challenge is creating questions that cultivate productive classroom interaction and discourse. Kay and LeSage (2009) recommend that questions should be ill-defined and vague so that students are required to think and debate to find the correct answer. They also recommend that questions should focus on deep reasoning rather than on the memorisation of factual content and that they should identify and help to resolve misconceptions. Designing a batch of questions to match these criteria each week was challenging. Several forms of questioning were employed. One type involved a series of five statements about data structures and algorithms, one of which was false. Another type of question involved a piece of code with some calculations and options for possible outputs. Other questions presented students with a piece of code and challenged them to count the number of errors within it. This was particularly conducive to discussion because different students would spot different errors, and the question could only be answered successfully by pooling all of the information together. Another type of question presented a real-world problem (e.g. a set of items to be sorted by height) and a range of options for how this would be processed using a particular algorithm. All of the questions were based around deep conceptual issues so that answers could only be identified with confidence given a comprehensive understanding of the concept. We also aimed to highlight common misperceptions by deliberately creating surprising solutions and then having students discuss them afterwards. Our previous research has shown that surprising experiences motivate the learner to engage in a representational updating process, therefore enhancing the depth of processing of the material (see Grimes-Maguire & Keane, 2005; Maguire & Keane, 2006; Maguire & Maguire, 2009; Maguire, Maguire & Keane, 2007; Maguire, Maguire & Keane, 2011; Maguire, Moser, Maguire & Keane, 2013).

Kay and LeSage (2009) recommend that questions should be sprinkled throughout a lecture at a rate of two to five questions per 50 minute class, with no more than 20 minutes in between each question. The average number of questions presented was 3.75 per each hour-long lecture. As team rankings were time dependent, this motivated students to respond as quickly as possible, providing a clear picture of the difficulty of each question. Once the majority of students had responded, an additional 30 seconds of time was allowed before closing the voting. To reduce student anxiety about marks not being properly recorded (Caldwell, 2007) all results were posted online later that day.

2.5 Questionnaire development.

A questionnaire was devised for evaluating students' overall enthusiasm for using the clickers, as well as their expectations regarding effect on attendance and attention in class. Responses were obtained using the clickers themselves, with students rating their agreement to a series of statements on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Students were questioned on their attitudes and expectations in the first week of clicker use, and in the last week of semester they again responded to the same questions retrospectively.

3. Results.

3.1 Student Perceptions.

Table 1 displays the mean scores for each question posed to students in the first and last week of clicker use. As can be seen, students remained positive towards clickers throughout the semester, with the largest perceived benefits in terms of attendance. Dependent t-tests showed no significant differences in the pre and post test scores for each of these measures ($p < 0.05$).

Table 1: Mean student responses on the perceived benefits of clickers.

Question	First Week	Last Week
How enthusiastic are you about using clickers?	3.62	3.67
Will/did clickers enhance your attendance?	4.16	4.01
Will/did clickers make you pay more attention?	3.75	3.5

Given that the implementation of clickers necessitated team interaction, students were also questioned on their team dynamics, as well as their attitudes towards working in teams, halfway through the semester. On the whole these results revealed that most students were happy with the collaborative element of clickers, with only some exceptions. 63% said that they already knew both of the people on their team, while another 22% knew at least one. 58% said they were sitting beside both of their team members in that lecture, with 26% sitting on their own.

68% of students reported that they were very happy with their team.

3.2 Effect on attendance.

Comparing weekly attendance rates between semester 1 (when clickers were used), as opposed to semester 2 (when clickers were not used), it can be seen that there was a significantly higher proportion of attendance recorded in the clicker group. Figure 1 shows that the lecture attendance in the first semester, when clickers were used, exceeded all of the lecture attendances in the second semester, when clickers were not used ($p < 0.01$).

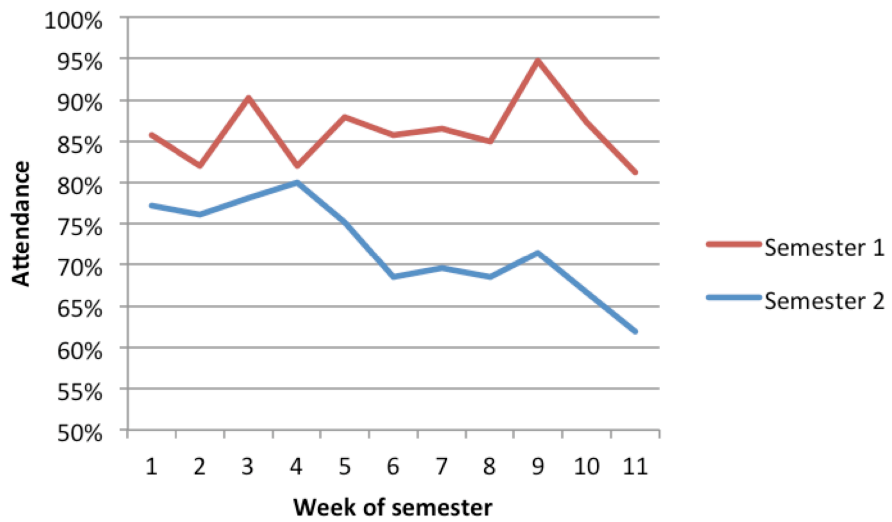

Figure 1. Class attendance in Semester 1 (clickers used) and Semester 2 (no clickers)

3.3 Student Engagement.

In previous years teaching the same module, interaction during lectures was minimal, with few questions posed and few students responding. In contrast, the use of clickers had a dramatic effect on the dynamics of the class. Students were very vocal in defending their choices and would argue extensively to communicate their opinions, spurred on by other students who shared the same view. The presence of ambiguities or mistakes in the questions themselves also created a significant amount of debate. In line with Beatty (2004), through the act of selecting a particular answer, students developed an emotional involvement in the question. They would raise their hands to reveal errors in the code. They would type the code into a laptop to check if it worked, or search online to find information supporting a point. At one stage, students refused to leave the lecture hall until the answer to a ‘cliff-hanger’ clicker question was revealed. Students would email the lecturer corrections to the lecture slides which at times had gone unnoticed, or unmentioned, for years.

The amount of discussion the clicker questions generated was also evidenced by the activity on the Moodle news forum. Table 2 shows that, in the second semester, when clickers were not used, the volume of activity from students dropped markedly. Without emotional involvement, students became more reluctant to commit themselves and engage in discussion.

Table 2. Activity on the Moodle news forum by semester

	Semester 1 (clickers)	Semester 2 (no clickers)
Threads started by lecturer	12	10
Threads started by students	16	8
Replies by lecturer	24	21
Replies by students	73	40

3.4 Student Retention.

Another advantage of using clickers was that it allowed the lecturer to monitor how each of the students was performing throughout the year. Any sustained absences were noticed by fellow team members and reported to the lecturer, as well as being revealed each week by the grading system. This meant that the lecturer had an enhanced awareness of which students were at risk of disengagement, allowing any problems to be tackled early on. Table 3 shows a decrease in the number of students failing to take the final exam when clickers were used, relative to the two previous years.

Table 3. Number of students completing by year

Year	Students Enrolling	Students completing	Dropping rate
2012 (clickers)	133	128	3.75%
2011	121	114	5.79%
2010	97	90	7.21%

3.5 Exam performance.

In the final week students were asked whether they felt that the use of clickers would have a positive effect on their exam performance. The average response on a 5-point Likert scale was 3.03, indicating that overall students did not feel clickers would have any impact, positive or negative. Correlation analysis revealed that exam performance was moderately correlated with clicker question scores (Pearson's $r = .385$; $p < 0.01$). When comparing exam scores with those of the same module from the preceding year (where clickers were not used), a significant difference was found, $t(240) = -2.69$; $p = .008$. However rather than achieving higher results, the clicker group scored lower in the exam with a mean of 45.55% (SD = 21.273) compared to the previous year's mean score of 52.47% (SD = 18.26). The exam failure rate, which averaged 21.7% in previous years, more than doubled to 44.4%. Students appeared to have a very poor grasp of programming and to have put less effort than usual into studying. On the surface these outcomes undermine the assumption that clickers would be beneficial to the class.

4. Discussion.

The literature on the relationship between clicker use and learning outcomes is mixed. Martyn (2007) found that although clickers were consistently rated more positively than class discussion, the test scores of students using clickers were actually lower than those involved in class discussion. Similarly, Fitzpatrick, Finn and Campisi (2011) concluded that although clickers enhanced engagement, their hypothesis of increased student performance was not supported. In contrast, several other studies have demonstrated beneficial effects (e.g. Preszler et al., 2007; Crossgrove & Curran, 2008; Reay et al., 2008). For example, Mayer et al. (2009) carried out a study involving three groups, one using clickers, another exposed to the exact same questions but without clickers, and a control group. They found that the clicker group had a significant gain of approximately one third of a grade point over the other two groups. Bojinova and Oigara (2011) also found that while clickers did not significantly affect examination results, there was less variation in scores within students who used clickers relative to those who did not. In light of these mixed findings, Kay and LeSage (2009) conclude that no firm link between clicker use and learning performance has been established. Rather, they suggest that it is the implementation of appropriate pedagogical strategies in combination with clickers that influences student success.

Questionnaires were handed out to everybody in the class at the beginning of the subsequent semester to investigate what had led to the poor performance in exams. Students were invited to provide anonymous feedback on their experience of clickers. The general feedback was that, while they enjoyed working in teams, this may have disincentivised many students from trying to understand the concepts for themselves. Many teams featured one strong programmer who would end up making most of the decisions. Rather than benefitting from the opportunity to engage in peer learning, students were instead availing of the opportunity to take a back seat, as opposed to taking responsibility for their own learning. Students also reported that the marks awarded for clicker participation were too high, with many ending up doing less study for the exam because fewer marks were needed to achieve a pass grade overall.

On the whole students reported enjoying clickers and the majority were in favour of using them again in other modules. Many were of the opinion that clickers had improved their attention in class and they enjoyed the competitive element, though some admitted simply clicking random buttons. Students reported self-organising into informal groups outside their officially recognised group and regarded the scoring system where one answer was selected at random from the pool of team responses as unfair and demotivating. The following quote is representative of the feedback received: "I *liked the clickers. They made me focus during lectures, and gave me motivation to turn up…I learned better by myself. Having groups helped me out, but I think I relied on my group too much*."

5. Conclusion.

The feedback above suggests that it was the group-based paradigm that was responsible for the decrease in exam performance, rather than the use of clickers per se. It appears that imposing complex structures for motivating participation, such as competitive group-based questions, actually encourages students to delegate responsibility rather than enhancing peer learning. Learning how to work in a team is an important skill, especially in computer science where large scale software projects are necessarily collaborative. Nevertheless, the current study suggests that, for modules where the learning outcomes are centred on the development of individual skills, the advantages of group work are outweighed by the reduction in students' overall level of participation.

Attempting to promote a peer-learning environment by controlling how students interact may be unconstructive. A more pragmatic approach might be to allow students to make their own choices about how to organise themselves, allowing them to take responsibility for their own learning. Students naturally organise themselves into dynamic groups within the class, where peer learning can take place. In future we intend to facilitate this natural interaction by allowing students to discuss questions freely with those around them. However, marks will be awarded individually so that all students are incentivised to participate.

Group work aside, the introduction of clickers was successful as regards enhancing attendance, attention and engagement. Anecdotally, the positive effects on the overall dynamics on the class, in terms of assertiveness, confidence and engagement persisted beyond the study. In light of this, we intend to continue using clickers to teach data structures and algorithms in future years, albeit without the group-based element.

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