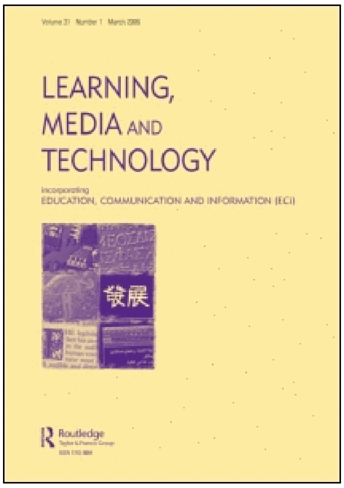

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Vibrant student voices: exploring effects of the use of clickers in large college courses

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Vibrant student voices: exploring effects of the use of clickers in large college courses

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Teachers have begun using student response systems (SRSs) in an effort to enhance the learning process in higher education courses. Research providing detailed information about how interactive technologies affect students as they learn is crucial for professors who seek to improve teaching quality, attendance rates and student learning. This study investigates social, educational and emotional effects of the use of SRSs – clickers – at the University of Colorado at Boulder. Methods include participant observation, survey data from over 2000 students enrolled in three semesters of General Chemistry, and in-depth interviews exploring the nature of student experiences with clickers. Findings suggest clickers significantly alter the social environment experienced by students as they learn. Clickers create learning environments characterized by greater activity, cooperation and conceptual application compared to traditional, lecture-based instruction. Gender also influences whether students choose to work with peers during clicker-prompted interaction. The qualitative analysis presented here extends upon themes identified in existing research on the effects of clickers for learning.

Keywords: clicker; student response system; student attitudes

Introduction

In recent years, student response systems (SRSs) have become increasingly common around the world (e.g. Australia, Canada, UK, USA, Scotland). Existing research on SRSs – or clickers – relies primarily on quantitative methods designed to assess the effects of clickers for learning, retention and engagement (e.g. Rice and Bunz 2006). While this data is certainly useful, qualitative research programs designed to provide greater explanatory depth into the trends being observed in this literature are just beginning to emerge. Recently, Penuel, Abrahamson, and Roschelle (2007, 2) called for greater attention to the *communicative* and *interpretive* behaviors of students as they use clickers, so educators might better understand 'how teaching and learning unfolds in these networked classrooms'. Following this call, the current project investigates how students interpret their experiences with using clickers in large college classes. By soliciting the views and experiences of students directly, the current analysis offers valuable information for educators in a variety of disciplines.

The problem: large lecture classes and disengaged students

The use of a lecture format, where the educator does most of the talking and students sit quietly taking notes, is widely perceived to be common in universities today. Effective

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teaching demands a great deal of time, commitment, and preparation; given their other commitments, educators may feel they have little choice but to rely upon a lecture format or may even take for granted the ways in which institutional constraints structure the learning environment in large courses.

Structural features of large university courses – the number of students, little time spent in class, and auditorium-style seating – combine to produce a learning environment that feels passive and impersonal for many undergraduates. University classes in the USA regularly enroll a hundred or more students. Any individual who has taken (or taught) a course in a large lecture hall knows how daunting it is to raise one's hand and participate in such an environment. Often, just thinking about speaking or asking a question starts the heart pounding. Large university courses also usually meet for a short period of time; the need for efficiency encourages reliance on a lecture format. Lecturing leaves the flow and content of the class in the hands of the instructor, who maintains control by monopolizing speaking time. A necessary feature of large courses, auditorium seating combines with lecturing to produce feelings of distance. Sitting among rows and rows of unknown others, many students feel disconnected from the lecturer, the material, and their peers (Gleason 1986).

Regardless of the good intentions of the instructor, lecturing provides few opportunities for students to evaluate critically, discuss, or apply what they are learning during class. While the vast majority of teachers probably prefer their students be engaged with what is going on, established educational research suggests lecturing engenders passive, dependent learners (Boud 1981). McKeachie (2002, 67) believes lecturing encourages students to 'assume a passive, non-thinking, information receiving role'. Trees and Jackson (2007) argue the role of student as note-taker and silent observer decreases motivation to engage with course content. Cooper and Robinson (2000, 6) claim, 'The large-class-lecture-centered approach seems to be inviting increasing degrees of student disengagement'. Whether in a large lecture hall or smaller classroom, when educators do not provide opportunities for active engagement with course concepts during class, they effectively train students to act as passive recipients of knowledge.

Using clickers to facilitate problem-based learning

Theoretical perspectives in education address this issue. One approach, constructivist pedagogy, claims students learn more effectively when they are encouraged to construct their own understandings of course concepts actively (Anderson 1987). Following this perspective, educators should work to establish learning environments where students can regularly practice applying, evaluating, and critiquing course concepts during class. Student response systems (clickers) represent a form of teaching technology particularly suited to facilitating *problem-based learning* in large courses. Problem-based learning techniques stimulate active student involvement during the learning process by placing students into small groups where they work together to apply course concepts. Research suggests problem-based learning is conducive to *cognitive elaboration*, as students work cooperatively to develop into 'communities of learners who discuss, debate, and summarize academic content' (Cooper and Robinson 2000, 10). Comparing the effectiveness of lecture and small group discussion, Garside (1996) suggests small group discussions offer greater opportunity to develop higher level critical thinking skills.

Cooperative, peer group discussions supporting problem-based learning can be facilitated in a variety of ways. A recent paper by Stowell and Nelson (2007) compared four methods for increasing student engagement with course concepts, measured in terms of participation rates and positive emotion. Compared with standard lecture, hand-raising, and response cards, use of clickers was most effective at facilitating student engagement in class: formal participation rates significantly increased in the group using clickers, compared with the other three methods. If increased verbal participation can be reliably assumed to indicate increased student engagement with, or greater processing of, course concepts, then this study provides preliminary support for the particular strength of clickers as a facilitator of problem-based learning. Moreover, while in this study clicker use produced just a small positive effect on student enjoyment of lectures, the authors suggest 'it might not be the experience of enjoyment that mediates the benefits of clickers [as much as] the *enhanced cognitive processing*' incited by their use (Stowell and Nelson 2007, 256, emphasis added).

By exploring the effects of clickers for student engagement, learning, and emotion qualitatively, the current study offers greater opportunity to discern the particular nature of clickers as a problem-based learning facilitator. The research questions include:

- If integrating clickers into large classrooms creates a 'more active' learning environment, as suggested by existing research, how do students experience this change?
- Does the integration of clickers into large classrooms create a 'more cooperative' learning environment?
- How do students experience clicker-prompted peer interaction? What reasons do they give for working together versus choosing to work alone?
- What is the role of gender and emotion in interactive classrooms?

Methods

Research setting and SRS used

This research examines clicker use in several sections of one course, general chemistry (CHEM 1111), over a period of three years. General chemistry is taught in three sections in the fall (three sessions per week) and one section in the spring of each academic year. The course enrolls approximately 800 students in the fall and 300 students in the spring. While 90% of students take the course to fulfill a degree requirement, a mere 5–10% are chemistry majors. Two female professors each teach one-half of the semester. The course enrolls approximately equal numbers of men and women: most (80–90%) are in their first or second year of college; non-traditional students comprise about 5% of the population.

The SRS implemented in CHEM 1111, Hyper-Interactive Teaching Technology (H-ITT), uses infrared signals to collect student responses to clicker questions. Like other constructivist pedagogies, H-ITT (www.h-itt.com) is used to facilitate problem-based learning through application and discussion of chemistry concepts during class. CHEM 1111 uses a format similar to the 'bookends procedure' for small group work described by Smith (2000): periods of lecture (10–12 minutes) are alternated with peer discussions of clicker questions (2–3 minutes). CHEM 1111 lectures include an average of 3–5 conceptual application opportunities (clicker questions) per 50-minute period. Students are awarded one point for any answer and three points for a correct response. The total number of 'clicker points' earned comprises 5% of the student's grade. A small number of these points are 'dropped' to lessen anxiety when problems with clickers occur (e.g. left at home).

Data collection and analysis

An ethnographic study, this research focuses upon the *meanings* students assign to their experiences with using clickers to learn new concepts. The research design achieves triangulation through participant observation, survey questions, and qualitative interviews. Conducted over a three-year period, the study examines a population of over 2000 students who used clickers in a general chemistry course from 2003–05. The dataset includes 28 interviews, 3 semesters of survey data, and 27 sets of observation notes (recorded in fall 2004, spring 2005, and fall 2005 semesters). Observing chemistry classes helped the researcher to become familiar with the interactive, teaching and learning aspects of the course. Survey questions were designed to gather information on student attitudes toward the course and the use of clickers. The questions were always preceded by an instruction overview designed to: (1) communicate the purpose of the survey, (2) encourage students to respond in an honest and sincere manner, and (3) provide students with contact information should they have a question about the research. Survey responses were collected using the clickers and students received a small amount of extra credit for participating.

Interviews were designed to explore variation in student perceptions of clickers as observed in the survey data. In the fall of 2004, 20 interviews were conducted using a semi-structured interview guide. Participants were recruited through in-class announcements and a flyer. Interviews took place in a faculty office on campus; informed consent was secured from all participants. Interviews were audio-recorded for later transcription: students were advised that the recording device could be stopped at any time, but none requested this be done. Interviews ranged in length from 35–91 minutes (mean, 56 minutes). Variation in interview length occurred as a result of differing student experience: participants who had used clickers in prior courses were asked to compare these experiences with the use of clickers in general chemistry. The chemistry department at CU-Boulder funded the project; students were paid $20 for participating in interviews.

Interview questions were designed to guide relaxed conversation with the goal of helping the interviewee feel as comfortable as possible sharing their experiences with using clickers. In December 2004, initial review of the interview data suggested the majority of the participants approved of using clickers in general chemistry. To understand the experiences of students less favorable to clickers better, in the spring of 2005 students were solicited who 'disliked or had concerns about' the use of clickers in general chemistry. Eight more interviews were completed, for a total sample of 16 young women, 10 young men, and 2 non-traditional students (one of each gender). Nineteen interviewees self-identified as white (68%); 5 as Asian-American (18%); and 15 (54%) had used clickers in at least one prior course. Interviewees were asked to choose an interview pseudonym; the names used in the report conceal individual identities but will be familiar to the participants should they read the report.

Qualitative data for this study, interview transcripts and participant observation notes are coded with an eye for locating and preserving the depth of meaning that students attach to their experiences with clickers. Data analysis is conducted through *in vivo* coding (Coffey and Atkinson 1996): a form of open coding designed to allow conceptual categories to emerge from the data. Coding and analysis are done by hand (not with a computer program); a process which produces an informed principal investigator who gains extensive knowledge into the complexity of the subject under examination. Survey data are used to supplement observation and interview data, and student responses are presented in percentage form.

Results

This research is designed to illuminate the interpretations assigned by students to the experience of using clickers in general chemistry. The paper first offers student descriptions of 'what it is like' to use clickers in CHEM 1111. Observation notes and interview data suggest that the majority of the time, clickers facilitate effective problem-based learning: they engage students by fostering a learning environment that *looks* and *feels* more active than traditional, lecture-based instruction. Next, the report examines the extent to which clickers encourage cooperative behavior. For many students, the data strongly indicate that the use of clickers helps to make the large course feel less passive and impersonal. Then, the paper explores some of the reasons interviewees gave for why students may choose to work alone during clicker questions. This information should be useful for educators seeking greater understanding for what to expect when incorporating a SRS into the large course. The paper also explores the effects of gender and emotion, concluding with a discussion of implications of SRSs for higher education.

Using clickers

In general chemistry, the professor most commonly lectures for 10–12 minutes before posting a clicker question – called a ConcepTest (CT) (Mazur 1997) – for students to solve. Observation notes confirm posting a CT transforms the relatively calm, passive learning environment produced by lecturing into a surprisingly noisy, engaging learning experience. Professors encouraged peer discussion through instructions such as, 'Feel free to work with your neighbors' and 'Remember, two heads are better than one' and students turn to their neighbors to discuss the questions, challenging one another to explain the reasoning behind their answers. Students are given just one attempt at discussion; after 2–3 minutes of peer interaction, they are notified they have a small amount of time left to click in. When the time expires, a histogram of student response frequencies is displayed. The histogram allows both students and the lecturer to confirm visually how well the students have grasped the concepts being learned. The lecturer then explains the correct interpretation of the concept and/or clarifies the ways in which students may be having trouble with it. In CHEM 1111, the professors regularly alternate between lecturing and providing opportunities for conceptual application in the form of clicker questions.

Survey data indicate the majority of CHEM 1111 students feel the course is challenging. A five-credit course, general chemistry students are graded on a curve, and this makes many anxious. Responses indicate 80–90% of these students are concerned about whether or not they will pass the course, and 55–65% report feeling anxious 'often' in general chemistry. Similarly, less than 10% of these students indicate they would feel comfortable enough to respond to a professor's question by raising their hand in the large lecture hall. Thus, it should be kept in mind that even when clickers are used to increase engagement with course material, it is difficult to remove the sense of distance and impersonality felt in large courses entirely. Hal, a non-traditional student, said it is 'easy to feel distant from the professor' when sitting in the back of the lecture hall. He intentionally arrives early to secure a seat up front:

> I think when you sit in the front of the class you can be more actively involved … if you are up front, and you're making eye contact with the person who is speaking to you, or they're making eye contact with you, it just engages the whole idea of, 'Am I understanding [this]?'

Hal's statement expresses a desire to be *actively engaged* with what is going on during class, as well as supports existing research suggesting that students prefer professors to make eye contact while teaching (Brooke 1999).

For many, general chemistry represents one of the most challenging courses a student will take in their early years of college (see Table 1).

Table 1. Response percentages.

Q: I am afraid of receiving a poor grade in this class.

	Fall 2004				Fall 2005		
	Section					Section	
	100	200	300	Spring 2005	100	200	300
	$N = 240$	$N = 134$	$N = 256$	$N = 266$	$N = 151$	$N = 112$	$N = 233$
SA/agree	87	82	86	83	88	87	90
Neutral	6	7	6	0[a]	7	5	3
Disagree/SD	7	11	8	17	5	8	7

Note: [a]This option was omitted to assess how students might respond in the absence of a 'neutral' response category.

Despite the challenge presented by the course, most students felt positively about the use of clickers in general chemistry (see Table 2).

A more active learning environment

Clickers make the learning environment feel more active because students *see* and *hear* more activity than they would during a traditional lecture. Observation notes and interview data confirm clickers create a more engaging learning environment than would be the case with lecture alone. In interviews, participants repeated time and again that students are simply more likely to pay attention during lecture when 'they know a CT is coming.' Abigail explains:

> The clicker actively makes us have to pay attention. There's more going on, and there's more commotion around people, like in other lecture halls, it could be dead silent because the professor is talking… but here, there's peaks in the noise level because people are talking and discussing.

Clickers afford opportunities to regularly discuss the material, help students stay focused and generate noise that alleviates the boredom (or passivity) commonly felt in the large lecture hall.

When used intermittently, then, clickers offer a perceptual 'break' from the passive note-taker role so often required of college students. When students work together to discuss

Table 2. Response percentages.

Q: How do you feel about answering ConcepTests using clickers in this class?

	Fall 2004				Fall 2005		
	Section				Section		
	100	200	300	Spring 2005	100	200	300
	$N = 224$	$N = 143$	$N = 267$	$N = 285$	$N = 147$	$N = 111$	$N = 228$
Love it/like it	40	49	56	54	53	58	52
Neutral	34	34	23	27	34	32	33
Dislike it	25	16	21	17	12	11	15

concepts, they become active processors of information, rather than passive note-takers. Many interviewees said they looked forward to the times when they were able to talk with their peers during CTs. They believed clickers were a great addition to large courses precisely because they generate noise that makes learning feel more active. Lisa explains:

> It [using clickers to answer CTs] gives you an incentive to pay attention more… It breaks up the lecture… being able to discuss with other people and kind of take a break from sitting and absorbing someone talk for a whole 50 minutes. I think it engages your learning better.

The functional nature of clickers as noise/discussion/activity generator is also observable on a more macro scale. As histograms are displayed and CT answers revealed, student voices can often be heard in communal expressions such as: 'YES', 'Ughhh', and 'Ohhh!'

Next, interviewees explained that the lecture feels more active because they are using the knowledge they are learning each day, instead of waiting for the exam to do so. Clickers are beneficial to learning because they prompt students to apply concepts *during* class. Course material becomes more meaningful to them because they are consistently seeing how it might appear in actual problems. Similarly, clicker histograms help students to regularly discern whether they understand the concepts. One interviewee, Robert, said:

> It definitely picks up class a little bit. It's kind of like a 'pit stop' because you know the [CT] question is going to be the juncture between this idea and the next idea. It helps me to sum up the ideas, and it helps me understand why we learned this, and what we're going to use it toward.

A few interviewees went as far as to suggest that CTs were most helpful when they got the question wrong. Histogram data help students see when they do not fully understand, enabling them to more effectively determine which concepts to review in greater detail before exams.

A more cooperative learning environment

Students experience the use of clickers and CTs differently depending upon how they position themselves relative to their peers. Some form discussion groups of 3–5 early in the semester and work with these peers regularly; others find a seat where they can, working with whomever happens to be sitting around them when they feel comfortable doing so. Clickers increase the activity level in the large lecture hall, but not all students choose to collaborate with others (data indicate 15–20% do not feel comfortable working cooperatively during CTs). When a CT is posted, students decide whether to work with peers according to: (1) the difficulty level of the CT question and (2) the student's affinity for working with others. Ann describes working cooperatively in her regular peer group:

> The first thing we do [is] read the question. We'll go through and flat out eliminate some of the answers. Um, we can usually narrow it down to one or two, and that's when we pick whichever one we feel is the most right, and we'll click it in. Then we'll try to reason through why we chose it… We usually come to a consensus before the time has run out.

Like many others, Ann works with the same people everyday, but her peer group functions differently depending upon the difficulty of the concept being applied. Ann continues:

> I think I've gotten most of my clicker questions right. A lot of times I'll come up with my own answer [first], and I'll click it in before I'll talk with them and then we'll reason it out. There

> are some questions though, probably about 50% of the questions, where I'll talk with them directly before I'll choose an answer … and that really does help. Two brains are always better than one, and sometimes it forces you to doubt your answer… Talking with people around you can be reinforcing and you can … learn from your mistakes a little bit better.

Interview data suggest that if a clicker question is easy enough, students will most often choose an answer on their own, before turning to peers 'to check their answer'.

Interestingly, as CTs become more challenging, a gendered pattern emerges. Male interviewees seemed much more likely than female participants to state they intentionally tried to answer the questions on their own. Hal, the non-traditional student referred to earlier, termed this a 'self-test' of his knowledge:

> The clicker forces you to pause, after you've kind of absorbed something … it allows you to pause, reflect on it, check yourself… 'Do I understand what's happening?' versus sitting there for 50 minutes and absorbing all this material without a break, and I think that's great.

During interviews, many young men explained that they wanted to engage in their own reasoning, before hearing about how others approached the question. Viewing CTs as symbolic opportunities to 'self-test' their knowledge, these students deliberately tried to answer the CT questions on their own, and turned to others only when they felt very unsure of their answer.

This trend suggests that gendered expectations shape student behavior when using clickers. Chemistry is traditionally considered one of the 'hard sciences': scientific concepts such as objectivity and autonomy have long been associated with masculinity, and for many, the title 'scientist' draws to mind a lone male, the independent and capable researcher. Combine pressure to succeed in a traditionally male-dominated field such as chemistry with the cultural belief that men are more adept at working with new technology than women, and one unearths a strong explanation for why male students may 'prefer to work alone'. Observation notes confirm women tend to cooperate with each other more often than men: when someone was working alone, it was most often a male. Students were asked about this in interviews: 'If you happened to be sitting alone one day and had a question about a CT, who would you feel most comfortable turning to for help, a guy on your left or a girl on your right?' The majority of the interviewees said that they would most likely ask a girl first.

For most students, using clickers has the effect of making the learning environment feel more cooperative in general chemistry. Through peer discussions, students help each other by evaluating each other's reasoning and 'catching each other's mistakes'. Clicker-prompted discussions allow them to 'switch roles' and 'play the role of teacher'. Using clickers, students discover how much they know by 'talking it out'. Mike explains:

> A question will be put up and if I don't have my clicker on me, I'll grab it. Then, I will read the question and go about reasoning [it]… I'll talk to my partners and either convince them of my answer or hear their answer. I'll hear their logic, and then I'll put in my logic if I don't agree. If I do agree, if I do think they're right, I'll have them explain to me why they're right. We generally go back and forth about what we think it is … occasionally we'll get help from another surrounding neighbor, and then we'll click in.

For students like Mike who choose to work in a regular peer group, discussing CTs solidifies the group's commitment to helping each member understand the material. Over the course of the semester, working with the same people time and again affirms the cooperative nature of the group. Mike continues:

> I mean, if you don't get something, it's in your best interest to ask for help and in the clicker situation, the best reference is your neighbor, in your vicinity. And I think as the year goes on, it gets more lax. First couple days, you may be a little timid … as it goes on, you become more comfortable. I sit with my friends … and I'm a freshman so when I didn't know people, I think that's probably how I got to know them … it kind of confirmed … [Using clickers] kind of solidified something that was informal before.

Working cooperatively also allows students to get to know their peers in an on-task format. Tiffany termed this a 'structured talking environment'.

> … Because when you're just going lecture, lecture, sometimes you get bored. If you're tired, you doze off. If you're anxious, you talk to someone else… But with clickers, it's just like, 'Oh good, we can actually talk about chemistry.' I mean, you're able to talk, but it's structured, so you talk about what you're supposed to be talking about, rather than the party you went to during the weekend.

Tiffany's comment suggests the noisy, cooperative atmosphere fostered by clickers may help to alleviate the occasional boredom that accompanies learning in a large course, yet this is not the case for all. In another interview, Nadine said she found the level of noise unnerving at times.

> For me, when a clicker question goes up, there's like a rush to get the answer, and it's loud and noisy, and if I want to concentrate, I need quiet and I can't rush myself … this is personal, that is just how I am. I need my own pace and my own time to think about it.

Nadine suggested professors who use clickers establish something akin to a '10-second reading time' for CTs, so students can read the question in relative quiet before others begin talking about it. The noise that bothers some, however, may benefit others. Ann, mentioned earlier, felt clickers could be really beneficial for students with Attention Deficit/Hyperactivity Disorder. Because clicker questions provide a change of pace (a new activity) every 10–12 minutes, they should alleviate some of the difficulty associated with sitting still and keeping focused for students with ADD/ADHD.

Emotion in interactive classrooms

General chemistry is challenging, but many students said clicker-prompted peer interaction helps to minimize anxiety associated with learning new concepts in this course. Students said they sometimes laugh and joke around with their peers during CTs, and while using clickers can be fun, interaction benefits students because it helps them take a 'laid back attitude' toward using clickers. They are doing problems everyday in class, and in interviews, students emphasized the importance of not getting 'too stressed out' while answering CTs. Josey explains:

> If you want to hear some of the complaints I've heard about [clickers], I can tell you what was around. Some people feel far too pressured… I [heard] someone say, 'Oh, no, I told everybody the wrong thing!' and really, it was a devastation! I've advised people wrong, but it doesn't devastate me… there were some students that took it really [hard] and really, it's just a clicker. I think it's worthwhile to have many clicker tests and to be able to lose 50 points or something, because then it's not that big of a pressure and yet I'm working toward something worthwhile.

As with learning any new technology, the level of anxiety experienced is a function of how maturely the individual deals with the learning curve. Haley describes her experience:

> Yeah, it can be fun. Especially because now I am more relaxed about it. I think before I was too stressed about it and I took it too seriously… I think I just adapted to it. It was something I had never done before. I thought it was going to be one of those things where you couldn't talk and you had to do it on your own… but I like that [we] can collaborate.

Haley's comment reflects the experience of many who use clickers for the first time: unsure of what to expect, they feel some anxiety. Over time, they become more comfortable with clickers and cooperative interaction. Madison offers her experience:

> Most people, we'll just talk about the answer … it doesn't mean we chat for the rest of the class, but people are open to discussing how they got their answers. It's weird, because I'm not the most outgoing person, but it just doesn't seem to be anything significant to turn to whoever's next to me and ask, 'Did you get the same answer as me?' or 'Why do you think it's this?'

Whether working with the same peers or with different people each day, talking with others helps alleviate anxiety by allowing students to relate with others during the learning process. Survey responses confirm 70–80% feel 'somewhat' or 'very' comfortable working with others during CTs (see Table 3).

Table 3 also indicates 5–15% feel 'somewhat' or 'very' uncomfortable working with others during CT discussions. Why might students choose to work alone? Interview data suggest three reasons.

Why students work alone

First, students experience anxiety when they do not come to class prepared, having done the assigned reading. Over two semesters, across four sections of general chemistry ($N = 987$), 30–45% of students admit (anonymously, using the SRS) to 'not very often/never' doing the assigned reading before class. When students are unfamiliar with the concepts being applied in CTs, they have good reason to avoid talking with others, because they risk being exposed for lack of preparation. Liz's statement reflects this:

> Um, I think if I'm not prepared there's definitely a little anxiety that comes with it, like, Oh, gosh, these people are going to be asking me what I think and I don't even know how to do it, I don't even know what this is over…

Table 3. Response percentages.

Q: When clickers are used, how comfortable do you feel when exchanging ideas with another student/s?

	Fall 2004			Spring 2005	Fall 2005		
	Section				Section		
	100	200	300		100	200	300
	$N = 234$	$N = 145$	$N = 275$	$N = 262$	$N = 150$	$N = 116$	$N = 228$
Very comfortable	41	48	44	46	47	47	46
Somewhat	29	32	30	29	24	41	34
Neutral	18	12	17	16	13	7	12
Somewhat/very	12	8	9	10	16	5	8

During her interview, Liz admitted to not often doing her reading before class … on the days she is not prepared, she said she is more likely to work alone on CTs.

Next, while observation notes suggest most do work with peers, a minority prefers to do CTs on their own. These students said they prefer to wait for CT explanations from the professor (which they know will be correct), rather than listening to potentially incorrect reasoning from a peer. For some, it is 'better to work alone than to lead someone astray'. Liz explains:

> It's frustrating because if you think you understand it correctly and you don't, then you're leading other people to understand it incorrectly, and their answers get affected. It's reassuring that you still get a point regardless of what you choose, but … it's a little bit nerve-racking to feel like you may make someone lose their points [if] you encourage them to choose a different answer than it really is.

Faced with the possibility one might better remember the incorrect reasoning of a peer over the correct explanation offered by the professor, some choose to 'sit out' peer discussions.

Lastly, because CHEM 1111 is a large course, students can work alone if they want to. Interviewees emphasized the professor can (and does) encourage students to work together, but in the end, it is up to the individual 'to take the initiative' to turn to others. Josey explains:

> I think anyone who is looking for a cooperative environment could have found one, but they had to [try]. If they're sitting in the back and not participating, then the clicker [doesn't] do much good … and it's a whole different thing if you're talking than if you pull away… You explain [the concept], and you have it down in a different way than if you just heard it [in lecture].

When I asked Tina if she works with others, she replied:

> Generally, I'll just come up with my answer and look around and see what other people are pushing in. I usually sit on the end and if someone sits next to me then they do, and if they don't, they don't. Probably, two-thirds of the time I just do it on my own … I figure either way [the professor] is going to go over the problem.

One must take care not to assume that students who work alone are 'slackers', however, because in CHEM 1111, working alone is permitted. Over many months of observation, I never once saw a professor chastise, stare at, or in any other way sanction a student for working alone.

Conclusions

When using any new teaching technology, faculty and students will be skeptical at first. Clickers challenge student expectations of their role as passive recipients of information (Duncan 2005), and some dislike that clickers establish accountability for coming to class prepared. Yet, for students in general chemistry, clickers create an active learning environment that affords greater opportunity to practice new concepts. When asked whether clickers are beneficial to learning, 95% of students in CHEM 1111 agreed CTs are at least minimally useful. 40% felt clickers are 'quite' or 'extremely' useful to learning.

Trees and Jackson (2007, 27) argue:

> The success of clickers depends less on the instructor and more on student[s] because clickers require a change not simply in the mode of communication between instructors and students

> … but in the very culture of the classroom environment. The success of clickers is in many ways dependent on social, not technological, factors.

The data presented here support their claim. Clickers enable efficient problem-based learning in large courses, in an anonymous manner that is less anxiety provoking than other methods (e.g. holding up a response card that peers can see). The explaining and debating that go on during clicker-prompted peer discussions also make the learning *community* more visible to students: they see in histograms how others are doing, and this 'narrows the distance' between them (e.g. 'I am not the only one confused').

This project explores one example of a 'locally constituted' material structural change (Naples 2003) in the university environment. Contemporary citizens live in increasingly service-oriented economies. Whether educators like it or not, engaging students in the learning process is coming to be viewed as a component of the service teachers provide. Gathering information from students about how clickers affect the learning process is crucial; future research should address in greater detail how clickers affect students emotionally as they struggle to learn new concepts. A gendered analysis, comparing clicker use in diverse disciplines, would also be helpful. This research adds to scholarly dialogue regarding the ways clickers can be used to alleviate passivity in large courses. Yet, will clickers become nothing more than a 'pay attention' device? Will widespread use of clickers in higher education signal a transition from academic teaching to 'Edutainment?' Because clickers help students focus upon presented course material, as opposed to distracting them from it, increasing use of SRSs does not necessarily signal a negative transition in higher education. SRSs help students to develop conceptual knowledge, work with discipline specific terminology, practice critical thinking, and cultivate peer relationships beneficial to the learning process.

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References

Anderson, C.W. 1987. Strategic teaching in science. In *Strategic teaching and learning: Cognitive instruction in the content areas,* ed. B.F. Jones, 73–91. Alexandria, VA: Association for Supervision and Curriculum Development.

Boud, D. 1981. *Developing autonomy in student learning.* London: Kogan Page.

Brooke, C.P. 1999. Feelings from the back row: Negotiating sensitive issues in large classes. *New Directions for Teaching and Learning* 77: 23–33.

Coffey, A., and P. Atkinson. 1996. *Making sense of qualitative data.* Newbury Park, CA: Sage.

Cooper, J.L., and P. Robinson. 2000. The argument for making large classes seem small. In *New directions for teaching and learning: Energizing the large classroom,* ed. J.L. Cooper and P. Robinson, 5–16. San Francisco, CA: Jossey-Bass.

Duncan, D. 2005. *Clickers in the classroom: How to enhance science teaching using classroom response systems.* San Francisco, CA: Pearson Education.

Garside, C. 1996. Look who's talking: A comparison of lecture and group discussion teaching strategies in developing critical thinking skills. *Communication Education* 45: 212–27.

Gleason, M. 1986. Better communication in large courses. *College Teaching* 34: 20–4.

Mazur, E. 1997. *Peer instruction: A user's manual.* Upper Saddle River, NJ: Prentice Hall.

McKeachie, W.J. 2002. *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers.* Boston, MA: Houghton Mifflin.

Naples, N.A. 2003. *Feminism and method: Ethnography, discourse analysis, and activist research.* New York: Routledge.

Penuel, W.R., L. Abrahamson, and J. Roschelle. 2007. A sociocultural interpretation of the effects of audience response systems in higher education. In *Audience response systems in higher education: Applications and cases,* ed. D.A. Banks, 187–208. Hershey, PA: Information Science.

Rice, R.E., and U. Bunz. 2006. Evaluating a wireless course feedback system: The role of demographics, expertise, fluency, competency, and usage. *Studies in Media & Information Literacy Education* 6: 1–10.

Smith, K.A. 2000. Going deeper: Formal small-group learning in large classes. *New Directions for Teaching and Learning* 81: 25–46.

Stowell, J.R., and J.M. Nelson. 2007. Benefits of electronic audience response systems on student participation, learning, and emotion. *Teaching of Psychology* 34: 253–58.

Trees, A., and M. Jackson. 2007. The learning environment in clicker classrooms: Student processes of learning and involvement in large university-level courses using student response systems. *Learning, Media and Technology* 32, 21–40.