



Use of classroom “clickers” to promote acquisition of advanced reasoning skills

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KEYWORDS

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Assessment;
Reasoning

Summary Use of classroom response systems (a.k.a. “clickers” or “audience polling systems”) are growing in popularity among faculty in colleges and universities. When used by faculty in a strategic instructional design, clickers can raise the level of participation and the effectiveness of interaction, promote engagement of students in active learning, foster communication to clarify misunderstanding and incorrect thinking, and provide a method to instructionally embed assessment as a learning activity rather than reliance on the traditional approach of summative assessment for assigning grades. This article describes the use of clicker technology in a baccalaureate nursing program to promote acquisition and application of advanced reasoning skills. Methods are suggested for embedding formative assessment and the tactical use of questioning as feedback and a powerful learning tool. Operational aspects of *clickers* technology are summarized and students’ perceptions and satisfaction with use of this teaching and learning technology are described.

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Introduction

Instructors have long struggled with devising methods to capture and maintain students’ attention in the classroom. An even greater challenge is that of designing effective presentation of complex content in a manner that limits intimidation, generates student interest, and provides opportunities for active student engagement in learning. The use of classroom response systems (a.k.a. “clickers” or “audience polling systems”) is growing in popularity among faculty in colleges and universities.

These response systems offer enhanced opportunities for interaction during the learning process and provide both students and faculty immediate, real-time feedback reflecting students’ understanding of presented material. When used by faculty in a strategic instructional design, clickers can raise the level of participation and the effectiveness of interaction, promote engagement of students in active learning, foster communication to clarify misunderstanding and incorrect thinking, and provide a method to instructionally embed assessment as a learning activity rather than reliance on the traditional approach of summative assessment for assigning grades. Beyond these benefits,

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clicker technology can support innovative instructional designs and the delivery of dynamic learning events in the classroom that result in high-level synthesis and application of complex concepts, thereby promoting advanced reasoning.

Good thinking in nursing practice

Critical thinking is a contemporary label for what many educators have long described as higher-order cognitive processes. The processes involved in thinking critically are widely agreed to include interpreting, synthesizing and internalizing concepts and principles; applying facts, concepts, and principles to demonstrate effective decision-making and problem-solving; making inferences based on evidence and experience resulting in accurate predictions; and evaluating the effectiveness of outcomes based on these thinking processes. The goal of thinking critically is to achieve a "coherence of understanding" (Forneris, 2004).

Reasoning is about using intellectual power to draw conclusions, form judgments, and make inferences based on evidence, education, and experience. Reasoning involves the self-awareness of both the content and process of thought (metacognition). The practical significance of acquiring skill in advanced reasoning is to move to the level of predictive clinical reasoning which enables one to anticipate both ideal and likely outcomes given a set of data. Predictive reasoning, guided by expertise in pattern recognition and description of defining features, enables one to confirm that data are associated in order to make accurate inferences.

Competence in nursing practice represents the dynamic integration of knowledge, technical and thinking skills, and experience applied to optimize patient outcomes. Effective nurses must develop, apply, and maintain capacity, confidence, and capability (Stephenson and Yorke, 1998). Capacity is developing potential to acquire, retain, and apply new knowledge and skills that enable performance. It is about the acquisition of fundamental skills that serve as a foundation to build range in abilities and performance. Capability is observable behavior that is purposive, sensible, and effective considering the variables and context. Capable practitioners use knowledge and reasoning to function equally well in both familiar and highly-focused contexts, and in unfamiliar environments with dynamic, complex variables. Confidence is self-awareness of the power or impact of one's knowledge and skills and how these relate to a given circumstance. Confidence enables capa-

bility. Capability is observed when people are confident in their ability to take effective and appropriate action, explain their thinking and rationale for actions, demonstrate interpersonal skills to work effectively with others, and continue to learn from their experiences (Stephenson and Yorke, 1998). These abilities represent the essence of good thinking in nursing practice.

Instructional imperatives for the interactive classroom

Nursing faculties are challenged to provide learning experiences for students that are as authentic as possible to represent the complex and dynamic nature of contemporary patient care settings. The lecture format is economical, efficient, and commonly used to impart didactic information and explanations to large groups, but this format limits options for instruction. Small-group sessions are more effective for building advanced reasoning skills and clinical problem management expertise because they enable manageable communication between faculty and students. Fewer students in the classroom creates more opportunities for interaction and in-depth feedback using iterative questioning, coaching, and collaboration. Establishing and maintaining an inquiry-based, participative classroom environment is challenging, and more so when class sizes must remain large. Using interactive classroom response systems and high-level questions that are strategically placed throughout instruction can enhance participation and feedback, even in very large-size classes.

Participation and feedback

Undergraduate students in classrooms are often not actively engaged with either the process or content of the learning experience (King, 1993; McKeachie, 1994). Many variables impact interaction and participation in classrooms, including the course instructional design, the instructor's presentation skills, standards and expectations for student participation in discussions, individual learning styles that avoid involvement, communication and feedback mechanisms, students' confidence in their own interpersonal skills, and student preparation for class. When students do not prepare assigned readings or homework they arrive in the classroom unprepared to actively participate in the learning process, which often manifests as disengagement and inattention (Buck, 1997), and negatively impacts academic

achievement (Nystrand and Gamoran, 1989). Results of some studies suggest that when instructors do not regularly question students in class about assigned reading, students habitually delay reading until just prior to exams (McDougall and Cordeiro, 1992; Tuckman, 1994). When students are not prepared to participate in class sessions, they passively receive information and then attempt to memorize it for the upcoming examination (Buck, 1997).

Large class sizes wherein the instructor is physically far away from student seating and content is delivered by didactic one-way lectures are perceived by students as impersonal and intimidating. Students fear being identified as uninformed, unprepared, or reluctant to express an unpopular opinion. Neer (1990) described this avoidance of verbal participation in the classroom as "classroom communication apprehension". Neer asserts that it limits academic achievement, but adds that faculty behaviors and instructional methods can mediate this apprehension about communication. In a study of the effects of random oral questioning in college classrooms, Buck (1997) found that students demonstrated reduced levels of classroom communication apprehension and were more prepared for class when the instructor used questioning during instruction.

Providing feedback to students during learning engages them in active learning and positively impacts achievement. Hattie (1992) reviewed almost 8,000 studies and reported that the most powerful effect on enhancing student achievement is contributed by instructor feedback to students. Formative feedback during the learning process helps students to correct misunderstandings, gain clarity, to identify gaps in knowledge, and flaws in logic (Beatty, 2004). Feedback from students to the instructor allows on-the-spot adjustments to instruction, such as trying a different explanation, providing amplification with discussion, or using additional learning exhibits such as graphics, pictures, sounds, or video clips.

A review of the literature on feedback (Marzano et al., 2001), suggests the following strategies are critical: (a) feedback should be specific to the targeted knowledge or skill (criterion-referenced feedback is more powerful than norm-reference feedback), (b) feedback must be timely, immediately following assessment, (c) feedback should be corrective in that it clearly provides students an explanation of what they are doing and understanding that is correct, and what is incorrect, and (d) instructors should design opportunities for students to provide their own feedback through monitoring their progress (e.g. performance rub-

rics and scoring guidelines for assignments and exams).

Questioning as an instructional strategy

Tactical use of focused questioning is a powerful method to provide feedback to students. The consistent use of questioning as an instructional strategy during class lectures and discussions has been shown to promote preparation for class, enhance active participation, and results in higher achievement (Buck, 1997; Dean, 1986; Gall, 1984; Redfield and Rousseau, 1981). In a widely cited meta-analysis of research on the instructional use of questioning, Redfield and Rousseau (1981) report that use of higher-level questions during instruction demonstrates positive gains on student achievement for both factual recall and application of thinking skills. In a review drawn from 37 research documents, Cotton (2000) reports there is consensus that instruction that employs questioning during class sessions is more effective in increasing achievement than instruction without questioning students, and that oral questions posed during class sessions are more effective for learning gains than written questions.

Using questioning, instructors can shift the focus of classroom interaction from recall to reasoning. An interesting phenomenon occurs when instructors use a clicker system to manage the questioning technique. Because students become focused on the task of responding, they concurrently engage in the process of reasoning, make a commitment and externalize their answers through public display, and become emotionally invested in the learning process. This investment heightens attention and focus in the classroom (Beatty, 2004). In a summary review of 26 studies exploring outcomes of using clickers in a variety of settings, Roschelle et al. (2004) report the common findings: greater student engagement and participation in learning; increased understanding of subject content matter; higher levels of student enjoyment of class sessions; improved group interaction; a consistent mechanism is established for students to gauge their understanding of material being taught; and instructors report an increased awareness of those students having difficulties.

Clickers technology

Classroom response systems (clickers) are handheld, pocket-size remote control-like devices that



Figure 1 Radio frequency receiver and response pad.

use infra-red or radio-frequency signals to transmit and record audience responses to questions. Vendors for these products are easily located by Internet search. The response system used in this study is the Classroom Response System™ developed and marketed by eInstruction, Inc. (<http://www.eInstruction.com>). The system is based on a computer software program that processes radio frequency input from a small handheld multi-button “response pad” (Fig. 1) that transmits a signal to a receiver unit connected to a computer in the classroom. Students register their clickers by accessing an online website provided by the vendor. Once students register their own clicker and enroll in a course, a unique signal is identified by the classroom receiver and tracks responses by individual students (optionally students may use a generic clicker supplied to them for each class session that remains anonymous).

During class sessions the software program records student entries and response data are instantly aggregated and displayed (Fig. 2). Questions can be created within the software itself (templates for a variety of formats are included) or because the program is designed to function as an add-in to PowerPoint and runs “in the background” (a toolbar for the application appears at the bottom of the screen), existing PowerPoint lessons can be used. Graphics, pictures, and multime-

dia can be embedded in PowerPoint slides providing rich-context learning objects for student response using the clickers.

a Fact FLASH !

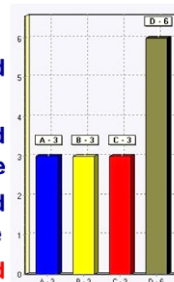
The immediate concern when stridor is demonstrated is:

- A. Impaired cardiac output
- B. Impaired gas exchange
- C. Impaired immune response
- D. Impaired airway

b Fact FLASH !

The immediate concern when stridor is demonstrated is:

- A. Impaired output
- B. Impaired exchange
- C. Impaired response
- D. Impaired



What is your FIRST best action upon discovery of this sign ?

Figure 2 On-screen question with response display.

Features of the software are plentiful and include such options as a grade book (which students can view online), attendance and participation monitoring, and recording answers to quizzes and exams (students enter answers via the clicker rather than on paper or scan forms) with results available immediately upon completion. Following each class session, instructors can view and export various reports and databases, including analysis of response frequencies by question, answer, distracters, and even by individual student if desired.

Elements of design for engaging learning events

Chickering and Gamson (1987) posit seven "principles for good practice in undergraduate education" (Fig. 3). Many of these "good practices" are enhanced by use of clickers. Using clickers to pose questions in the classroom connects students with the instructor's perspective of critical content and priority principles, and encourages dialogue about thinking and reasoning. The resulting dialogue not only communicates the instructor's expectations for performance and participation, but capitalizes on the positive effects of collaborative, cooperative learning. By the tactical placement and frequency of questions, instructors can focus time on task and impart clear direction about what is most important content. When clickers are used with text and multimedia learning prompts (pictures, graphics, sounds, video clips, and animation), students' diverse learning styles are respected and accommodated-kinesthetic learners love clickers!

In advance of each classroom clicker session, both cognitive and application goals should be considered. Learning goals may include: (a) expressing

1. Encourage contact between students and faculty
2. Develop reciprocity and cooperation among students
3. Encourage active learning
4. Give prompt feedback
5. Emphasize time on task
6. Communicate high expectations
7. Respect diverse talents and ways of learning

Chickering and Gamson (1987)

Figure 3 Seven principles for good practice in undergraduate education.

pre-requisite knowledge, beliefs, and perceptions; (b) clarifying areas of confusion or misunderstanding; (c) differentiating two related concepts (compare and contrast); (d) identifying similarities, associations, and connections among ideas, concepts, and principles; (e) elaborating, extending, and amplifying a concept; or (f) exploring implications of an idea in new context (Beatty, 2004).

Consider beginning each class with a series of questions focused on important content from pre-class reading and assignments. Unannounced quizzes work well for this purpose and clicker systems can capture and record these responses as well. Posing questions right up front in the session creates a "mind-set" for the lecture or discussion, and also provides feedback to students about the effectiveness of their preparation. Asking questions does not necessarily lead to answering them. Posing one question may lead to more questions. This is actually an ideal opportunity for the instructor to point out associations and identify similarities, differences, and related topics. Inquiry-based learning is not about correct answers and not limited to problem-solving. It is about problem-posing as well. Anticipate likely incorrect responses and prepare "talking points" for discussion as this facilitates "thinking on your feet" and makes more visible to students how an expert uses heuristics, reasoning, and refined problem-solving skills to gain command of a clinical situation. The concept of "witnessed dialogue" is a powerful teaching strategy (DeBourgh, 2002). When the expert "thinks aloud" in the presence of a novice about what, why, and how they are thinking, that novice becomes a witness to expert thinking, reasoning, and actions (responses). The developing practitioner sees how the expert uses factual knowledge and experience to effectively recognize and respond to complex situations.

Through careful design of the questions, instructors can use provocative or even purposefully vague questions to stimulate debate and discussion. The technique of "deliberate engineering" of questions (Beatty, 2004) can advance pedagogic goals. Ambiguity in question design helps sensitize students to the variability, subtle nuances, and lack of certainty that are expected in clinical practice settings. During instruction, the goal is not to teach the right answers, but to demonstrate thinking strategies, as developing this capability is far more powerful for future clinical practice than memorizing correct answers for a test. Wrong answers during class sessions are not failure—they guide the path to correct understanding if concurrent discussion is conducted. Ask students follow-up questions in the context of the original question


but change the focus to add new variables, such as “What if the patient developed this sign or symptom?”, or “Why is this a priority at this time?”, or even “What would make the other answers correct?” Using questions to frame discussion and present new content promotes flexible knowledge and creates a more interesting, lively, and interactive classroom environment than presentation of content by lecture alone.

Pacing and placement of questions are critical considerations. Teachers commonly underestimate how often they ask questions in classroom settings. Posing questions too frequently can result in cognitive overload. Learners use a lot of thinking energy to focus on the context of each question. Using “sets” of related questions helps to reduce cognitive load because the circumstances are familiar. Reusing a situation and applying sequential questions allows students to concentrate on the princi-

ple or concept rather than spending mental energy constructing a mind set and sorting out which information is related. Questions used about every 20 min will maintain engagement, attention, and refocus important aspects. Posing multiple questions (repetition) on a given learning point while the context of the question and concept are current, improves learning results over a single question (Boyd, 1973).

The progression of question slides begins with the question and response options (Fig. 2), the clickers are activated and when the time limit is reached, the response histogram is revealed as an overlay, followed by the correct answer, and then a follow-up reasoning question. In this example, the histogram indicates that most students selected the correct answer “D”, but not all of them. In the example about priorities for asthma interventions (Fig. 5), note that student responses are distributed over all options, alerting the instructor that the students were guessing on this question and additional instruction is needed. Asking a volunteer who selected the correct response to explain why that option was selected creates a peer-to-peer teaching moment and benefits both those students answering incorrectly and the stu-

a



Data for Decisions . . .
Clinical Reasoning Progressive Case Study: Ella C.

Ella C. is brought to the emergency department (ED) after being involved in a minor motor vehicle crash (MVC). She was alert and oriented at the scene, according to the person who was involved in the crash with Ella, but as the police officer was completing the crash report, Ella became disoriented, her speech became slurred, and she was unable to walk due to “weakness in her legs.” An ambulance was called and transported Ella to the ED.

Initial Appraisal
You are on duty in the ED when she arrives. Ella received oxygen in route through a nonrebreather mask. She has an IV in place with LR infusing at TKO. Her vital signs are: BP 164/100, HR 76 (irregular), temperature 98° F (36.7° C), and her SpO₂ is 92%. The police officer is asking for a blood alcohol level to be drawn due to her behavior at the scene.

b

Fact FLASH !

Ella’s heart rate is 76 and irregular. What is a potential concern related to these data that could be causing her problem?

- A. Ella’s heart rate is not sufficient to generate effective C.O.
- B. Ella’s heart rate should be much faster to match her high BP level
- C. Ella may be taking beta blockers that are preventing an increase in HR to compensate for internal bleeding
- D. Ella’s irregular heart rate may be generating emboli

c

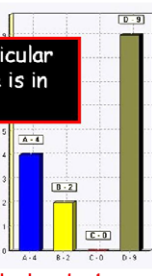
Fact FLASH !

Ella rate is irregular. What is a potential concern related to these data that could be causing her problem?

And why isn’t the ventricular rate much higher if she is in atrial fibrillation?

much faster to match her high BP lev

- C. Ella may be taking beta blockers that are preventing an increase in HR to compensate for internal bleeding
- D. Ella’s irregular heart rate may be generating emboli



Option	Count
A	4
B	2
C	0
D	9


Figure 4 Progressive case study with question and follow-up prompts.

a

Fact FLASH !

The **FIRST** priority action for a client experiencing asthma exacerbation is:

- A. Quickly auscultate breath sounds
- B. Position to reduce work of breathing
- C. Administer bronchodilators via O₂-driven nebulizer
- D. Determine history of last attack and Rx

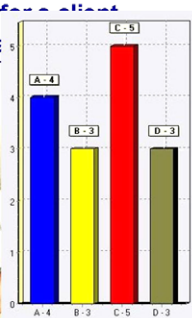


b

Fact FLASH !

The **FIRST** priority action for a client experiencing asthma exa

- A. Quickly auscultate breath sounds
- B. Position to reduce work of breathing
- C. Administer bronchodilators via O₂-driven nebulizer
- D. Determine history of last attack and Rx



Option	Count
A	4
B	3
C	5
D	3

Figure 5 On-screen question with response indicating guessing.

dent speaker who is practicing articulating rationale. Before "revealing" correct answers, consider facilitating a 50–50 decision process, wherein the instructor queries the students about which half of the response options should be eliminated from consideration and why. This technique helps students develop skill in discrimination and identifying relationships among data. Create additional practice in reasoning by asking students to turn to their nearest neighbor and convince each other of the ideal answer, the rationale for the correct answer, and why the other choices are not correct. After this brief peer-to-peer coaching session, re-launch the clicker software to update the class response to visually demonstrate how aggregate thinking has changed through the consultative process. This "peer-pair and share rationale" method is critical to minimize the potential for clicker "button pressing" to take the place of verbal articulation of response and rationale.

Using progressive clinical case studies with question prompts are another effective way to provide transitions, reduce cognitive overload, and build increasing complexity into simulated clinical scenarios (Fig. 4). Because clicker technology "runs in the background" with PowerPoint, on-screen case studies can be amplified by embedding pictures, graphics, and sound clips to represent clinical signs, symptoms, and manifestations. Video clips can also be inserted with or without sound to display dynamic representations of clinical conditions. Patient cases can be "progressed" throughout the class session and series of questions

inserted to highlight important aspects of patient care management. Playing video clips of interpersonal interactions depicting conflict or scenes related to ethical or moral issues that evoke strong emotional responses among students, with questions posed afterward is another powerful use of the anonymous clicker response system. Taking the class "temperature" on controversial topics without fear of judgment is an excellent discussion starter.

Student perceptions of clicker use

A convenience sample of students enrolled in a 15-week advanced nursing therapeutics course was surveyed for perceptions of clicker use in the classroom. Ninety-two students were enrolled in the course, with 65 completing an anonymous satisfaction survey during the 14th week of the semester (70.54% response rate). University Human Subjects Committee approval was granted by policy, as voluntary anonymous participation in the survey was part of the course evaluation process and isolated from assignment of grades. Data were collected using online survey methodology to inform the instructor of students' satisfaction with operational aspects of using the technology, and for their perceptions of the effectiveness of this tool in facilitating understanding complex concepts and development of advanced reasoning skills (response items are represented in Tables 1–3).

Table 1 Student satisfaction with operation of clickers

Please rate the following logistical activities with your clicker:	Really easy	Somewhat easy	Neither easy nor hard	Somewhat difficult	Very difficult	Mean	SD
Purchasing your clicker from the USF bookstore	73% (47)	16% (10)	9% (6)	0% (0)	2% (1)	4.52	0.91
Registering the clicker on the eInstruction Website	43% (28)	32% (21)	12% (8)	11% (7)	2% (1)	4.05	1.07
Turning on the clicker	58% (38)	22% (14)	8% (5)	11% (7)	2% (1)	4.25	1.09
Joining during the initial class session	52% (34)	28% (18)	6% (4)	12% (8)	2% (1)	4.17	1.10
Joining during subsequent class sessions	64% (41)	11% (7)	16% (10)	9% (6)	0% (0)	4.30	1.05
Sending my responses during classes	66% (43)	17% (11)	12% (8)	5% (3)	0% (0)	4.45	0.88
Determining if my clicker was working during class	38% (25)	32% (21)	9% (6)	11% (7)	9% (6)	3.80	1.31
Total respondents							65
Skipped this question							0

Total enrolled = 92; total responding = 65; response rate 70.65%. Likert-type scale: really easy = 5; very difficult = 1.

Table 2 Student ratings of clicker use for understanding

Please rate the instructional effectiveness of the clicker system	Very useful	Somewhat useful	Neither useful nor unhelpful	Somewhat unhelpful	Very unhelpful	Mean	SD
Testing my pre-requisite knowledge	52% (33)	33% (21)	11% (7)	2% (1)	2% (1)	4.33	0.86
Testing my comprehension of the textbook readings	48% (30)	29% (18)	16% (10)	6% (4)	2% (1)	4.14	1.01
Confirming my understanding of a concept being discussed in class	63% (40)	24% (15)	8% (5)	5% (3)	0% (0)	4.46	0.84
Confirming my understanding of a concept from the textbook readings	45% (28)	26% (16)	26% (16)	3% (2)	0% (0)	4.13	0.91
Correcting a misconception or misunderstanding from the textbook reading	48% (30)	22% (14)	29% (18)	2% (1)	0% (0)	4.16	0.90
Correcting a misconception or misunderstanding of a concept being discussed in class	59% (37)	19% (12)	19% (12)	3% (2)	0% (0)	4.33	0.90
Providing feedback about my decision-making about case studies	60% (38)	22% (14)	14% (9)	3% (2)	0% (0)	4.40	0.85
Total respondents							63
Skipped this question							2

Total enrolled = 92; total responding = 65; response rate 70.65%. Likert-type scale: very useful = 5; very unhelpful = 1.

On the average, students were highly satisfied with both operational aspects and instructional effectiveness of using the technology in the classroom, with 75.8% ($n = 47$) recommending continued use of clickers and 12.9% ($n = 8$) of respondents indicating "maybe". Table 1 displays students' satisfaction scores for operational aspects. The vendor (www.elinstruction.com) provides online instructions for students to create their personal profile (school affiliation, demographics, and contact data), register their newly purchased clickers (establish personal clicker identify), and to enroll in courses using clickers. Students quickly and easily learned to operate the clickers and except for the occasional battery failure, no other technical complications occurred during the semester using either the radio-frequency clicker technology or the database software.

Table 2 provides students' ratings of the usefulness of clickers as an instructional tool for validating their understanding of concepts, correcting misconceptions, and for providing feedback during learning activities. Strong positive ratings were reported for use of the clicker for testing pre-requisite knowledge and comprehension of preparatory textbook readings (85% and 77% very useful or somewhat useful, respectively), for confirming understanding of concepts from class discussion and textbook readings (87% and 71% very or some-

what useful, respectively), and for correcting misconceptions about content from readings and from class sessions (70% and 78% very or somewhat useful, respectively). When clickers were used to provide feedback to students about the accuracy of their thinking and decision-making in case studies, 72% ($n = 52$) of students found this immediate feedback as very or somewhat useful.

When students were asked to comment on how clickers supported their understanding (immediate feedback about concepts, focusing on the "big picture", and heuristics to apply knowledge), students again reported high ratings (Table 3). Of interest was the finding that 66% of students responding to the survey reported that use of clickers helped them to "do better" on quizzes and exams. Application-style questions requiring students to synthesize knowledge and to determine priorities of patient care management were used in class. The formats for practice questions and for those on quizzes and exams were consistent. Fifty-three percent of students ($n = 42$) perceived that use of clickers in classroom learning activities encouraged them to come to class "better prepared".

Samples of students' narrative comments are provided in Table 4. Overall, students perceived an *added value* in using clickers in the classroom. Comments indicate students became more aware

Table 3 Student ratings of clicker use for reasoning

Please rate your level of agreement with the following statements about clicker use in your class:	Strongly Agree	Somewhat Agree	Neither Agree nor Disagree	Somewhat Disagree	Strongly Disagree	Mean	SD
Using clickers gave me immediate feedback about my understanding of a concept	65% (40)	26% (16)	6% (4)	3% (2)	0% (0)	4.52	0.76
Using clickers encouraged me to focus on the "big picture" in class	48% (30)	27% (17)	18% (11)	5% (3)	2% (1)	4.16	0.99
Using clickers allowed me to understand "rule of thumb" and "general approach" strategies in class	57% (35)	30% (18)	10% (6)	2% (1)	2% (1)	4.39	0.86
Using clickers encouraged me to really understand the materials rather than just recognizing the correct answer	47% (29)	31% (19)	11% (7)	6% (4)	5% (3)	4.11	1.10
Using clickers helped me to apply the concept during class	58% (36)	26% (16)	6% (4)	8% (5)	2% (1)	4.31	1.02
Using clickers with case studies in class helped develop my clinical reasoning skills	52% (32)	31% (19)	10% (6)	6% (4)	2% (1)	4.24	0.99
Using clickers helped me to identify misunderstandings and misconceptions in my thinking while in class	53% (33)	29% (18)	11% (7)	5% (3)	2% (1)	4.27	0.96
I prefer the more traditional lecture approach rather than the clicker approach	26% (16)	13% (8)	18% (11)	23% (14)	20% (12)	3.10	1.49
I do more thinking during clicker sessions than in regular lecture sessions	40% (25)	24% (15)	21% (13)	10% (6)	5% (3)	3.92	1.15
Using clickers in class helped me do better on quizzes and exams	34% (21)	32% (20)	23% (14)	5% (3)	6% (4)	3.82	1.15
Using clickers encouraged me to come to class better prepared	34% (21)	19% (12)	29% (18)	8% (5)	10% (6)	3.60	1.30
Given two class sections that are the same in all other respects, I would prefer the section that uses clickers	48% (30)	19% (12)	19% (12)	6% (4)	6% (4)	3.97	1.24
Total respondents							62
Skipped this question							3

Total enrolled = 92; total responding = 65; response rate 70.65%. Likert-type scale: strongly agree = 5; strongly disagree = 1.

of their thinking strategies, were able to practice various approaches to complex problem solving, and that using clickers provided prompt, specific feedback during the teaching and learning process. Many students reveal that using clickers in the classroom reduces the intimidation factor related to participation in class, and the anonymity together with the opportunity to "answer freely" without a penalty for the wrong answer encourages them to participate more in class and to "understand the class topics better". Students offer that

class is more "fun" using clickers compared with the traditional lecture format, and that they are prompted to spend more time preparing for class knowing that "fact flash" clicker questions will be posed in the classroom.

Costs and challenges

Most vendors for classroom clicker products offer free-of-charge to instructors adopting the technol-

Table 4 Sample narrative comments of students using clickers**The most useful thing about using clickers this semester was:**

I was not embarrassed if I had the wrong answer. I could see immediately if I was going down the wrong path for understanding the main points

Being able to be active in my learning

I could choose the answer freely from what I thought without being penalized by choosing a wrong answer with a grade and using the clicker to select the answers helped me to participate more in class and understand the class topic(s) better

Anonymously answering the questions. . . .seeing what classmates were thinking. Seeing instant results from the question being asked.

The discussion before and after questions was extremely helpful in pointing out key elements as well as explaining the thinking process

Gave my answers anonymously which later helped me understand why my answer was correct or incorrect without being humiliated.

I had to focus in on the question and with four possible answers, I had to logically see the big picture when selecting an answer.

Also, I found this helpful in timing myself to process the question being answered.

Seeing the responses and thoughts of other students as we worked through material-good to see whether or not I was thinking the same way as others

Helped me focus on clinical reasoning skills and test taking. Case studies helped me in the clinical practice and to see the big picture.

Clickers were fun and did allow for class participation and discussion. They also, along with your other teaching techniques, such as the quizzes, homework assignments and the calling on students individually to answer questions, most assuredly encouraged me to come to class well prepared. This was crucial in such a class as this, that covers so much complex material.

The least useful/least fun aspect of using clickers this semester was:

Cost. There were times when the clicker did not work or ran out of battery?

The initial learning of how to turn the clicker on and join was the only problem I can think of

Paying so much for the clicker each semester and forgetting to bring the clicker to class

Worrying about getting the answer in time, the case study questions brought up more questions than did solve questions

I think it is way too expensive a machine to use in class. It is also something we'll never use again and we can't even sell it back.

The fact that other classes do not use the clicker right now seems hard to justify the price for one semester.

The questions were often extremely difficult and presented too quickly for my learning style. That is especially true for the questions you asked on material just presented.

It was really difficult to see if my clicker was working or not

Why or why not would you recommend continued use of clickers in this class?

The clickers show the classroom understanding of concepts. Everyone is able to participate instead of one person answering the questions.

Because they are useful and help people be more involved during class, and they help people think more critically

It is helpful to incorporate the students to focus and participate more in your class, There are people who do not like to ask during the class because they think that the other students will laugh at him/her because of making a stupid question?. It is also helpful because you are given an idea to the students how to prepare for your exams and what to focus on.

It assisted in my attention span in class. . . .and also jogged my memory in learning

Provided good immediate feedback and helped students participate that would not have normally participated.

It helps understanding. Plus it helps students read the questions and how to become a good test taker by only taking out what is needed from the question.

Students are encouraged to be prepared prior to class. Active participation motivates students to learn the concept rather than to memorize everything.

It makes class more fun. It makes class more interesting and helps us grasp difficult concepts.

It's too expensive. I think we could learn the material with or without it.

It keeps the student interested in the lecture. It is a form of stimulant and much better than having just a plain lecture

Total enrolled = 92; total responding = 65; response rate 70.65%.

ogy the program software (on CDROM), access to the online vendor-maintained database, as well as the clicker receiver and a "practice clicker". Costs to students for the clicker itself (a one-time purchase) and a semester registration fee vary among providers, however these costs are nominal compared with other required resources for courses, such as skills laboratory use fees, clinical equipment and uniforms, and textbooks. Cost for the radio-frequency (RF) model clicker itself averages about \$22.00 (US dollars). Although the RF clicker is slightly more costly than infra-red models, the later technology is becoming outdated and not recommended due to limitations in distance for reception of signal transmission and in the number of students accommodated (RF models accommodate as many as 1000 students on a single receiver unit). Student registration fees for an unlimited number of "clicker courses" each semester averages \$13.00–\$15.00 (US dollars) (www.elinstruction.com). Some vendors will "bundle" or package the clicker without charge to students when they purchase textbooks from affiliated publishers (www.turningtechnologies.com), however this single-source arrangement may limit faculty options for textbook adoptions. Students' reactions to cost are highly influenced by how effectively and frequently faculty integrate and use the clicker technology. If students perceive value, they see clickers as a tool for successful learning and feedback about their performance.

A most important consideration is standardization across the educational enterprise. Requiring students to purchase and learn operation of different clicker products generates unnecessary costs, complaints, and influences adoption and acceptance of this teaching and learning technology for both students and faculty. Other important considerations are the availability of cross-platform software (PC and MAC), and the availability of knowledgeable technical assistance to faculty for setting up the computer interface, operating the technology during class, and problem resolution.

Challenges for students in courses employing classroom clickers are minimal. Students learn to operate the clicker itself without difficulty as most contemporary college-age students were born in an era where use of computer and communications technologies have always been part of their lives. Because clicker use promotes higher levels of individual engagement and classroom participation, and because faculty have the ability to "track" this individual participation, expectations for preparing for class and participation during class are increased, and some students may resent this performance expectation.

Challenges for instructors include learning the technology, increased pre-class preparation time to develop questions that promote higher-order thinking, decisions about where to strategically place them in the instructional plan, and the time for analysis of response data. The task of learning to set up and operate the clicker system is achieved rather quickly. The rich data that are recorded during class sessions create opportunities for analysis at many levels: individual responses to specific questions, response trends for students working in teams, scores on clicker quizzes and exams, and question item-response statistics. Although time-consuming, analysis is facilitated by the well-designed software databases that enable one to select specific elements for user-defined data reports. The greatest challenge is the new role for faculty-to plan the curriculum and instruction around "deep comprehension" rather than "covering content" using a traditional lecture format. "The art of designing effective questions is deceptively non-trivial and can be time-consuming for an instructor new to [classroom communication systems]." (Beatty, 2004, p. 6) The investment of time and the willingness to refocus instructional goals and roles become well worth the effort once faculty and students experience a change in the classroom. The learning environment is modified from an imperative teacher-directed approach (lecture) to an interrogative model wherein frequent but highly selective higher-order questions are posed to stimulate interaction with the content and to increase awareness of metacognition (thinking about thinking). When used with a purposeful pedagogy, clickers motivate students to actively interact with the content in a less-threatening learning session that provides immediate performance feedback to students and faculty. Research suggests that use of this higher-order questioning technique can actually create additional synapses between nerve cells in the brain-called neural branching (Cardellichio and Field, 1997). Just as physical exercise builds muscle tissue, the frequent use of a variety of higher-order questions during instruction enables new connections, strengthens brain function, and enhances thinking.

Conclusion

Classroom response systems provide faculty with options to enhance interaction during the learning process and provide both students and faculty immediate, real-time feedback reflecting students' understanding of course content. Integrated with a

purposeful instructional design, use of clickers increases the level of student participation, promotes engagement of students in active learning, supports innovative instruction that results in high-level application and synthesis of complex concepts, and supports skill development for advanced reasoning. Students report high levels of satisfaction with clicker use and appreciate the individual feedback instructors can provide during the learning process using this technology.

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