Understanding the components of the *i*clicker system that promote learning, retention, and generalization of classroom knowledge

Introduction

A variety of innovative classroom techniques are currently used by STEM educators (see Hoffman & McGuire, 2010) and one such technique that will be the focus of this research is the clicker technique. This technique has been implemented internationally on almost 700 higher-level education campuses (i>clicker, 2009) in a wide range of courses, including physics, astronomy, statistics, and cognitive psychology. The use of the clicker technique involves instructors presenting periodic multiple-choice questions to a class of students, who respond via a hand-held device, a "clicker." Instructors and students receive immediate feedback in the form of a frequency distribution that displays how many students selected each answer choice. The results of these tests can aid instructors in deciding whether or not to spend additional time on the questioned material and in identifying and understanding where confusion might be occurring. Classroom data suggest that students believe that clicker use helps increase their understanding of material (Greer & Heaney, 2004) and that the anonymity of students' clicker responses facilitates student participation by providing a secure environment for students to answer in-class questions without risk of embarrassment (Stuart, Brown, & Draper, 2004). Despite the clicker technique's popularity and success in the classroom, there is very little empirical research comparing it to other classroom testing procedures and there is almost no examination of laboratory analogues of the clicker technique. It is important to identify which components of the technique produce benefits for learning and to establish methods of use that maximize the benefits derived from using the technique.

There are other systems similar to the clicker technique such as personal response systems (PRS), wireless response systems (WRS), and electronic voting systems (EVS), but all of these systems operate according to the same principles. The current literature on the clicker technique and related systems points towards a positive correlation between clicker use and learning outcomes. Kennedy and Cutts (2005) found a positive correlation between learning outcomes and the proportion of clicker questions answered correctly during class. One explanation for this relationship was offered by Mayer et al. (2008), who found that a class that received clicker questions earned 1/3 of a grade point higher in the course than sections of the same class that did not receive clicker questions. According to a generative theory of learning (Wittrock, 1989), the class that received clicker questions was more cognitively engaged than the class that did not receive clicker questions (Mayer et al., 2008). Donovan (2008) found performance improvements between an in-class concept question and a corresponding exam question. Smith et al. (2009) documented performance improvements between two related clicker questions, following an intermediate discussion period. Campbell and Mayer (2009) found laboratory evidence in favor of a questioning effect, by which students learn better when they answer questions and get feedback during college lectures than when they are presented with the same information in a traditional lecture style.

The effectiveness of the clicker technique also seems to be related to students' class standings and attitudes as well as instructors' experience teaching with the clicker technology. Lower-division university-level students tend to be more accepting than upper-division university level students of the clicker system's potential to have a positive impact on learning (Trees & Jackson, 2007). Students who are educated about the value of feedback for learning and who are already inclined to participate tend to benefit more from the technology than students who are not (Trees & Jackson, 2007). Thus it is important for instructors to inform students as to why they are using the clicker technique, before use has begun, in order for students to accept the system as a potentially valuable learning tool (Duncan, 2005). Further, learning benefits increase as instructors gain experience and flexibility with the clicker technique (Draper & Brown, 2004; Duncan, 2005).

Despite research indicating connections between clicker use and positive learning outcomes, little is known about what cognitive mechanisms contribute to the clicker technique's success. Caldwell (2007) reviewed the research on clickers in the classroom and concluded that "much of the research so far is not systematic enough to permit scientific conclusions about what causes the benefits" (p. 13) of the clicker technique. The proposed research seeks to address this gap in the literature by building off of Lindsay Anderson's Master's Thesis research, which addressed questions about two proposed components of the clicker technique, and off of her advisor's, Dr. Alice Healy's, prior research in cognitive psychology to determine the relative importance of some of the proposed components of the clicker technique.

Proposed Method

In order to experimentally evaluate the clicker technique, both an identification of the technique's components that may potentially contribute to learning and the development of a laboratory model of the clicker technique are necessary. We have already developed a laboratory model of the clicker technique and Lindsay Anderson's Master's thesis research established the validity of this laboratory model (Anderson, Healy, Kole, & Bourne, 2010a, 2010b).

The Model. In classroom practice, the clicker technique often involves dropping from further lecture material that is largely understood by the class, as indicated by the results of the clicker questions. One laboratory model from cognitive psychology that resembles the clicker technique is the dropout procedure, in which items mastered by an individual are dropped from further study rounds (Karpicke & Roediger, 2008; Rock, 1957). Evidence reveals no difference between full repetition of study items and the dropout procedure, indicating that extra study over mastered material is not necessary for improved performance. The dropout procedure has been proposed as an effective method of reducing individual students' study time (Pyc & Rawson, 2007). Given the similarities between clicker use and the dropout procedure, the latter findings highlight a potential way in which the clicker technique can be used to compress, or conserve, teaching time.

Lindsay Anderson's Master's Thesis research involved the completion of two preliminary experiments utilizing the model of the clicker technique described above. These experiments established the validity of our model and the first experiment provided initial support for the clicker technique as a successful method of compressing instructional time (Anderson et al., 2010a), which is important because conserved time can be allocated to more problematic material. The second experiment provided support for the clicker technique promoting generalization of knowledge (Anderson et al., 2010b), which is important because this finding demonstrates that the clicker technique promotes learning that extends beyond superficial memorization.

Mechanisms. Learning is the result of a successful interaction between a teacher and a student; therefore, a cognitive analysis of the mechanisms of the clicker technique and the components of those mechanisms relevant to both agents is crucial. Below is a summary of the mechanisms that we will experimentally evaluate during the funding period of this grant.

Teaching-Relevant:

1. Assessment: In order for teachers to gage the effectiveness of their communication of course material, they must assess the state of students' knowledge at various time points. Instructors are able to choose when they ask clicker questions. Some spacing schedules of tests are more effective than others for promoting learning (e.g., Cepeda, Vul, Rohrer, Wixted, & Pashler, 2008). Thus, appropriately ***spacing*** clicker questions with respect to the presentation of question-relevant content may be crucial to the effectiveness of clicker question.

Instructors often must convey different ***types of information***, such as factual knowledge, which is declarative, or skill-related knowledge, which is procedural. Procedural and declarative knowledge react differently in terms of their resulting durability and generalizability (Healy, 2007; Healy & Bourne, 1995). Thus the kind of information being taught is important to consider when designing questions about such knowledge. Both types of questions (requiring retrieval of declarative or procedural knowledge) can be asked for both types of information. It is important, therefore, to identify whether it is more effective to match question type to information type or whether one question type is most effective regardless of information type.

Student-Relevant:

1. **Testing**: Under the clicker technique, clicker questions test students' current understanding during lecture as opposed to a traditional passive lecture style. Research on the testing effect demonstrates that tests of information are more potent learning opportunities than re-studying of information (Carpenter, Pashler, Wixted, & Vul, 2008). The type and timing of ***feedback*** following clicker questions and the ***level of abstraction*** of tested material can mediate the strong learning benefits of tests.

2. **Desirable cognitive processes**: The clicker technique allows instructors to formulate their own questions and answer choices. Clicker questions can be designed to engage different cognitive processes, with some processes being more desirable than others in terms of their effectiveness. Presentation formats that require individuals to ***generate*** their own answers from memory are known to be more effective for strengthening knowledge than formats that encourage ***recognition***-based processes (Eysenck & Eysenck, 1979; Slamecka & Graf, 1978), but the current clicker system presents alternative answer choices of clicker questions in a multiple-choice format, which favors

such recognition-based processes. However, by presenting partially incomplete alternative answer choices, students would be required to generate the complete correct answer from memory.

Evaluation of Success

I will use statistical analyses, specifically, analyses of variance, to evaluate the success of these experiments. In addition, implementing the findings in classroom settings (see contributions to the home department below) will help to assess the effects of these mechanisms in the real world. Finally, through my various presentations of this work, I will gain feedback about how to interpret the results of these experiments.

Projected Timeline

Fall 2011: Complete two experiments addressing teaching-relevant aspects of the clicker technique. One experiment will address spacing schedules of clicker questions. Another experiment will address the relationship between the types of questions asked and the types of information conveyed (procedural vs. declarative).

Spring 2011: Complete two experiments addressing the student-relevant aspects of the clicker technique. One experiment will address the mediators (feedback and level of abstraction of tested knowledge) that strengthen or weaken the testing effect. Another experiment will address the effectiveness of various presentation formats (recognition vs. generation) of clicker questions.

Contributions

Broad Contributions. The clicker technique is widely used in classrooms; however it is not fully understood what mechanisms contribute to its effectiveness. This research will help to identify which teaching and learning mechanisms of the clicker technique maximize learning. The results of this research can hopefully be used to inform and provide insight about how to improve real-world classroom clicker use.

Contributions to Home Department and CU Community. Instructors of Statistics and Research Methods and Advanced Cognitive Psychology in the Department of Psychology and Neuroscience have expressed interest in the proposed project and are willing to implement our laboratory findings in their classrooms to test the ecological validity of our findings. This fellowship will support the development of evidence-based clicker use in our home department and the results of this research will be shared with the STEM community to inform and improve campus-wide clicker use in multiple disciplines.

Contributions to Graduate Student Development. This fellowship will contribute to my development by providing me with the resources to extend my master's thesis research to contribute to my multidisciplinary joint PhD in Cognitive Psychology and Cognitive Science. I believe that it is important to apply theoretical and empirical research to real-world problems. This fellowship will allow me to gain valuable experience communicating about empirical research and the real-world applications of this research through presenting the results of the proposed work at academic conferences, at the annual STEM symposium, to the CU STEM community, and to the STEM community at large.

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