

# On the use of clickers at CU

Prepared for: i>clicker (Bedford, Freedman, & Worth Publishing) and the Physics Education Research group (PER@C) at the University of Colorado at Boulder

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## Summary

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The purpose of this report is to summarize the main results from a study to evaluate faculty practices and student attitudes regarding clickers during the Spring 2007 semester at the University of Colorado at Boulder (commonly referred to as “CU”). Adoption of clickers by faculty has spread campus-wide at CU to presently 19 departments, 80 courses, and over 10,000 students. We study common pedagogical practices among faculty and attitudes and beliefs among student clicker-users across disciplines on campus. Data were collected via online surveys given to both faculty and students in the Spring 2007 semester. Additionally, we report on correlations between student perceptions of clicker use and the ways in which this educational tool is used by faculty. Areas where further work is needed is indicated appropriately.

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## I. Introduction

Since being introduced six years ago in one introductory physics course at the University of Colorado at Boulder, clicker<sup>1</sup> use has spread extensively, with nearly half the undergraduate population using clickers in one semester. Although their use is becoming more prevalent, it is not known how this tool is used by faculty at the campus level, nor do we understand student perceptions and attitudes towards this tool.

Research on clickers remains a popular topic within Physics Education Research (PER) and other science and education communities. (For example, see [1], [2], [3]; for an extensive literature review, see [4].) The purposes of the present study are to identify common faculty pedagogical practices regarding clicker use across the variety of disciplines at one institution, study student perceptions towards this tool, and look for correlations between faculty practices and student perceptions. We seek to identify effective clicker uses across these varieties of disciplines and environments in which they are employed. An ultimate goal will be to correlate faculty practices with student learning—others have already demonstrated correlations between student attitudes and beliefs and content learning gains in other contexts (e.g., see [5] and [6]). However, studying the impact of clickers on student learning gains is beyond the scope of the present work—it remains a daunting task to study student learning gains across many disciplines. In this report, we present the results from an extensive study of dozens of faculty and thousands of students.

The purpose of this report is to summarize the majority of findings from this study. Furthermore, due to the wealth of data collected during this study, there are sure to be certain elements that are not yet analyzed, or data that could be reanalyzed in a new light. As a result, future work still remains for this project and is noted appropriately.

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<sup>1</sup> We opt for the term "clicker," whereas others use "personal response system," "voting machine," and a myriad of other terms (see Reference [4]).

## II. Collected Data

### A. Institutional Data

Four sets of data were collected for this study. The first data set contains the courses that are using clickers at CU during the Spring 2007 semester and other demographics of these courses. These clicker-using courses were found by a number of methods, which are worth briefly discussing if one wishes to collect these data in the future.

First, some instructors using clickers chose to use the CU i>clicker course registration page, in which case one can easily see all the faculty that registered his/her course via this website (<http://capa.colorado.edu/cgi-bin/iClicker>).<sup>2</sup>

Second, a list of courses where the instructor requested clickers for his/her students can be requested from the CU Bookstore. These two methods described above will only include courses where instructors want to track clicker use among students and where students are required and/or recommended to purchase a clicker. However, a number of courses (mainly advanced STEM<sup>3</sup> courses) use a set of clickers that are not owned by students and instead owned by the instructor, department, or some other university organization. These clickers are brought into every class meeting by the instructor and handed out at the beginning and collected at the end of the class meeting. This method allows students to use clickers without purchasing them and allows instructors to share the batch of clickers among different courses. In order to track these courses, it is best to contact a faculty member or instructor in each department who would know of other instructors using clickers in this manner.

To collect demographic data on any course at CU, further information can be found through CU Connect's "Academics & Research" section, such as enrollment, instructor, number of lecture sections, and data on associated laboratory/recitation sections.

During the Spring 2007 semester at CU, clickers were used by 70 faculty in 94 lecture sections, with an average enrollment of 144 students in each lecture section. Although this breadth of use represents a tiny fraction of all faculty on campus (3%), it represents a significant fraction of the student body due to the high average enrollment of courses using clickers. In this semester, clickers were used by 10,011 unique students, which included 9,941 undergraduates and 70 graduate students. Students using clickers made up 44% of all undergraduate students and 1.6% of graduate students. Despite the widespread use among the undergraduate student body, there is still opportunity for clicker use to expand. Only 28% of departments on campus used clickers and only 24% of large lecture sections (where the enrollment is greater than 100) used clickers.

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<sup>2</sup> Note that this website may change in the future. Contact Michael Dubson for any changes: [dubson@spot.colorado.edu](mailto:dubson@spot.colorado.edu)

<sup>3</sup> STEM: Science, Technology, Engineering, and Mathematics.

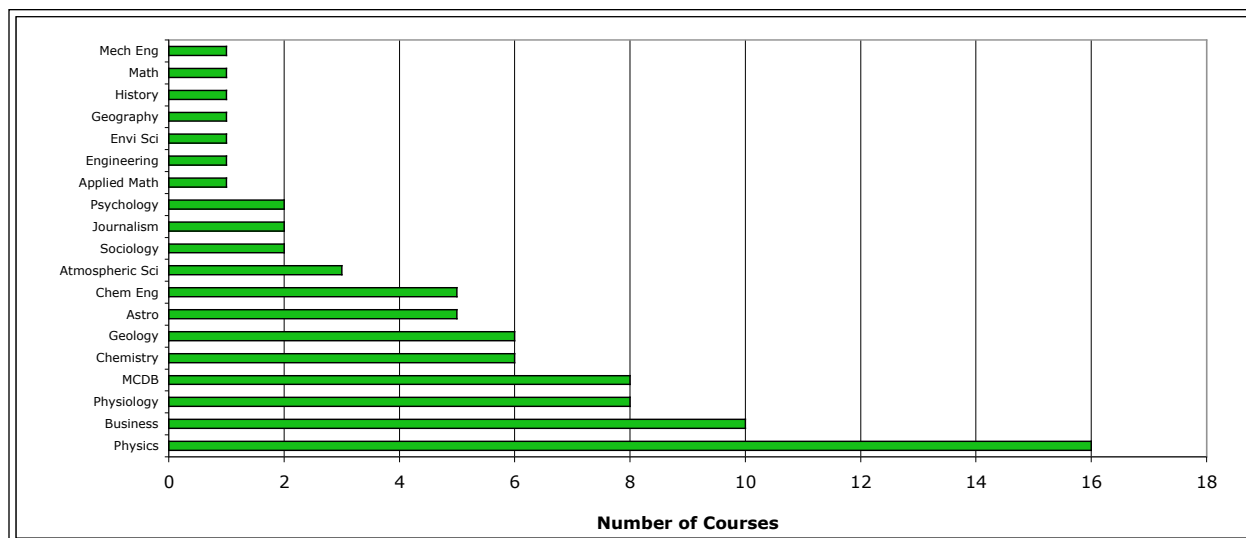


Figure 1: Number of courses using clickers in Spring 2007, listed by department. This graph is somewhat biased towards larger departments, since they offer more courses and can therefore teach more courses using clickers. Physics offers the most number of courses that use clickers (16). Note that all courses within the School of Business are combined (such as Management, Finance, Real Estate, etc.).

We find the majority of courses using clickers to be in STEM fields. The total number of courses that used clickers in STEM fields was 63, while there were 10 in Business, 6 in Social Sciences, and 1 in Humanities. Furthermore, of the 94 lecture sections using clickers, 79 of these are using i>clicker<sup>4</sup> and the remaining 15 are using H-ITT<sup>5</sup>.

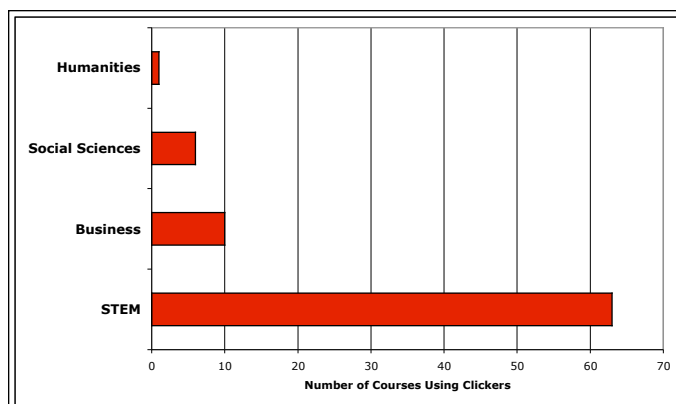


Figure 2: Number of courses using clickers by field. STEM (Science, Technology, Engineering, and Mathematics) offers the largest number of courses using clicker by far.

<sup>4</sup> <http://www.iclicker.com>

<sup>5</sup> <http://www.h-itt.com>

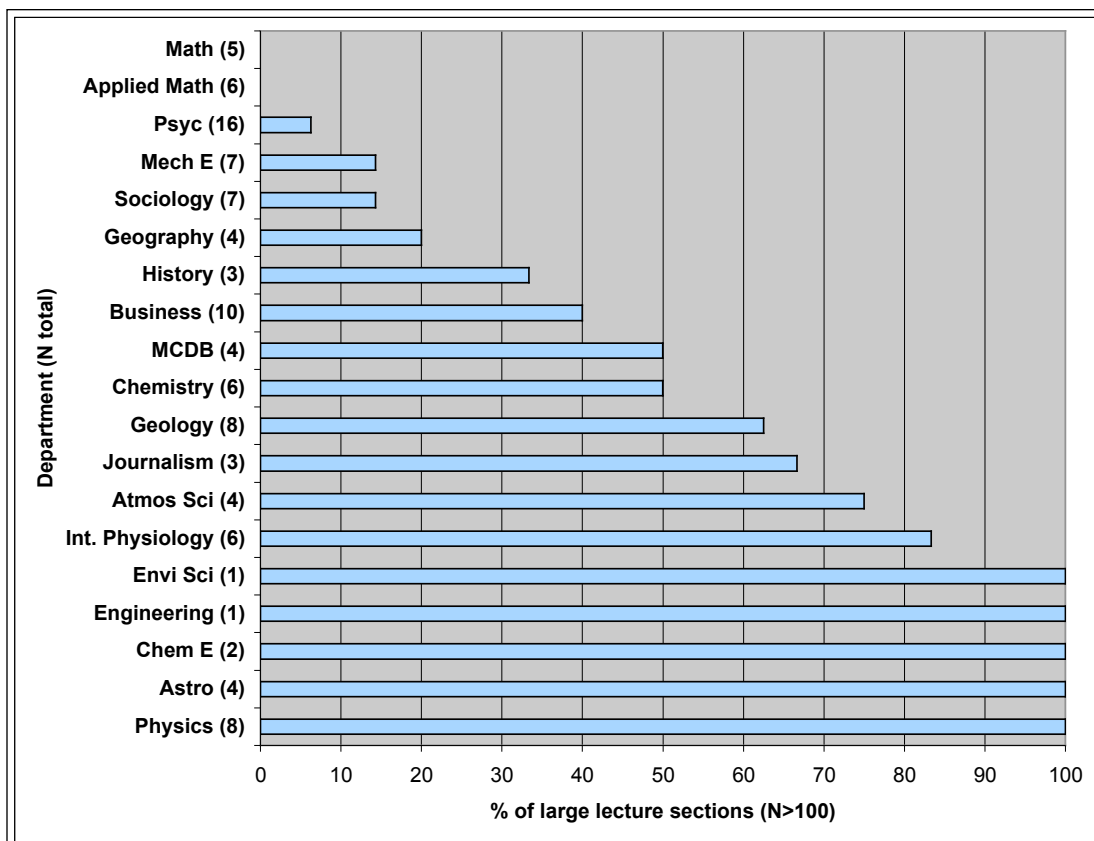


Figure 3: We see some departments that currently use clickers in all large lecture courses<sup>6</sup> that they offer, such as Physics, Astrophysics, and Chemical Engineering. Other large departments, such as Psychology and Sociology, use clickers in 1 and 2 large courses (out of 16 and 7, respectively).

There are 10,011 unique students who used a clicker in at least one course at CU during the Spring 2007 semester. Of these students, 70% used clickers in one course only, while 29% used clickers in 2 courses, and fewer than 1% used clickers in either 3 or 4 courses.

Number of Courses	Number of Students	% of Total
1	7064	71
2	2908	29
3	26	< 1
4	13	< 1
TOTAL:	10011	—

Table 1: Number of unique students who used clickers in multiple courses.

<sup>6</sup> We define a “large lecture course” as any course where the enrollment is 100 or greater.

Class	Number of Students	% of Total
FRESHMEN	3111	62
SOPHOMORE	3020	57
JUNIOR	1719	36
SENIOR	1602	28
SENIOR 5TH YR	419	25
UNCLASSIFIED UNDERGRADUATE	67	N/A
DOCTORAL CANDIDATE	46	N/A
UNCLASSIFIED GRADUATE	9	N/A
MASTER'S CANDIDATE	15	N/A
UNDERGRAD CERTIFICATE	3	N/A
TOTAL:	10011	—

Table 2: Number of students using clickers by class. Freshmen make up the largest fraction, which is due to the number of large-lecture courses using clickers, which also tend to be introductory courses.

## B. First Faculty Clicker Survey

Faculty using clickers were given two different online surveys. The first survey (see Appendix A for the complete survey) was given at the start of term approximately 3 weeks after the beginning of classes, and 54 faculty responded to 16 multiple-choice and long answer questions. Questions from this survey probed how faculty planned on using clickers in their own courses and on their experience and beliefs surrounding clickers. Below is a snapshot of the results from the data collected on this survey.

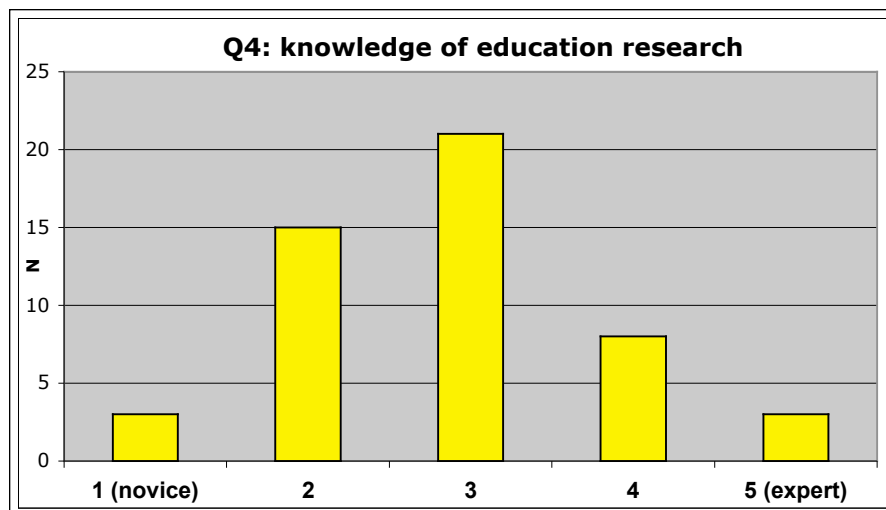


Figure 4: Question 4. Faculty self-reported their knowledge of education research on a scale of 1 (novice) to 5 (expert). Note that category descriptors were only used for options 1 and 5 (novice and expert, respectively), but no other descriptors were used to distinguish the remaining answer options.

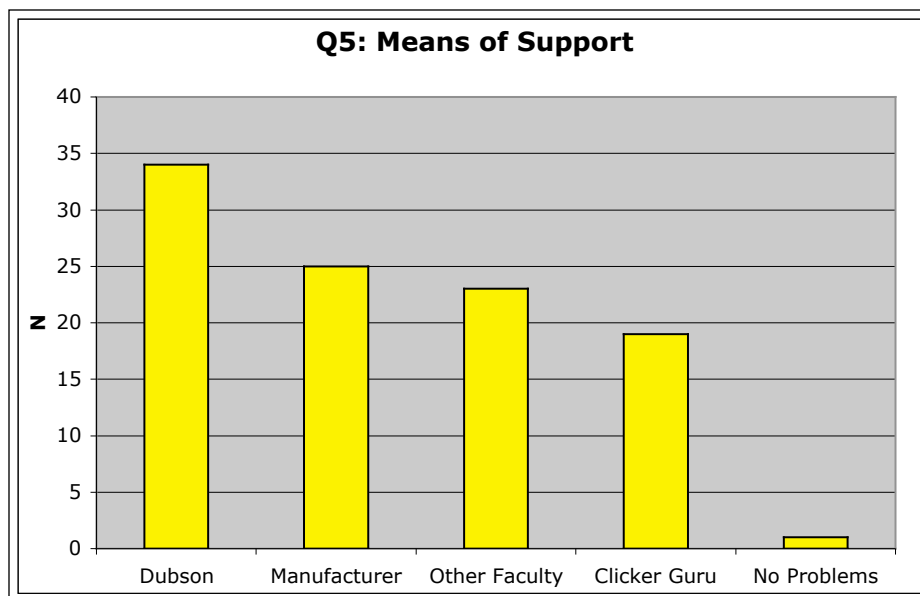


Figure 5: Question 5. Faculty claim to consult with Physics Professor Michael Dubson when problems with clickers arise more than any other means of support. Note that only one person indicated that he/she did not encounter any problems (but this was not an answer option--this faculty member chose the "Other" option and indicated in the space provided that he/she did not encounter any problems).

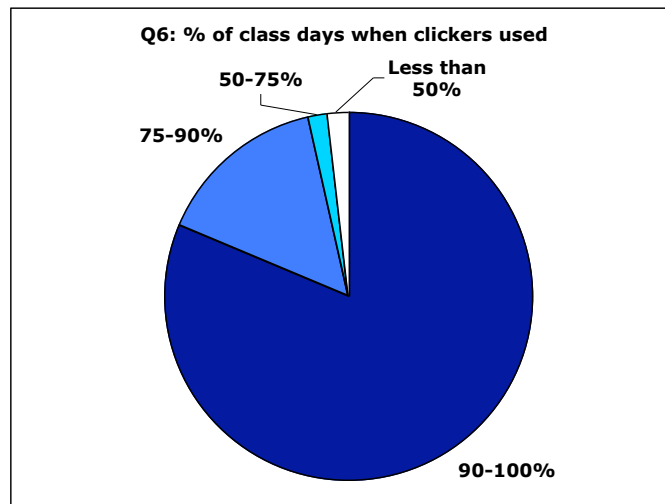


Figure 6: Question 6. This graph indicates how frequently clickers are expected to be used by faculty throughout the semester. Note that the majority of faculty expect to be using clickers 90-100% of all class meetings during the semester.

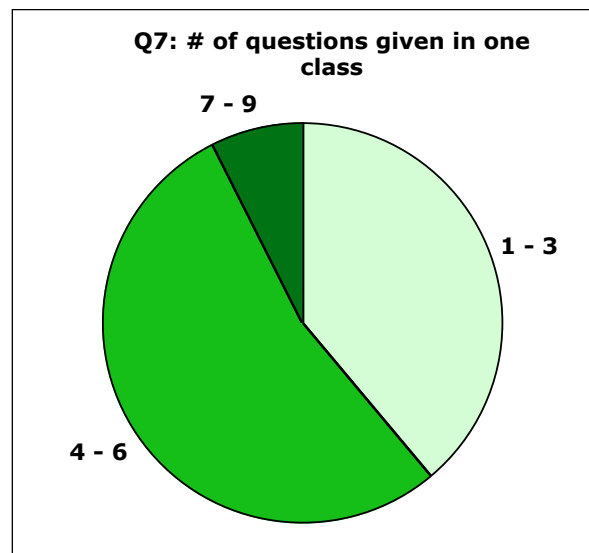


Figure 7: Question 7. This graph indicates the number of clicker questions (on average) that a faculty member intends on asking during each class meeting. Note that these data are for each class meeting—to more accurately compare different courses, one must calculate the number of questions given per hour.

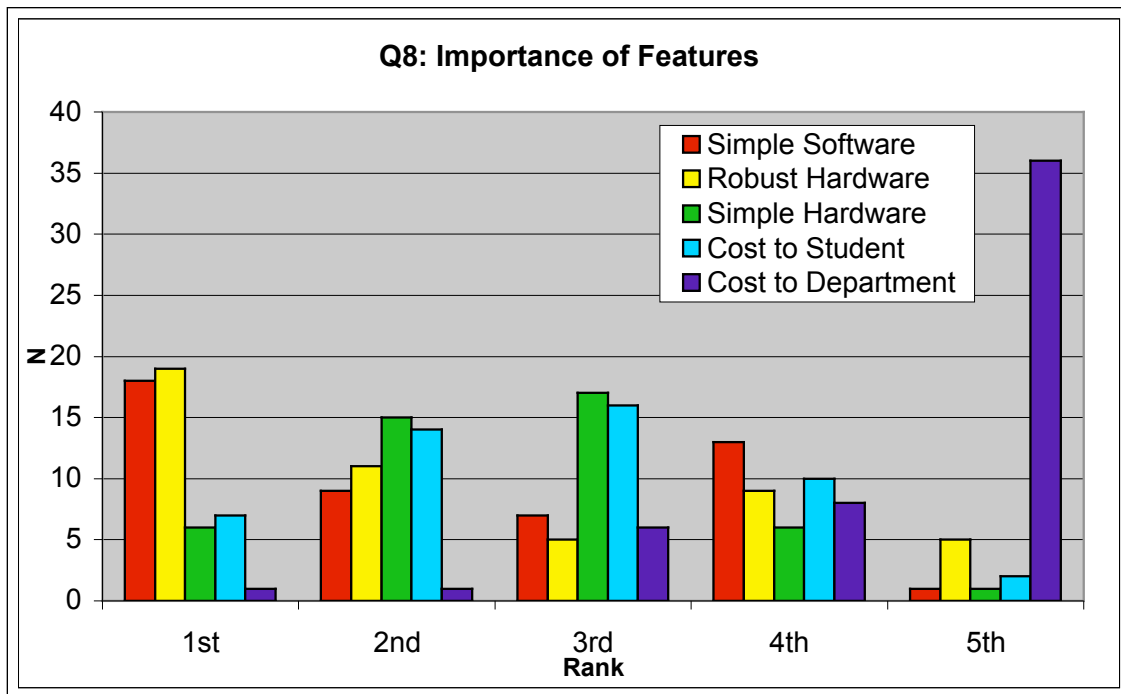


Figure 8: Question 8. Faculty self reported the importance of different features of clicker systems. Simplicity of software and robustness of the hardware were viewed as the most important features, while cost to the department was least valued.

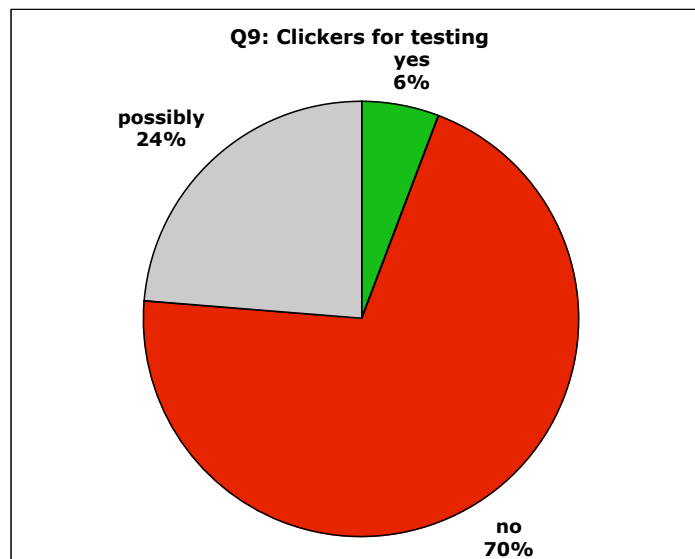


Figure 9: Question 9. Majority of faculty would *not* consider having their students use clickers to take a midterm or final exam in their course.

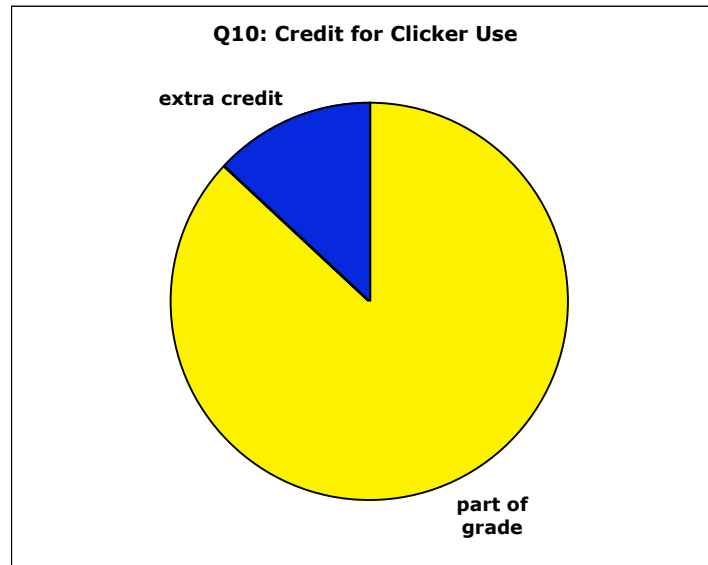


Figure 10: Question 10. Majority of faculty make clicker use part of students' course grade. Note that an option was available to indicate that clicker use is not part of students' course grade, but no one chose this option.

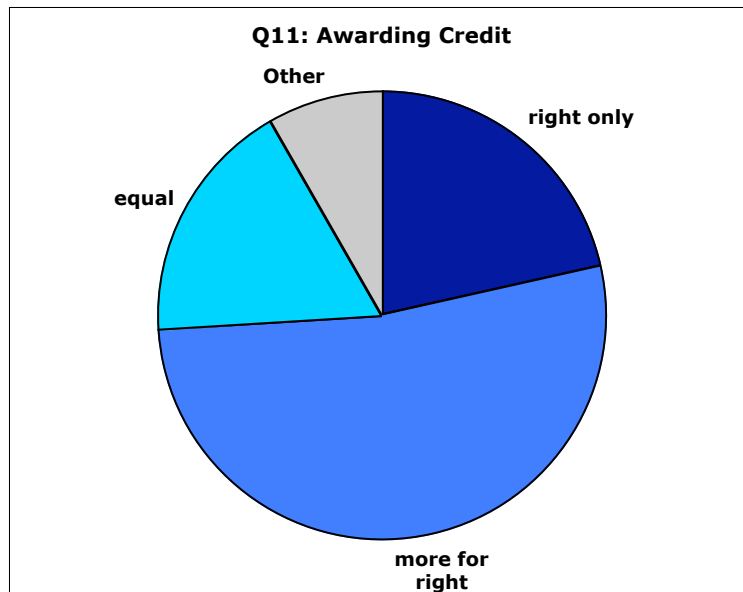


Figure 11: Question 11. Slightly over half of respondents indicated that they plan on awarding more credit to students for choosing the right answer, and less (but some) credit for the choosing the wrong answer when answering clicker questions in class.

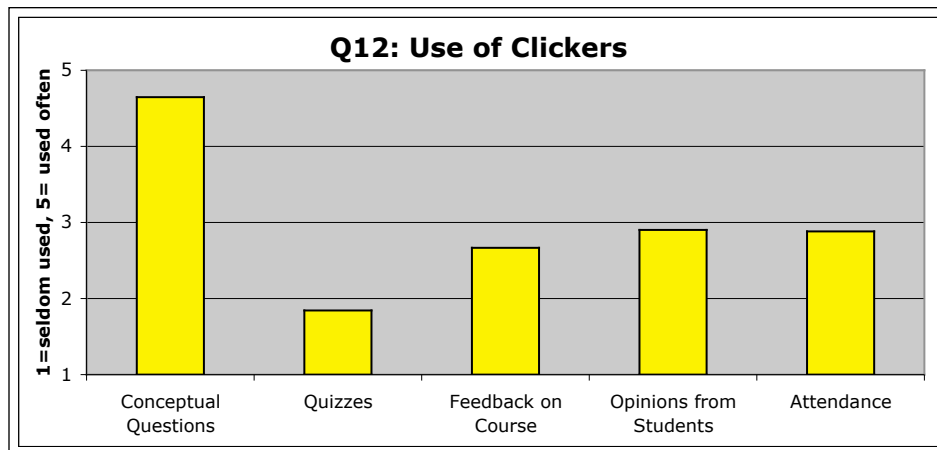


Figure 12: Question 12. Faculty self-reported average frequency of use of different types of clicker questions. Conceptual questions are most frequently used, and quizzes tend to be seldom used. Note that “Quizzes” was not clarified to mean a question where students are specifically instructed not to speak to each other. The “Attendance” option was meant for instances where faculty specifically ask students to click an option to indicate that they are present in class; however, awarding credit for any type of question is also a form of indirectly taking attendance (since students must be present to answer a question).

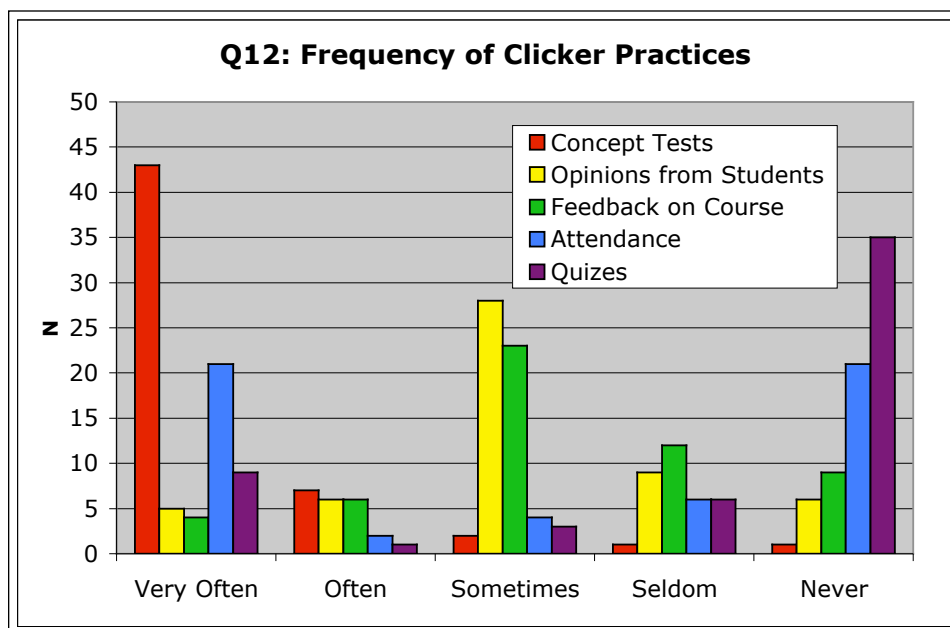


Figure 13: Question 12. This is the same data presented in Figure 12, but broken down by each answer choice.

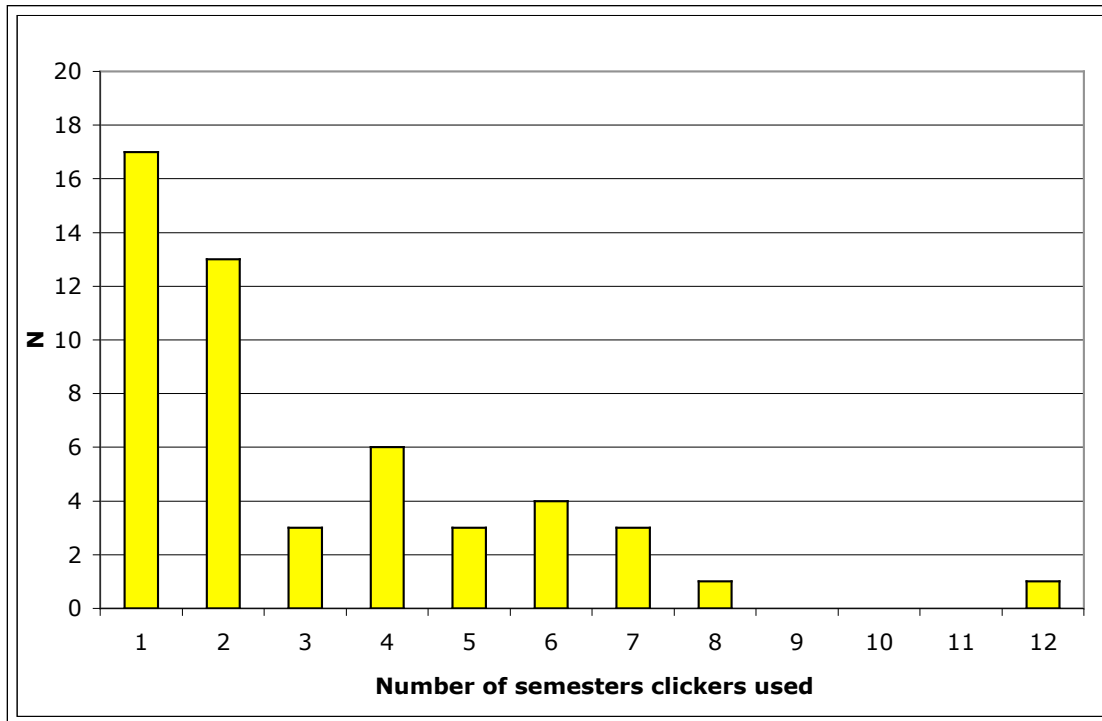


Figure 14: Faculty experience. Histogram of faculty experience using clickers. Note that the “1” category indicates the number of faculty (17) who are using clickers for the first time teaching a course; thus, “2” indicates faculty who are using clickers for the second time. The percentage of faculty in bins 1 and 2 is 59% of the total, indicating that the majority of faculty has little experience using clickers.

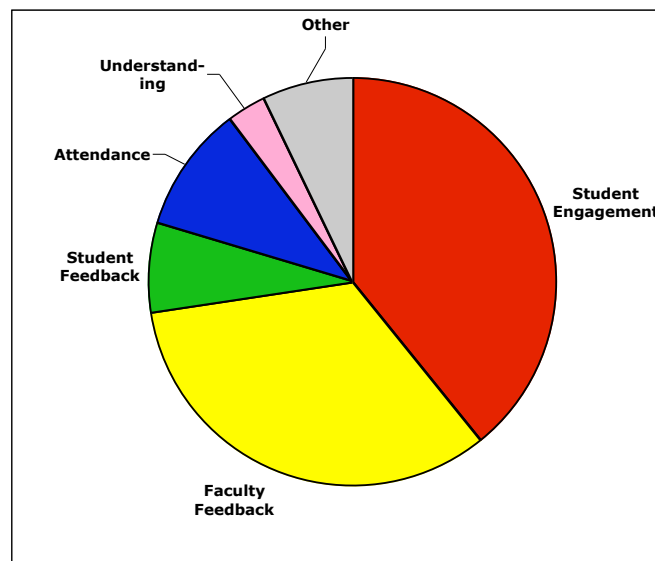


Figure 15: Question 14. Coded responses to faculty members’ opinions on the biggest advantage of using clickers. Faculty often gave multiple responses, and the above data is the fraction of that response occurring of all responses from faculty. Note that “Student Engagement” may imply that student understanding will increase. “Attendance” refers to increasing class attendance, not the ability to track attendance. “Other” responses include such comments as clickers empowering students and making lecture more fun.

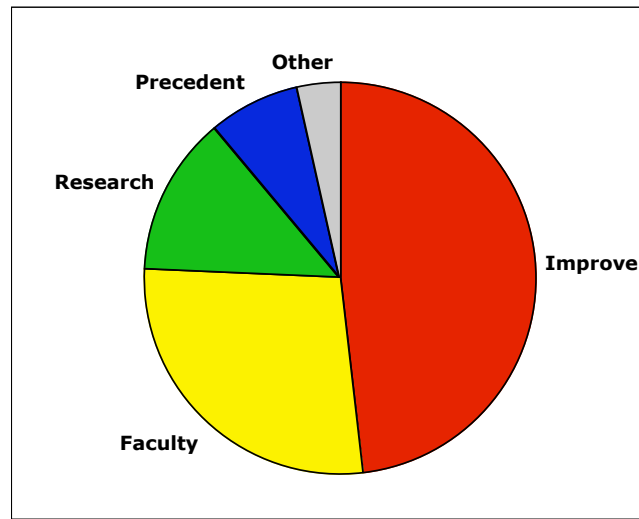


Figure 16: Question 15. Coded faculty responses to their initial reason for using clickers. This question was not clearly stated—faculty who fell into the “Improve” category stated why they wanted to use clickers, and faculty who fell into all other categories stated what influenced their decision (it is assumed that all faculty want to use clickers to improve their course, but we were searching for what initially prompted them to use clickers for the first time). Note that the “Faculty” category was meant to indicate faculty convincing other faculty to use clickers, but the “Research” and “Precedent” categories could also be part of this category, since research is conducted by faculty and precedents are established by faculty as well.

### C. Second Faculty Survey

The second online survey given to faculty was conducted at the end of term, and 69 responses were collected to 15 multiple-choice and long answer questions (see Appendix B for the complete survey). Questions from this survey probed how faculty used clickers in their own courses and on their experience and beliefs surrounding clickers. Below is a snapshot of the data collected on this survey.

Clicker System	% of Total
i>clicker	94
H-ITT	3
eInstruction	1
Other	1

Table 3: Question 3. When asked what clicker system faculty were likely to use in the future, faculty overwhelmingly chose i>clicker.

Support	% of Total
Solved Problems Alone	51
Clicker Manufacturer	38
Prof. Michael Dubson	32
Other Faculty	25
No Problems Encountered	12
Departmental Clicker Guru	9
Other	6

Table 4: Question 4. Faculty were asked to indicate what sources they turned to when encountering problems with or issues using a clicker system. Since faculty could choose more than one response, all percentages do not sum to 100%.

Roughly half of all faculty claim that they solved problems encountered with the clicker system on their own (see Table 4). One could interpret this as meaning the other half either did not attempt to solve problems on their own or could not solve problems on their own. However, the “I solved problems on my own” category may be misleading, since faculty who, for example, go online to seek advice from a user manual from the manufacturer could consider this to be solving a problem on their own and not seeking advice from the manufacturer. Also note that only 12% of faculty indicated that they did not encounter any problems.

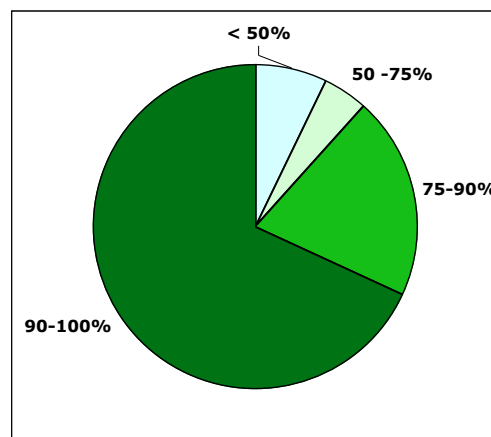


Figure 17: Question 5. Faculty were asked for what percentage of all class days in their course did students use clickers at least once. The majority of faculty (68%) indicated that they used clickers 90-100% of all class days over the semester.

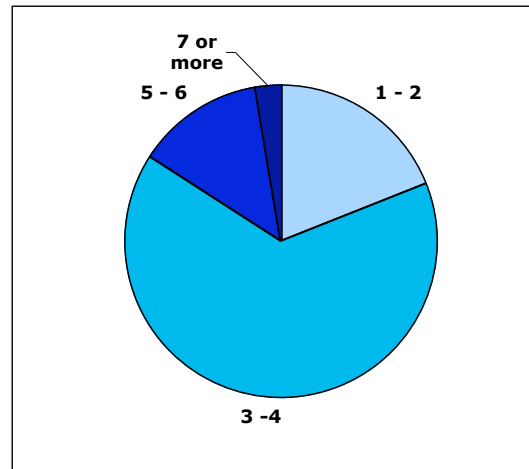


Figure 18: Question 6. Faculty were asked how many times students used clickers during lecture when clickers were used. The majority of faculty (65%) claim to ask 3-4 clicker questions per lecture. Note that this data may be slightly misleading since these are number of questions per lecture, and not per hour.

Awarding Credit	% of All Responses
Part of students' grades	86
Extra-credit	12
Not part of students' grades	4
Other	1

Table 5: Question 7. Faculty were asked if students were given credit for clicker use, and 86% of faculty indicated that clicker use is part of students' grades. Note that since faculty were able to choose more than one response, all possible options do not add to 100%. Faculty were allowed to choose more than one option because of the varying methods of awarding credit.

Method of Awarding Credit	% of all Responses
Award credit for correct answers only	8
More credit award for right answers, and some (but less) credit awarded for wrong answers	62
Same amount of credit awarded for either right or wrong answers	32
Other	6

Table 6: Question 8. Faculty were asked (if they did award credit) exactly how credit was awarded to students using clickers. The majority of faculty indicated that they awarded more credit for the right answer and less (but some) credit for wrong answers. However, it is not known how much credit was awarded (relative to final course grade).

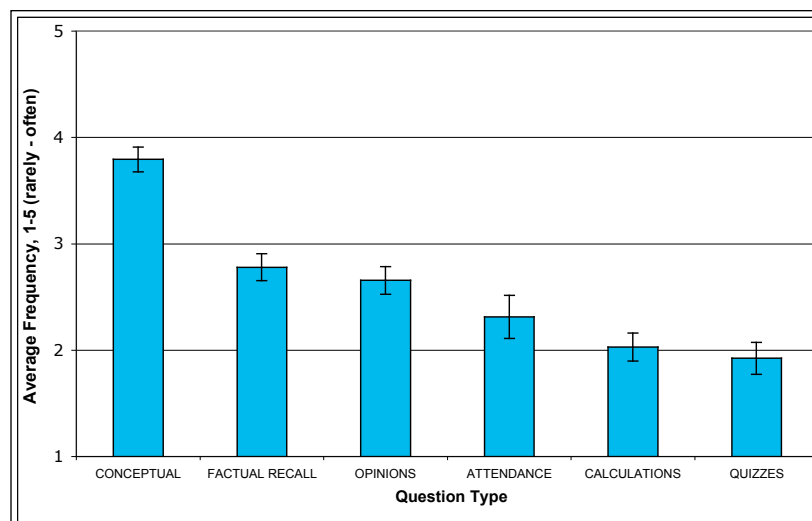


Figure 19: Question 9. Faculty were asked to rate how often the following uses of clickers were implemented in their course. Note that “Attendance” was meant to designate when faculty specifically use clickers to take attendance, but if faculty award credit for using clickers, this can be viewed as indirectly taking attendance.

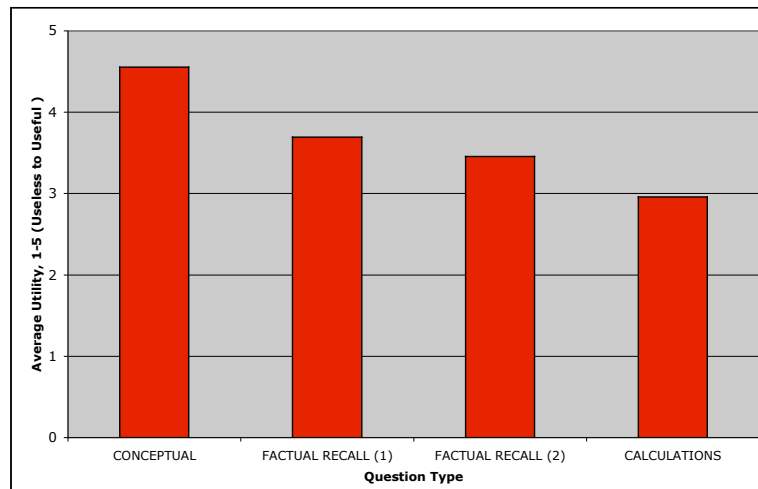


Figure 20: Question 10. Faculty were asked to rate how useful for their students' learning they view different types of clicker questions. If faculty did not implement a type of question, they could indicate so. "Factual Recall (1)" indicates "questions that require students to recall a fact from the text or a prior lecture," while "Factual Recall (2)" indicates "questions that require students to recall a fact that was just stated."

Extent of Discussion	% of Total
I do not allow discussion	3
Allow discussion, but do not encourage it, and a <i>small</i> fraction of students discuss	6
Allow discussion, but do not encourage it, and a <i>large</i> fraction of students discuss	6
Encourage discussion, and a <i>small</i> fraction of students discuss	22
Encourage discussion, and a <i>large</i> fraction of students discuss	63

Table 7: Question 11. Faculty were asked to what extent they usually encourage student-to-student discussion about clicker questions in class and how their students usually respond. Note that "small" and "large" fractions were not described in detail and were left to faculty to interpret.

Faculty Practice	% of Total
I stayed at the front of the classroom	30
I walked around the classroom to listen to students' conversations	30
I discussed the question with students in small groups around the classroom	17
I discussed the question with the entire class while they were responding to the question	10
Other	12

Table 8: Question 12. While students were voting on and/or discussing a typical clicker question, faculty were asked what they usually did during this time. "Other" responses included a variety of responses, and some faculty indicated that they did all of the above to a certain degree.

Recommend Clickers	% of Total
Definitely Not Recommend	0
Not Recommend	0
Neutral	12
Recommend	28
Definitely Recommend	61

Table 9: Question 13. When faculty were asked if they recommend the use of clickers, the vast majority indicated that they recommend their use to other instructors who teach this course in the future.

Faculty expressed comments about clickers in Question 15, which was a free response question. Some common themes were seen, such as frustrations with the clicker system, or particular problems that reoccurred throughout the semester. Additionally, three faculty members expressed interest in accessing a database of clicker question, if such a database exists:

*"It would be nice if a repository for 'good' clicker questions on particular topics were developed, so professors don't have to reinvent the wheel (and some people find writing good clicker questions easier than others)"*

*“Clickers also take a fair bit of time to use well - I use them for opinion questions (lots of that in an environmental studies class) but haven't use them as much for quantitative or conceptual questions. The conceptually detailed questions are also difficult to pose with multiple choice answers so it would be nice to have some insights into how to do that more effectively.”*

*“Designing challenging conceptual questions in multiple choice format is very difficult and very time-consuming, and I would be grateful for opportunities to participate in workshops or a password-protected website where professors display their best-practice clicker questions.”*

#### **D. Student Survey**

Approximately one month prior to the end of term, an online survey was distributed to students in courses where clickers were currently being used (to see the entire student survey, see Appendix C). Of the 10,011 students using clickers, 3,697 responses were collected. The 11 multiple-choice questions on the survey probed students' attitudes and beliefs about clickers and asked them to respond to how clickers are currently being used in their courses. Of the 80 courses using clickers, data from students were collected in 51 courses. The data presented in this section summarize the results from the student survey.

<b>Number of Semesters</b>	<b>% of Total</b>
1 (first semester using clickers)	25
2 - 4 semesters	65
5 or more semesters	10

Table 10: Question 3. Students' prior experience with clickers. 25% of students who used clickers during the Spring 2007 semester are using clickers for the first time (this figure will most likely be larger during the Fall semester when Freshman are taking courses for the first time).

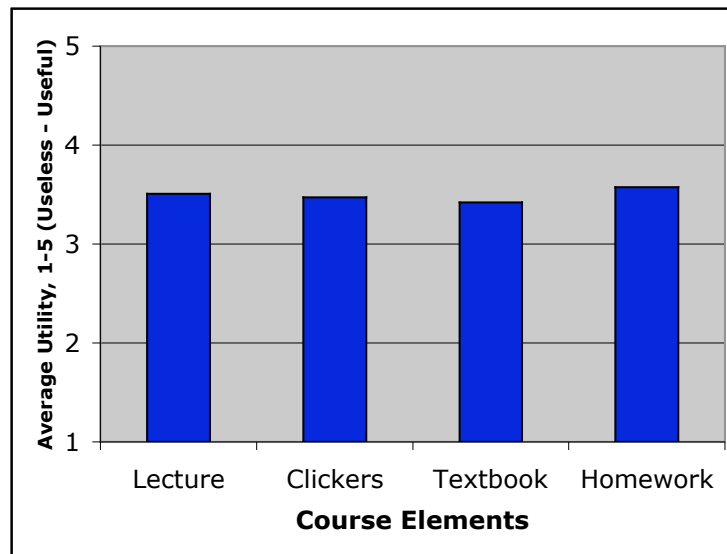


Figure 21: Question 6. Students were asked to rate how useful for their learning each of the following class activities are in their course. Note that the “Lecture” option was worded so students would be able to distinguish using clickers from when the instructor was only speaking: “Pure Lecture Presentation (only instructor talking).”

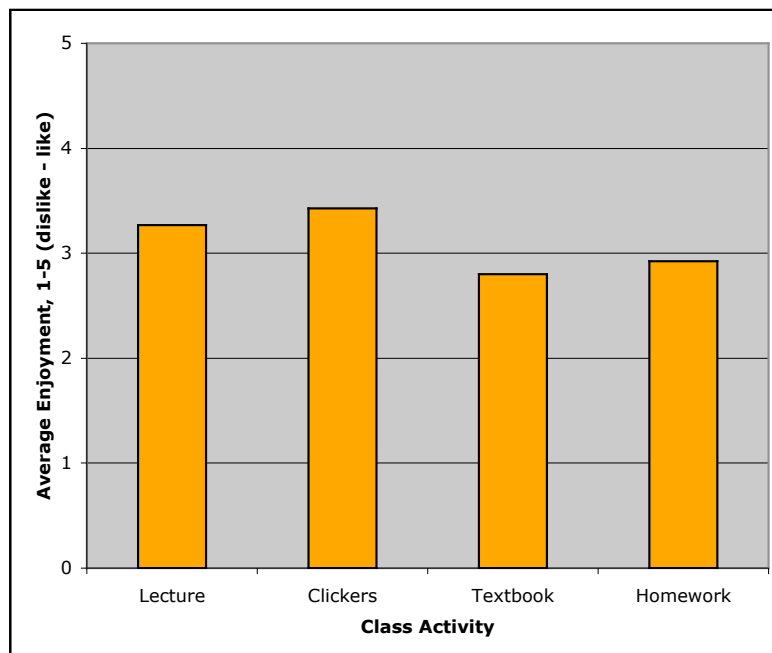


Figure 22: Question 7. Students were asked to rate how much they enjoyed each of the following class activities in their course [where "enjoyed" is meant in the sense of academic or intellectual pleasure].

Extent of Discussion	% of Total
Does not allow discussion	5
Allows discussion, but does not encourage it, and a <b>small</b> fraction of students discuss	10
Allows discussion, but does not encourage it, and a <b>large</b> fraction of students discuss	14
Encourages discussion, and a <b>small</b> fraction of students discuss	18
Encourages discussion, and a <b>large</b> fraction of students discuss	52

Table 11: Question 8. Students were asked to what extent their instructor usually encourages student-to-student discussion about clicker questions in class. Note that “small” and “large” fractions were not clarified and were left to the students to interpret.

Student Practice	% of Total
Does not apply—we are usually not allowed to talk with other students	2
I rarely use a clicker in this course	1
I guess the answer and do not check with other students	2
I actively think about the question independently and arrive at an answer without speaking or listening to other students	18
I listen to other students' answers and/or reasoning	18
I actively participate in discussions with other students around me	59

Table 12: Question 9. Students were asked to indicate what they *usually* do when their instructor gives the class a typical clicker question and they are allowed to talk with others. Students may change their practice depending on the type of question asked, but students were asked to report what they *usually* do.

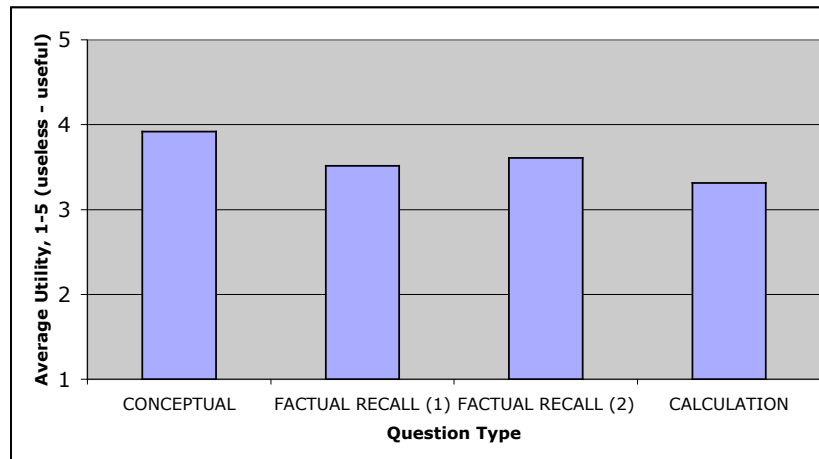


Figure 23: Question 10. Students were asked to rate how useful for their learning the following types of clicker questions are. “Factual Recall (1)” indicates “questions that require [the student] to recall a fact from the text or a prior lecture,” while “Factual Recall (2)” indicates “questions that require [the student] to recall a fact that was just stated.”

Recommending Clickers	% of Total
Definitely Not Recommend	5
Not Recommend	7
Neutral	17
Recommend	36
Definitely Recommend	36

Table 13: Question 11. When asked if students would recommend that other instructors, who teach this course in the future, use clickers, the majority of responses (72%) were positive.

### III. Analysis

Before determining relations between faculty practices and student perceptions, we can first look at correlations between students' practices and students' views regarding clickers. For some data collected on the student survey, where the survey responses inherently follow a numerical scale, we can calculate correlations between survey items. The table below lists correlation coefficients for selected survey items.

	EXPERIENCE (Q3)	ATTITUDE (Q4)	LEARN (Q5)	LECT-USE (Q6)	CLICK-USE (Q6)	TEXT-USE (Q6)	HW-USE (Q6)	LECT-ENJOY (Q7)	CLICK-ENJOY (Q7)	TEXT-ENJOY (Q7)	HW-ENJOY (Q7)	RECOMMEND (Q11)
EXPERIENCE (Q3)	1											
ATTITUDE (Q4)	-0.01	1										
LEARN (Q5)	0	0.68	1									
LECT-USE (Q6)	-0.02	0.51	0.46	1								
CLICK-USE (Q6)	-0.03	0.46	0.46	0.38	1							
TEXT-USE (Q6)	-0.02	0.13	0.18	0.03	-0.02	1						
HW-USE (Q6)	-0.02	0.37	0.38	0.22	0.36	0.24	1					
LECT-ENJOY (Q7)	-0.02	0.53	0.45	0.73	0.34	0	0.18	1				
CLICK-ENJOY (Q7)	-0.02	0.43	0.39	0.32	0.73	-0.03	0.25	0.35	1			
TEXT-ENJOY (Q7)	-0.01	0.22	0.21	0.06	0	0.65	0.21	0.13	0.05	1		
HW-ENJOY (Q7)	-0.03	0.31	0.27	0.12	0.17	0.21	0.56	0.15	0.19	0.4	1	
RECOMMEND (Q11)	0	0.39	0.39	0.26	0.7	-0.03	0.27	0.26	0.7	0	0.15	1

Table 14: Correlating Student Responses. The table above lists correlation coefficients for self-reported data obtained from the student survey. Category labels refer to different questions (e.g., "EXPERIENCE (Q3)" refers to Question #3 regarding students' past experience with clickers). Highlighted cells require further note.

Students' attitude towards the utility of clickers is well correlated with their attitude towards their enjoyment using clickers ( $r = 0.73$ ) and their recommendation of clickers ( $r = 0.7$ ). Students' attitude towards the utility of clickers is not correlated with how many semesters the students have used clickers in the past ( $r = -0.03$ ), suggesting that as students have more experience with this tool, they are not more likely to have a more positive (or negative) attitudes towards the

utility of this tool. Students' attitude toward utility is slightly correlated with how much students' feel they have learned ( $r=0.46$ ).

For survey items that do not follow a numerical scale, we cannot determine correlation coefficients. Instead, we can determine what percentage of respondents fall into different categories based on the different answer options from two different survey questions.

For example, on Question 8 of the student survey, students were asked to what extent their instructor encourages discussion. Because the possible answer choices to this question do not follow a numerical scale, we can instead determine what fraction of the students who chose each of the five possible choices also have a favorable attitude towards the utility of clickers (by "favorable", it is implied that students rated the utility of clickers as either "useful" or "very useful").

Extent of Discussion	% Favorable
Does not allow discussion	34
Allows discussion, but does not encourage it, and a <i>small</i> fraction of students discuss	40
Allows discussion, but does not encourage it, and a <i>large</i> fraction of students discuss	45
Encourages discussion, and a <i>small</i> fraction of students discuss	43
Encourages discussion, and a <i>large</i> fraction of students discuss	70

Table 15: Of the students who chose each answer option on Question 8, we can see what fraction of these students also have a favorable attitude (e.g., choosing either "useful" or "very useful") towards the utility of clickers. Note that of the students who indicated that their instructor "encourages discussion, and a large fraction of students discuss," 70% of these students have a favorable attitude towards the utility of clickers. Of the students who chose the remaining three options, the percent of these students who have a favorable attitude towards the utility of clickers is much less.

We can look at Question 9 in a similar manner, comparing student practices during the administration of clicker questions to attitudes towards the utility of clickers.

Student Practices	% Favorable
Does not apply—we are usually not allowed to talk with other students	28
I rarely use a clicker in this course	16
I guess the answer and do not check with other students	17
I actively think about the question independently and arrive at an answer without speaking or listening to other students	51
I listen to other students' answers and/or reasoning	45
I actively participate in discussions with other students around me	64

Table 16: Of the students who chose each answer option on Question 9, we can see what fraction of these students also have a favorable attitude (e.g., choosing either “useful” or “very useful”) towards the utility of clickers. Note that of the students who indicated that they “actively participate in discussions with other students”, 64% of these students have a favorable attitude towards the utility of clickers. Compare this to the remaining five options, where the percentage of these students who chose these options is much smaller. Also note that of the students who claim that they rarely use a clicker, 16% still have a favorable attitude towards their utility. These students do not regularly use this tool in class, yet they still have a positive opinion regarding this tool.

The final goal of the present work is to study what impact faculty practices regarding clickers have on student attitudes. We begin to determine these relations by correlating faculty use of this tool with student perception of clickers. The table below lists some of these correlations.

	LECT-USE (Q6) CLICK-USE (Q6)	LECT-ENJOY (Q7) CLICK-ENJOY (Q7)	CONCEPT-USE (Q10) RECALL1-USE (Q10)	RECALL2-USE (Q10)	CALCULATE-USE (Q10)	% ACTIVE (Q10)	RECALL2-USE (Q10)	CALCULATE-USE (Q10)	% ACTIVE (Q10)
PERCENTAGE (Q5)	-0.01	0.21	0.15	0.25	0.00	0.01	0.19	-0.14	0.12
NO. OF QUESTIONS (Q6)	0.04	0.21	0.12	0.15	-0.05	0.12	0.20	-0.10	0.16
CONCEPT-FREQ. (Q9)	0.33	0.06	0.37	0.07	0.12	-0.32	-0.16	-0.26	0.24
QUIZ-FREQ. (Q9)	-0.08	0.06	-0.08	0.08	0.18	0.10	0.14	0.17	0.07
RECALL-FREQ. (Q9)	-0.22	-0.17	-0.33	-0.22	-0.30	0.19	0.04	-0.13	-0.16
OPINIONS-FREQ. (Q9)	-0.11	0.08	-0.06	0.09	0.12	0.16	0.12	0.07	-0.16
ATTENDANCE-FREQ. (Q9)	-0.22	-0.21	-0.24	-0.26	-0.09	0.02	0.05	0.21	-0.06
CALCULATE-FREQ. (Q9)	-0.29	0.18	-0.40	0.02	0.18	-0.02	0.06	0.43	-0.01
CONCEPT-USE (Q10)	0.11	-0.11	0.20	-0.13	0.03	-0.33	-0.23	-0.40	0.22
RECALL1-USE (Q10)	-0.32	-0.36	-0.37	-0.35	-0.41	0.14	-0.09	-0.07	-0.35
RECALL2-USE (Q10)	-0.18	-0.18	-0.23	-0.26	-0.25	0.16	-0.01	0.06	-0.40
CALCULATE-USE (Q10)	-0.43	-0.13	-0.40	-0.25	-0.31	-0.03	0.05	0.46	-0.16
RECOMMEND (Q13)	0.11	0.09	0.29	0.09	0.03	0.00	-0.11	-0.26	-0.01
Ed RESEARCH (Q4)*	0.08	0.07	0.15	0.05	0.02	-0.02	0.11	-0.05	0.34
# OF SEMESTERS (Q13)*	0.29	0.52	0.36	0.40	0.37	-0.01	0.28	-0.02	0.43

Table 17: Correlating faculty practices with student attitudes. The table above lists correlation coefficients between faculty practices (on the vertical axis, data from post-faculty survey) with student attitudes (on the horizontal axis, averaged for each course, data obtained from student survey). Highlighted coefficients require further explanation below.

\*This question is from the first faculty survey.

In Table 17 above, correlation coefficients worthy of note are highlighted. Some of these correlations do not support (nor do they disagree) with commonly held beliefs about effective clicker use. For example, there is no correlation with the frequency at which faculty ask conceptual questions and students view of the utility of conceptual questions ( $r = 0.12$ ), enjoyment of clickers ( $r = 0.07$ ), and the utility of clickers ( $r = 0.06$ ). However, these null results may be expected, considering the fact that not all conceptually-based clicker questions are also considered to promote discussion, be at an appropriate level for students, be interesting, or well worded. In other words, not all conceptual questions are “effective” questions. [7] Furthermore, the range of frequency at which faculty ask conceptual questions may not be large enough—the average frequency at which faculty ask conceptual clicker questions is 3.79 (on a scale of 1 to 5, infrequent to frequent).

The frequency at which faculty ask clicker questions that are calculation-based (such as “plug-n-chug” problems) is negatively correlated with students’ attitude towards the enjoyment of lecture ( $r = -0.4$ ) and positively correlated with students’ attitude towards utility of calculation questions ( $r = 0.43$ ). This could possibly suggest that asking more calculation-based clicker questions results in students disliking lecture, but also students believing that calculation-based questions are useful for their learning. However, the frequency at which faculty ask calculation-based questions is not correlated with students’ attitude towards the utility and enjoyment of clickers ( $r = 0.18$  and  $0.02$ , respectively).

Some of these correlations agree with commonly held beliefs about effective clicker use. For example, asking factual recall questions may not be an effective pedagogy; likewise, the correlation between students’ perception of the utility of clickers and the frequency at which faculty ask factual recall questions is  $r = -0.36$ .

Some of these correlations suggest that further clicker use among faculty may improve student attitudes—the number of semesters that faculty have used clickers in the past is positively correlated with students’ attitude toward the utility, the enjoyment of clickers, and the percent of students that claim to be active during clicker use ( $r = 0.52$ ,  $0.4$ , and  $0.43$ , respectively).

The various methods for awarding credit can be analyzed to determine if some methods of awarding credit significantly impact students’ attitudes towards clickers.

<b>CREDIT</b>	<b>Average Clicker Utility</b>	<b>Average Clicker Enjoyment</b>
Clicker use not part of students' grades	4.08	4.13
Clicker use part of students' grades	3.54	3.51
Clicker use is extra credit	3.67	3.58
More credit awarded for right answers, and some (but less) credit awarded for wrong answers	3.49	3.44
Same amount of credit awarded for either right or wrong answers	3.71	3.70
Award credit for correct answers only	3.78	3.41
Other	3.59	3.52

Table 18: Impact of varying methods of awarding credit on student attitude. The table above lists the average student attitude towards the utility and enjoyment of clickers, equally weighted by course, for varying methods of awarding credit. It should be noted that there are only three courses that did not award any type of credit for using clicker. Two of these three were different courses taught by the same instructor, and the third was a graduate course.

<b>Faculty Practice</b>	<b>Average Clicker Utility</b>	<b>Average Clicker Enjoyment</b>
I stayed at the front of the classroom	3.45	3.55
I discussed the question with students in small groups around the classroom	3.68	3.61
I walked around the classroom to listen to students' conversations	3.54	3.42
I discussed the question with the entire class while they were responding to the question	3.71	3.63
Other	3.78	3.68

Table 19: Impact of varying faculty practices during clicker questions on student attitude. Listed are the averaged student responses, equally weighted by course, for courses where faculty indicated their usual practice during the administration of a clicker question (second faculty survey, Question 12). There does not appear to be any significant differences between different faculty practices on students' attitudes of the utility and enjoyment of clickers.

## Best vs. Worst Courses

Another way to identify effective uses of clickers is to compare how clickers are being used in courses that are the “best” to courses that are considered the “worst.” The metric that we will use to distinguish the “best” and “worst” courses is students’ perceptions of the utility of clickers. Below are the 5 highest and lowest rated courses as measured by students’ attitude toward utility of clickers.

Course	Utility of Clickers	Attitude of Learning	Enjoyment of Clickers	Freq. of Conceptual Q's	% Active	% of lectures using clickers
A	2.05	2.52	2.37	3.28	41.36	90 - 100
B	2.71	3.14	2.71	2.50	28.57	75 - 90
C	2.86	3.39	3.00	3.78	50.00	< 50
D	2.94	3.13	3.25	3.46	38.46	75 - 90
E	3.00	3.96	3.22	4.00	55.56	50 - 75
Average:	2.71	3.23	2.91	3.41	42.79	N/A

Table 20: Lowest rated courses, as measured by student perception of the utility of clickers.

Course	Utility of Clickers	Attitude of Learning	Enjoyment of Clickers	Freq. of Conceptual Q's	% Active	% of lectures using clickers
V	4.11	4.17	4.06	4.22	61.11	90 - 100
W	4.28	4.00	3.92	4.42	86.28	90 - 100
X	4.30	4.10	4.30	4.90	30.00	90 - 100
Y	4.33	4.53	3.93	4.07	60.00	90 - 100
Z	4.38	4.00	4.31	4.77	69.23	50 - 75
Average:	4.28	4.16	4.10	4.48	61.32	N/A

Table 21: Highest rated Courses, as measured by student perception of the utility of clickers.

Note that for the six categories listed in Tables 20 and 21 above, the averages for the five highest rated courses are all greater than the averages for the five lowest rated courses (although a significance test should be performed on this data set). No average is given on the category “% of lectures using clickers,” but four of five of the highest rated courses used clickers 90 -100% of all lecture section, compared with only one of five for the five lowest rated courses. Other cate-

gories can be compared to look for differences (or similarities) between the lowest and highest rated courses.

It should be noted that in courses using clickers on which student survey data was collected, not all students enrolled in a course attempted to take the student survey. This is to be expected, since rarely will 100% of the students volunteer their time to take part in a survey. This raises the question: what fraction of students in a course need to take the survey in order to be able make any reliable conclusions about the nature of clicker use in this course? Most would agree that 90% constitutes an accurate cross-section of the class, but what about 70%? 50%?

One way to verify that the students who took the survey are an accurate cross-section of the course is to look at the average final course grade of the students who took the survey and see if it is significantly different from the students who did not take the survey. The final course grades were obtained for every student in clicker-using courses where less than 50% of the enrolled students successfully completed our survey. The table below lists data obtained from the final course grades of these students.

COURSE	ENROLLMENT	% WHO TOOK SURVEY	Z-VALUE (1)*	Z-VALUE (2)**
1	596	2.3	2.81	2.75
2	402	2.7	0.81	0.79
3	342	3.2	3.14	3.03
4	216	3.2	1.18	1.14
5	304	3.9	1.97	1.89
6	208	4.3	0.15	0.15
7	335	4.5	1.13	1.09
8	199	4.5	3.84	3.67
9	193	4.7	0.16	0.16
10	158	5.1	<b>2.20</b>	<b>2.09</b>
11	341	5.3	1.20	1.14
12	150	6	<b>4.40</b>	<b>4.18</b>
13	292	6.5	<b>3.69</b>	<b>3.54</b>
14	138	8.7	0.87	0.81
15	61	14.8	0.41	0.35
16	87	14.9	0.76	0.65
17	62	19.4	1.27	1.03
18	239	20.5	0.17	0.14
19	401	21.4	<b>4.31</b>	<b>3.47</b>
20	127	22	1.68	1.32
21	211	23.2	<b>2.29</b>	1.81
22	45	26.7	<b>2.73</b>	<b>2.27</b>
23	45	26.7	<b>4.30</b>	<b>3.70</b>
24	152	30.3	<b>2.97</b>	<b>2.21</b>
25	135	32.6	0.55	0.40
26	389	34.7	<b>4.05</b>	<b>2.83</b>
27	34	35.3	<b>2.21</b>	1.54
28	205	43.4	<b>2.55</b>	1.62
29	339	44.2	<b>4.30</b>	<b>2.71</b>

\* "Z-VALUE (1)" refers to the z-value obtained from comparing the average final course grade of survey takers to the average final course grade of non-survey takers of students enrolled within a particular course.

\*\* "Z-VALUE (2)" refers to the z-value obtained from comparing the average final course grade of survey takers to the average final course grade of all students enrolled within a particular course.

Table 22: Statistical difference between survey and non-survey takers. The courses above are listed by the fraction of students who took the student survey within a particular course. Note that enrollments and the z-values seem to vary substantially and are not well correlated. The z-value was calculated in two different manners (see further explanation below). Bolded z-values are greater than 1.96, which corresponds to the level of significance for a 95% confidence interval (i.e., the difference in average final course grade is statistically different).

The z-value was calculated in two different manners. One can compare the average final course grade of students who took the survey to students who did not take the survey. This has the advantage of comparing two distinct groups, but the disadvantage that as the fraction of students who took the survey becomes a substantial fraction of all students, the group of students who did not take the survey becomes rather small and could possibly be statistically different from the vast majority. Despite one's assumption that, say, 98% of the students who take a survey is an accurate cross-section of the entire course, it is possible that this 98% will be statistically different from the 2% of students who did not take the survey.

Another way to calculate the z-value is to compare the average final course grade of students who took the survey to the average final course grade of all students in the course. This remedies the problem discussed in the previous paragraph, since comparing, say, 98% of the students to all the students is likely to result in the two groups being statistically similar. However, this method has the disadvantage of comparing two groups that are not distinct. Both methods of calculating the z-value are listed in Table 22, and further work should determine which method is better suited for this scenario.

Note that all data presented in this report is calculated without excluding any data based on the information presented in Table 22. However, further work will determine if (or which) data may need to be excluded from the data set based on the fact that for some courses, the fraction of students who participated in the survey does not accurately represent the entire course. Some results presented in this report may change due to this issue.

## IV. Conclusions

This study presents self-reported faculty pedagogical practices and self-reported student perceptions of clicker use at a large research university across many disciplines. Along with shedding new light on how this tool is being used by faculty and its corresponding perception by students, we wish to use these data to study how faculty practices impact student behaviors and views.

Student attitude is strongly impacted by the extent to which faculty encourage and succeed in generating peer-discussion during the administration of clicker questions. Students have a much more positive attitude towards the utility of clickers if faculty encourage discussion and are able to get a large fraction of students discussing. Likewise, student attitude is also improved when students are actively participating in discussions with their peers, as opposed to being passive or working independently.

However, some commonly held beliefs regarding the effective use of clickers are not supported by this study. For example, the frequency at which faculty ask conceptually-based questions (as opposed to recall or numerical calculation questions) does not appear to have a significant effect on students' attitude towards the utility of clickers. At least there appears to be no data that argue against this commonly held belief.

We wish to move beyond providing discipline-specific and/or anecdotal suggestions regarding the use of clickers. Rather, we seek to provide research-based evidence of their effective use. At this point, we can make two suggestions to faculty that are supported by this work: 1) encourage students to discuss with their peers during clicker questions and create an environment that promote student discussion; and 2) ask conceptual questions appropriate for most students' level of knowledge.

Other research-based suggestions may exist, but this is a topic for future work. Additionally, work needs to be completed to determine the validity of data collected from courses where only a small fraction of students participated in the student survey. Ultimately, this work attempts to provide general (not discipline specific) guidelines on the effective use of clickers to the expanding population of novice clicker-using instructors.

## V. Acknowledgments

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## VII. Appendix

### Appendix A: First Faculty Survey

The following survey was given to faculty using clickers at CU during the Spring 2007 semester approximately 3 weeks after the beginning of classes.

The online version of this survey can be accessed at:

[http://www.colorado.edu/physics/EducationIssues/podolefsky/clicker/clicker\\_survey.htm](http://www.colorado.edu/physics/EducationIssues/podolefsky/clicker/clicker_survey.htm)

#### Quick Clicker Survey

This brief survey will provide us with valuable information about the use of clickers at CU and should take no longer than 5 minutes to complete.

1. What is your name?
  
2. What course are you teaching this semester? [If you are teaching more than one course, please fill out this survey separately for each course. If a course has multiple lecture sections, you only need to fill out this survey once for that particular course.]
  
3. If you have used clickers prior to this semester, what clicker systems have you used in the past? [check all that apply--If this is your first semester using clickers, please skip to Question 4.]
  - H-ITT Clicker
  - i>clicker
  - eInstruction
  - Other (please specify):
  - Other (please specify):
  
4. On a scale from 1 (novice) to 5 (expert), how knowledgeable do you feel you are regarding education research?
  - 5 - expert
  - 4
  - 3
  - 2
  - 1 - novice
  
5. If you encounter problems with the clicker system, who will you turn to for support? [check all that apply]

- No Support
- Other Faculty
- Your Departmental Clicker Guru
- Physics Prof. Michael Dubson
- Clicker Manufacturer
- Other (please specify):

6. For what percentage of all class days in your course will students use clickers at least once? (For example, 50% = 15 out of 30 class days.)

- <50%
- 50 - 75%
- 75 - 90%
- 90 - 100%

7. On days when clickers are used in this course, how many times do you anticipate students will be using clickers?

- 1 - 3
- 4 - 6
- 7 - 9
- 10 or more

8. Please RANK ORDER the importance of features regarding clicker systems:

Feature	Most Important				Least Important
Robust Hardware					
Simplicity of Hardware					
Simplicity of Software					
Cost of System to Department					
Cost of Hardware to Student					

9. Would you ever consider having your students use clickers to take a midterm or final exam in this course?

- Yes, I would consider it
- No, never
- Possibly

10. Clicker use for this course is [check all that apply]:

- not part of students' grades [Skip to Question 14]
- part of students' grades
- extra-credit
- Other (please specify)

11. If clicker use is part of students' grades, how do you intend on awarding credit/points for their use? [check all that apply]

- award credit for correct answers
- more credit awarded for right answers, and some (but less) credit awarded for wrong answers
- equal amount of credit awarded for right and wrong answers
- Other (please specify)

12. Please rate how often the following uses of clickers will be implemented in this course:

Task	Very Often		Sometimes		Never Used
asking conceptual questions					
giving in-class quizzes					
gathering feedback on course					
gathering opinions from students					
taking attendance					
Other (please specify)					
Other (please specify)					

13. In which semesters have you used clickers in a course that you taught? [check all that apply]

- Fall 01
- Spring 02
- Fall 02
- Spring 03
- Fall 03
- Spring 04
- Fall 04
- Spring 05
- Fall 05

- Spring 06
- Fall 06
- Spring 07

14. What is the biggest advantage of using clickers in your class? [long answer response]

15. What initially convinced you to use clickers (whether or not this is your first course using clickers)? [long answer response]

16. Comments? [long answer response]

## Appendix B: Second Faculty Survey

The following survey was given to faculty using clickers at CU during the Spring 2007 semester at the end of term.

The online version of this survey can be accessed at:

[http://www.colorado.edu/physics/EducationIssues/surveys/clicker/post\\_survey.htm](http://www.colorado.edu/physics/EducationIssues/surveys/clicker/post_survey.htm)

1. What is your name?

2. What course did you teach this semester that used clickers? [If you are teaching more than one course, please fill out this survey separately for each course. If a course has multiple lecture sections, you only need to fill out this survey once for that particular course.]

3. If you plan on using clickers again in the near future, what clicker system will you most likely use?

- H-ITT Clicker
- i>clicker
- eInstruction
- Other (please specify)

4. When you encountered problems with the clicker system over the course of this semester, who did you turn to for support? [check all that apply]

- I encountered no problems
- I solved problems on my own
- Other Faculty
- Your Departmental Clicker Guru
- Physics Prof. Michael Dubson
- Clicker Manufacturer
- Other (please specify)

5. For what percentage of all class days in your course did students use clickers at least once? (For example, 50% = 15 out of 30 class days.)

- <50%
- 50 - 75%
- 75 - 90%
- 90 - 100%

6. On days when clickers were used in this course, how many times did students use clickers?

- 1 - 2
- 3 - 4
- 5 - 6
- 7 or more

7. Clicker use for this course was [check all that apply]:

- not part of students' grades [Skip to Question 9]
- part of students' grades
- extra-credit
- Other (please specify)

8. If you did award credit for clicker use, how did you award credit? [check all that apply]

- award credit for correct answers only
- more credit awarded for right answers, and some (but less) credit awarded for wrong answers
- same amount of credit awarded for either right or wrong answers
- Other (please specify)

9. Please rate how often the following uses of clickers were implemented in this course:  
Task:

Task	Never used	Rarely	Some-times	Often	Very Often
asking challenging conceptual questions, where students have to think and apply the ideas presented					
giving in-class quizzes where students answer independently					
asking factual recall questions					
gathering opinions from students					
taking student attendance					
asking questions where students have to plug numbers into an equation					
Other (please specify)					

10. Please rate how useful for your students' learning you view the following types of clicker questions (if you did not use a particular type of question, please indicate so):

	Completely Useless	Mostly Useless	Somewhat Useful	Useful	Very Useful	Not used in this course
Challenging conceptual questions, where students have to think and apply the ideas presented						
Questions that require students to recall a fact from the text or a prior lecture						
Questions that require students to recall a fact that was just stated						
Questions where students have to plug numbers into an equation						

11. To what extent did you usually encourage student-to-student discussion about clicker questions in class and how did students usually respond?

- I do not allow discussion
- Allow discussion, but do not encourage it, and a small fraction of students discuss
- Allow discussion, but do not encourage it, and a large fraction of students discuss
- Encourage discussion, and a small fraction of students discuss
- Encourage discussion, and a large fraction of students discuss

12. While students were voting on and/or discussing a typical clicker question, what did you usually do during this time?

- I stayed at the front of the classroom
- I walked around the classroom to listen to students' conversations
- I discussed the question with students in small groups around the classroom

- I discussed the question with the entire class while they were responding to the question
- Other (please specify)

13. Would you recommend that other instructors, who teach this course in the future, use clickers?

- Definitely Not Recommend
- Not Recommend
- Neutral
- Recommend
- Definitely Recommend

Why?

14. What was the biggest advantage of using clickers in your class?

15. Comments or anything else you would like to share?

## Appendix C: Student Survey

The following survey was given to students using clickers at CU during the Spring 2007 semester approximately one month prior to the end of term.

The online version of this survey can be accessed at:

<http://www.colorado.edu/physics/EducationIssues/surveys/clicker/survey.htm>

1. CU login ID: [Note: This is your login name for your CU email account. For example, do not enter "john.smith"; it will be something like "smithj." It is NOT your 9-digit numerical ID.]

2. Enter your first and last name:

3. For how many semesters have you used clickers at CU?

- 1 (this is my first semester)
- 2 - 4 semesters
- 5 or more semesters

4. Overall, how do you feel about this course?

- Awful course
- Not a good course
- Neutral
- Good course
- Great course

5. Regardless of how you feel about it, how much did you learn in this course?

- Almost nothing
- A small amount
- A reasonable amount
- Quite a bit
- A great deal

6. Please rate how useful for your learning each of the following class activities are in this course:

	<b>Completely Useless</b>	<b>Mostly Useless</b>	<b>Somewhat Useful</b>	<b>Useful</b>	<b>Very Useful</b>
Pure Lecture Presentation (only instructor talking)					
Use of Clickers					
Textbook or Course Readings					
Homework and/or Course Assignments					

7. Please rate how much you enjoyed each of the following class activities in this course [where "enjoyed" is meant in the sense of academic or intellectual pleasure]:

	<b>Strongly Dislike</b>	<b>Dislike</b>	<b>Neutral</b>	<b>Like</b>	<b>Strongly Like</b>
Pure Lecture Presentation (only instructor talking)					
Use of Clickers					
Textbook or Course Readings					
Homework and/or Course Assignments					

8. To what extent does your instructor usually encourage student-to-student discussion about clicker questions in class?

- Does not allow discussion
- Allows discussion, but does not encourage it, and a small fraction of students discuss
- Allows discussion, but does not encourage it, and a large fraction of students discuss
- Encourages discussion, and a small fraction of students discuss
- Encourages discussion, and a large fraction of students discuss

9. When your instructor gives your class a typical clicker question AND you are allowed to talk with others, what do you usually do?

- Does not apply--we are usually not allowed to talk with other students

- I rarely use a clicker in this course
- I guess the answer and do not check with other students
- I actively think about the question independently and arrive at an answer without speaking or listening to other students
- I listen to other students' answers and/or reasoning
- I actively participate in discussions with other students around me

10. Please rate how useful for your learning the following types of clicker questions are:

	Completely Useless	Mostly Useless	Somewhat Useful	Useful	Very Useful	Not used in this course
Challenging conceptual questions, where I have to think and apply the ideas presented						
Questions that require me to recall a fact from the text or a prior lecture						
Questions that require me to recall a fact that was just stated						
Questions where I have to plug numbers into an equation						

11. Would you recommend that other instructors, who teach this course in the future, use clickers?

- Definitely Not Recommend
- Not Recommend
- Neutral
- Recommend
- Definitely Recommend

## Appendix D: 2007 Physics Education Research Conference paper

# Research-based Practices For Effective Clicker Use

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**Abstract.** Adoption of clickers by faculty has spread campus-wide at the University of Colorado at Boulder from one introductory physics course in 2001 to 19 departments, 80 courses, and over 10,000 students. We study common pedagogical practices among faculty and attitudes and beliefs among student clicker-users across campus. We report data from online surveys given to both faculty and students in the Spring 2007 semester. Additionally, we report on correlations between student perceptions of clicker use and the ways in which this educational tool is used by faculty. These data suggest practices for effective clicker use that can serve as a guide for faculty who integrate this educational tool into their courses.

**Keywords:** Clickers, Personal Response Systems, Classroom Response Systems

**PACS:** 01.40.gb, 01.50.-i, 01.50.H-, 01.40.Fk

## INTRODUCTION

Since being introduced six years ago in one introductory physics course at the University of Colorado at Boulder, clicker<sup>7</sup> use has spread extensively, with nearly half the undergraduate population using clickers in one semester. Although their use is becoming more prevalent, it is not known how this tool is used by faculty at the campus level, nor do we understand student perceptions and attitudes towards this tool.

Research on clickers remains a popular topic within PER and other science and education communities. (For example, see [1, 2, 3]; for an extensive literature review, see [4].) The purposes of the present study are to identify common faculty pedagogical practices regarding clicker use across the variety of disciplines at one institution, study student perceptions towards this tool, and look for correlations between faculty practices and student perceptions. We seek to identify effective clicker uses across these varieties of disciplines and environments in which they are employed. An ultimate goal will be to correlate faculty practices with student learning—others have already demonstrated correlations between student attitudes and beliefs and

content learning gains in other contexts (e.g., see [5] and [6]). However, studying student learning gains is beyond the scope of the present work. In this piece, we present limited results from an extensive study of dozens of faculty and thousands of students.

When correlating faculty practices with student attitudes, we find that the students' perception of the utility of clickers improves as faculty encourage peer-discussion and succeed in getting students to discuss with each other in lecture. Additionally, students find conceptual questions slightly more useful than factual recall or calculation-oriented questions.

## INSTITUTIONAL USE OF CLICKERS

During the Spring 2007 semester at the University of Colorado at Boulder, clickers were used by 70 faculty in 94 lecture sections, with an average enrollment of 144 students in each lecture section. Although this breadth of use represents a tiny fraction of all faculty on campus (3%), it represents a significant fraction of the student body due to the high average enrollment of courses using clickers. In this semester, clickers were

<sup>7</sup> We opt for the term "clicker," whereas others use "personal response system," "voting machine," and a myriad of other terms (see Reference [4]).

used by 10,011 unique students, which include 9,941 undergraduates and 70 graduate students. Students using clickers made up 44% of all undergraduate students and 1.6% of graduate students. Despite the widespread use among the undergraduate student body, there is still opportunity for clicker use to expand. Only 28% of departments on campus are using clickers and only 24% of large lecture sections (where the enrollment is greater than 100) are using clickers. We see some departments that currently use clickers in all large lecture courses that they offer, such as Physics, Astrophysics, and Chemical Engineering. Other large departments, such as Psychology and Sociology, use clickers in 1 and 2 large courses (out of 16 and 7, respectively).

We find the majority of courses using clickers to be in STEM fields. The total number of courses that used clickers in STEM fields was 63, while there was 10 in Business, 6 in Social Sciences, and 1 in Humanities.

Of the 94 lecture sections<sup>8</sup> using clickers, 79 of these are using i>clicker<sup>9</sup> and the remaining 15 are using H-ITT<sup>10</sup>. Of all unique students who used clickers, 70% used clickers in one course only, while 29% used clickers in 2 courses, and fewer than 1% used clickers in either 3 or 4 courses.

## FACULTY PRACTICES

Faculty using clickers were given two different online surveys. The first survey was given at the start of term approximately 3 weeks after the beginning of classes, and 54 faculty responded to 16 multiple-choice and long answer questions. The second online survey was given at the end of term, and 69 responses were collected to 15 multiple-choice and long answer questions. To access both surveys, see [4]. Questions from both surveys probed how faculty used clickers in their own courses and on their experience and beliefs surrounding clickers. The results presented in this section were collected from both faculty surveys. Observational data of classroom practices demonstrate some similar trends as seen in faculty self-reported data presented here for a subset of physics courses using clickers. [7]

The majority of faculty using clickers has little or no experience using this tool—59% of the respondents are using clickers for the first time or have only one prior semester of clicker experience.

Some slight variation does exist in how frequently faculty use clickers, in terms of the average number of questions given per day and the overall percentage of

class days when clickers are used throughout the semester (see Table 1 & 2). However, the majority of faculty asks 3 to 4 questions per day and use clickers 90 – 100% of class meetings over the semester.

**TABLE 1.** Average number of questions given per class meeting, reported by faculty

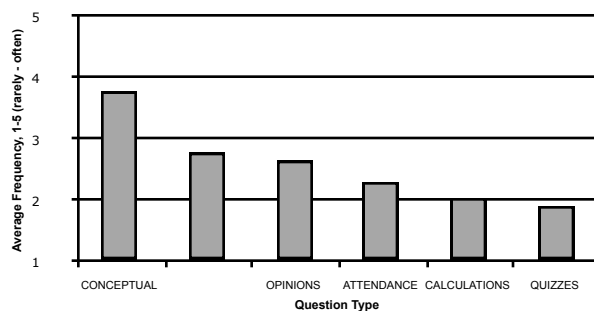
Number of Clicker Questions	% of Courses [standard error] <sup>†</sup>
1 to 2	19 [5]
3 to 4	65 [6]
5 to 6	13 [4]
7 or more	3 [2]

<sup>†</sup>Bracketed numbers in tables are estimated standard error of the mean.

**TABLE 2.** Percent of all classes days when clickers are used, reported by faculty

% of class days	% of Courses, N=69
< 50%	7 [3]
50 - 75%	4 [3]
75 - 90%	20 [5]
90 - 100%	68 [6]

In addition to reports of frequency of use, we examine how clickers are used. Figure 1 reports the frequency of use of several broad categories of clicker questions.



**FIGURE 1.** Types of clicker questions used, reported by faculty.

We see some variation in the extent to which faculty encourage discussion among their students, and the extent to which students do discuss with their peers in lecture (according to faculty). The majority of faculty claim to encourage discussion and claim to succeed at getting a large fraction of students to discuss in lecture (see Table 3).

<sup>8</sup> Note that many courses have multiple lecture sections; hence the difference between 80 courses and 94 lecture sections.

<sup>9</sup> <http://www.iclicker.com>

<sup>10</sup> <http://www.h-itt.com>

**TABLE 3.** Extent of peer-discussion, reported by faculty

Type of Discussion	% of Faculty
Do not allow discussion	3 [2]
Do not encourage discussion, & <i>small</i> fraction of students discuss	6 [3]
Do not encourage discussion, & <i>large</i> fraction of students discuss	6 [3]
Encourage discussion, & <i>small</i> fraction of students discuss	22 [5]
Encourage discussion, & <i>large</i> fraction of students discuss	63 [6]

## STUDENT PERCEPTIONS & PRACTICES

Approximately one month prior to the end of term, an online survey was distributed to students in courses where clickers were currently being used. To access the student survey, see [4]. Of the 10,011 students using clickers, 3,697 responses were collected. The 11 multiple-choice questions on the survey probed students' attitudes and beliefs about clickers and asked them to respond to how clickers are currently being used in their courses. Of the 80 courses using clickers, data from students were collected in 51 courses. The data presented in this section are a summary of results from the student survey.

Overall, we find students' experience with clickers to be positive. 56.4% of students responding had a favorable attitude towards the *utility* of clickers in their respective courses (compared to 22.9% that were neutral and 20.7% that had unfavorable attitudes) and 55.3% of students had a favorable attitude towards the *enjoyment* of clickers (compared to 24.5% that were neutral and 20.2% that had unfavorable attitudes). These favorable results for clickers are noted elsewhere (for example, see [8]).

**TABLE 4.** Student discussion practices during clicker questions, reported by students

Student Practice	% of Students, N=3,697
Usually not allowed to talk with other students	2 [0.03]
Rarely use a clicker in this course	1 [0.01]
Guess the answer and do not check with other students	2 [0.03]
Actively think about the question independently and arrive at an answer without speaking or listening to other students	19 [0.3]
Listen to other students' answers and/or reasoning	18 [0.2]
Actively participate in discussions with other students around me	59 [0.4]

When asked what they normally do during the delivery of a clicker question, most students claim to be actively participating in discussions with their peers (see Table 4).

The utility of different types of clicker questions was rated. Students found conceptual questions the most useful ( $3.92 \pm 0.02$ , on a scale of 1–5, negative to positive), followed by factual recall ( $3.51 \pm 0.02$ ), and numerical calculations ( $3.32 \pm 0.02$ ).

## CORRELATIONS BETWEEN FACULTY PRACTICES & STUDENT ATTITUDES

The final goal of the present work is to study what impact faculty practices regarding clickers have on student attitudes. We begin to determine these relations by correlating faculty use of this tool with student perception of clickers.

It is commonly argued that encouraging discussion among students is of greater benefit than passively using clickers in lecture [2]. We find there to be a strong relationship between the extent of peer-discussion in lecture and students' attitude towards the utility of clickers. Of course, students do not uniformly agree within a single course when asked to what extent their instructor encourages discussion. Taking the mode of student responses to be an accurate representation of how instructors encourage student discussion, the average fraction of students with a favorable attitude towards the utility of clickers is 66% in courses where instructors encourage discussion and get a large fraction of students to do so (see Table 5).

**TABLE 5.** Average percent of students who have favorable attitudes towards clicker use, listed by classes where plurality of students reported use of clickers in stated fashion.

Type of Discussion	% Favorable
Does not allow discussion	38 [5]
Does not encourage discussion, & <i>small</i> fraction of students discuss	37 [8]
Does not encourage discussion, & <i>large</i> fraction of students discuss	36 [22]
Encourages discussion, & <i>small</i> fraction of students discuss	55 [8]
Encourages discussion, & <i>large</i> fraction of students discuss	66 [3]

Similarly, we examine how the role of students during a question correlates with their perceived utility of the clickers. We see a trend toward students finding clickers more useful as they become more active in lecture, with 64% of the students who claim to be actively participating in discussion having a favorable attitude towards the utility of clickers (see Table 6).

We also see a strong correlation between the instructor's experience with clickers (i.e., the number of prior semesters where an instructor has taught with

clickers) and student perception of utility ( $r=0.52$ ), suggesting that faculty become better over time at effectively using this tool and that novice faculty may need more assistance.

In addition to students finding conceptual questions more useful than other types of questions, the fraction of students in a course who claim to be actively participating is correlated with the average student rating of utility of conceptual clicker questions within a course ( $r=0.43$ ), suggesting that conceptual questions are most useful when students discuss the questions with their peers.

**TABLE 6.** Percent of students from each student role who have favorable attitudes toward the utility of clickers.

Student Role	% Favorable
Does not apply--usually not allowed to talk with other students	28 [5]
Rarely use a clicker in this course	16 [6]
Guess the answer and do not check with other students	17 [4]
Actively think about the question independently and arrive at an answer without speaking or listening to other students	51 [2]
Listen to other students' answers and/or reasoning	45 [2]
Actively participate in discussions with other students around me	64 [1]

## CONCLUSION

This study presents self-reported faculty pedagogical practices and student perceptions of clicker use at a large research university across many disciplines. In addition to shedding new light on how this tool is being used by faculty and its corresponding perception by students, we wish to use these data to study how faculty practices impact student behaviors and views.

Student attitude is strongly impacted by the extent to which faculty encourage and succeed in generating peer-discussion during the administration of clicker questions. Students have a much more positive attitude towards the utility of clickers if faculty encourage discussion and are able to get a large fraction of students discussing. Likewise, student attitude is also improved when students are actively participating in discussions with their peers, as opposed to being passive or working independently.

We wish to move beyond providing discipline-specific and/or anecdotal suggestions with regard to the use of clickers. Rather, we seek to provide research-based evidence of their effective use. At this point, we can make two suggestions to faculty that are supported by this work: 1) encourage students to discuss with their peers during clicker questions and create environments that get students to discuss; and 2) ask con-

ceptual questions appropriate for most students' level of knowledge.

Other research-based suggestions exist, but this is a topic for future work. For example, how do faculty practices differ between the highest and lowest rated courses, as measured by student perception of the utility of clickers? How useful to students are clickers compared to other course resources? How do varying methods of awarding credit for clicker use affect students' attitudes? Future work will seek to answer these questions to provide guidelines on the effective use of clickers to the expanding population of novice clicker-using instructors.

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