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Translating Neuroscience: When is the use of Clickers Effective for Student Learning?

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Abstract-
Objective: Teaching large content heavy classes presents a challenge to faculty in any discipline. In nursing education, particularly pharmacotherapeutics, student learning is critical to patient safety. Therefore, effective teaching practices are a must. But, there is a lack of education literature that connects the neuroscience of why a specific method such as using the technology of personal response systems (PRS) contributes to student learning. This study discusses the use of action research to evaluate the effectiveness of the use of personal response systems (PRS) or "clickers" in an undergraduate nursing pharmacology course, using knowledge of neuroscience to interpret the results.
Methods: Action research was used to apply Neuro-semantic Language Learning Theory to the use of clickers in a nursing pharmatherapeutics course. Action research design allowed for the continuity of assessment and reflection by the faculty.
Results: Outcomes were measures quantitatively using ATI (Assessment Technologies Institute) test scores pre- and post-intervention. ATI scores improved with the use of clickers. Qualitative student comments indicated satisfaction with the use of clickers to improve learning. Neuroscience and learning theory are used to explain the results of the study.
Conclusion: Clickers by themselves do not necessarily create better learning, but thoughtful, purposeful integration of the technology, using techniques based on neuroscience elicit higher order thinking and provides deeper conceptual learning.

Keywords-clickers; Neuro-semantic Language Learning Theory; nursing pharmacology; nursing education

Teaching large classes of complex content presents a challenge to faculty in any discipline. In nursing education, particularly pharmacotherapeutics, teaching presents not only the usual problems but student learning is critical to patient safety. In this study, the authors used personal response systems (PRS) or "clickers" as a deliberate strategy to create better learning opportunities for students. This study shows how the knowledge from the neuroscience about learning can inform the use of clickers in a nursing pharmacotherapeutics course.

I. STATEMENT OF THE PROBLEM

Nursing pharmacotherapeutics is historically a difficult course for students, with many drug classes and individual medications to learn, all critical to patient safety. With a looming nursing shortage in the United States, class sizes have grown due to the need to increase enrollment combined with a shortage of nursing faculty. Faced with the challenge of teaching a large undergraduate nursing pharmacotherapeutics class of 60 or more students per semester, and students who historically scored low on a nationally- normed pharmacotherapeutics content exam, the researchers sought methods to improve student learning. Knowledge about learning theory along with clickers were implemented in the pharmacotherapeutics course to determine if student learning could be enhanced.

II. REVIEW OF LITERATURE

Clickers, also known as personal response systems (PRS) are a method of teaching. However, methods of teaching do not inform how students learn. The literature shows that clickers result in inconsistent learning. The analysis of the literature suggests that it is how and when clickers are used in the classroom that influences the learning outcomes.

A. Clicker Technology

Clickers are handheld electronic devices that allow students to anonymously select responses to questions that are posed to the whole class, typically on a power point slide. Most of the clicker devices are limited to student responses of true/false or multiple choice type answers. Students' responses are sensed by a receiver attached to a faculty computer in the classroom in order for the students to "click" their answers on the keypad. A software program in the faculty's computer electronically collects the answers of the whole class and quickly displays the student responses in a histogram on the screen so that the whole class can see the results. Some of these software programs offer the faculty the ability to track student responses overtime or conduct graded quizzes or

exams. The assumption is that if students are physically involved, they will learn.

Clickers have been used in classrooms since the 1950s, but have significantly gained attention and increased use in the last ten years. Mareno, Bremner and Emerson [29] conducted an extensive review of the clicker technology from 1956-2010. Their literature review identified the following advantages of using clickers: facilitates peer instruction, improves student engagement, improves student motivation, facilitates assessment of student preparation and understanding, and improves student perception of positive learning environment.

The disadvantages to clicker technology all stem around the cost and difficulty of implementing the technology [29]. In addition, they noted there is a significant lack of literature on how the use of clickers has specifically improved or changed teaching practices.

Clickers have been found to increase student engagement in course content, especially in traditionally large classrooms where student-teacher and student-student interactions are limited [12]. According to Sullivan [44], the use of clickers increases student engagement and is a way to change a passive-absorptive learning method into a participatory active learning strategy. The increase in student engagement with the use of clickers may be attributed to the anonymity of the answers which might decrease fear and anxiety in the students about having a wrong answer ([10]; [29]; [46]). Students self report using clickers increases their engagement; and, students perceive that clicker use increases their understanding of material ([11]; [12]; [13]; [20]; [29]; [31]; [41]; [43]; [45]). However, it is important to note that just because students like using this technology it does not necessarily mean that students learn more. Furthermore, student engagement is not necessarily better learning.

After reviewing much of the recent literature many questions remain unanswered relative to how to use clickers to improve student learning. Different study designs were used in the clicker literature, therefore it is not possible to use a meta-analysis approach to determine if the use of clickers actually increases student learning [11]. Some studies used clickers in assessment and evaluation ([12]; [18]; [28]; [31]) while others used clickers as learning-teaching strategies ([7]; [34]; [43]). Some studies attempted to compare the use of clickers with different active learning strategies ([18]; [25]; [31]). Some included the use of peer interaction as part of the methodology where students were encouraged to discuss their possible answers and then submit their answers ([8]; [18]; [28]; [42]). Class size was found to vary among the studies in this review of literature.

Most of the studies did not describe the type of questions that were used with the clicker technology or what type of learning the studies expected from the students. Even though the use of clickers has been found to increase interaction among students and between the students and the faculty, when using clickers solely as a teaching strategy without merging it with learning theory, it cannot be determined if learning is increased when using clickers ([11]; [20]; [31]; [42]).

The use of clickers may or may not be the actual learning tool in these studies. For example, the way the faculty ask questions and the type of questions with or without discussion may be factors in student learning. Sullivan [44] states that to determine if the use of clickers is an effective teaching tool, then the development of the questions is a critical component. Beatty [5] notes that questions can be developed that 1) express prior knowledge, 2) clarify confusion, 3) differentiate concepts through compare and contrast, 4) identify similarities and connection of ideas, 5) extend a concept, and 6) explore ideas in a new context. Beatty, Gerace, Leonard & Dufresne [6] suggest that clicker questions must go beyond basic recall and factual questions. Questions should be designed based on a well-thought out pedagogical purpose that includes a content goal, a process goal targeting a specific cognitive skill, and a meta-cognitive goal measuring student understanding.

Mareno, Bremner & Emerson [29] indicate that the best teaching practices would be to design clicker questions for nursing students based on the NCLEX or the national nursing board format, which is in direct conflict with the focus of Beatty et al. [6] who say that "good" clicker questions are different than written test questions or those provided by test banks from textbook publishers. DeBourgh [12] advises that clicker questions can do more than focus on immediate recall when they are built around concepts that faculty know to be difficult for students. Furthermore, on-the-spot adjustments could be made to 1) offer different explanations, 2) amplify through directed discussion or specific talking points 3) create debate through questions asking who, what, when, where and why, and 4) explore more through graphics, videos and slides. In addition, DeBourgh points out clickers can be used with well-thought out progressive case studies. However, none of these teaching strategies that accompany clicker technology have been studied or shown to improve student learning.

Furthermore, clickers may or may not be used with other active learning strategies. Mazur ([32]; [33]) is credited with designing an active learning strategy called peer interaction (PI) that has shown to increase student engagement in large sized classrooms. Mazur [33] reports on the use of clickers in the classroom incorporate PI along with the clickers as an effective teaching strategy, however it is not known if students actually learn more when PI is used with clicker technology. Mazur [33] reported that the overall number of students who clicked the "correct answer" increased after peer interaction.

What is of most importance in this review of literature on the use of clickers is that there are many questions that remain unanswered relative to how using this technology actually enhances student learning. The purpose of this study is to use clickers to increase student learning, therefore designing and using clickers based on knowledge of learning theory is a crucial component of this study.

B. Learning Theory

Learning is typically defined as the ability of cells to chemically process, transmit, and recall sensory reception into cellular patterns ([3]; [39]). More recently, neuroscientists

have begun to realize that the human brain uses patterns to form circuits of cognition [38] that are concepts which "layer" into neuro-semantic cerebral networks of language. Language networking utilizes the greatest number of brain connections [19] and therefore is most likely to result in a semantic or long term memory [39]. Arwood defines this learning process as the Neuro-Semantic Language Learning Theory (NLLT) [2],

The network of layers comes in four conceptual stages [37]: At the sensori-motor level, there is sensory recognition of input but little conceptual thinking. The next level or preoperational thinking is about the learner in relationship to what the learner knows. such as "I know how to take blood pressure." "I raised the head of the bed because the manual told me to." "This is my patient." . At this level of learning, the learner is able to imitate or copy what others model. In a pharmacology class, students would be able to answer questions about repeated instructor given material. Or they would be able to give back basic knowledge learned in previous courses. At the concrete or third level of thinking, the student is able to think about the rules in pharmacology. Finally, at the formal level, the student is able to use language to explain, in the student's own words, what the symbols of pharmacology mean. Figure 1 shows the relationship between learning and development. The content of the class is arranged in a stair step developmental set of lessons; but, the students' conceptual learning occurs across time in a scaffold or cyclic process between the students' answers and the professor's assignment of meaning to their answers.

The literature suggests that higher order thinking or conceptual learning requires not only input but feedback, in order to layer meaning or neuro-semantic information into concrete and formal concepts. Furthermore, language has to be used at these higher levels (concrete and formal) of thinking to create the depth or layers of conceptual learning [2]. A learner's use of language names the concepts which results in the meaning being recorded in semantic memory. Semantic memory allows for long term access for better retention [3].

In summary, several authors suggest that the use of clickers can promote learning when it is coupled with appropriate pedagogies, however none of the studies or authors in the literature review explain in detail what the "appropriate pedagogies" should be ([5]; [6]; [17]). Mareno, Bremner & Emerson [29] note that there is a paucity of literature addressing how personal response system technology helps change teaching practices or improve student learning.

III. METHODS

The purpose of this study is to determine if the knowledge from neuroscience and learning theory informs the use of clickers in a nursing pharmacotherapeutics course to help students improve conceptual learning.

A. Participants and Setting

The use of clickers was implemented in an undergraduate baccalaureate nursing course of juniors in a small private northwest university. Institutional Review Board approval for the study was obtained. As only cumulative or de-identified data were used and because clickers did not influence students' grades in the course, student consent was not required to be obtained.

B. Study Design

Learning theory requires ongoing examination through reflection to understand whether or not students are learning, therefore, action research was the method of design for this study. Action research design "is a process in which participants examine their own educational practice systematically and carefully, using the techniques of research" ([16], p. 1). According to Ferrance the steps in action research are: 1) Identify the problem; 2) Collect and organize data; 3) Interpret data; 4) Determine the action, based on the data; and 4) Reflect on the process.

Prior to this study the nursing students were found to not retain the knowledge of pharmacotherapeutics at a high enough conceptual level to perform well on a nationally-normed content exam, therefore, knowledge of neuro-science of learning was used to design the clicker questions. Clickers provided a way to collect and organize the data. From a

FIGURE 1: DEVELOPMENTAL STAIR STEP LAYERED WITH CONCEPT ACQUISITION.
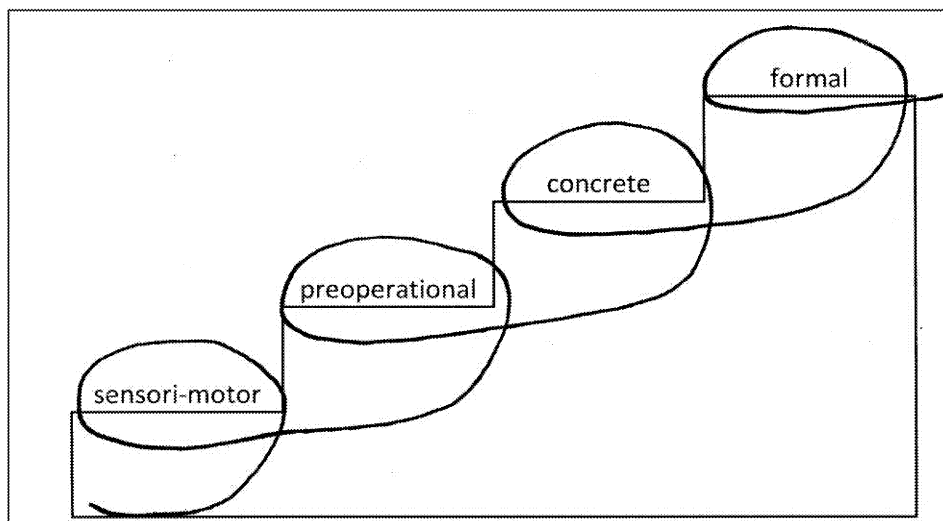
methods standpoint, steps 3, 4, and 5 in the Ferrance [16] model, above, were used continuously and simultaneously in this action research.

C. Technology

The technology used in the study was the *interwrite PRS*™ RF clicker and accompanying *interwrite PRS*™ software [15].

D. Procedures

Each student bought an *interwrite PRS*™ RF clicker at the campus bookstore that the student was responsible for bringing to class. During class the faculty member would project a question on a video screen. Students used their clickers to select their responses to the question. Students' responses were transmitted and tabulated automatically by the *interwrite PRS*™ software (2006) and results were projected on the screen. Cumulative results were presented as bar graphs of the distribution of the responses for each question

To apply Neuro-semantic Language Learning Theory (NLLT) [2] to the use of clickers in the classroom the following steps were employed:

1. Designed questions based on where the students were developmentally in understanding the pharmacotherapeutic concepts in the course. For example, in the beginning of the semester recall questions about topics such as pregnancy categories were primarily used, whereas later in the course the questions required more depth of knowledge and critical thinking such as the nursing care of a patient taking a medication for seizures.

2. Data was collected and organized by the *interwrite PRS*™ software in histogram format, which was displayed for students and faculty.

3, 4, & 5. Faculty assessed student understanding based on the percentage of students who correctly or incorrectly answered the question. If approximately 30% of the students incorrectly answered the question, faculty actively engaged the whole class in exploring their thinking. This real time data provided the faculty member with knowledge about the learning gaps between teaching and student thinking for conceptual learning.

Based on student understanding the faculty member would add meaning in a variety of ways: 1) re-explain the concept using different words and examples to use language for thinking; 2) peer interaction so students used their language to name their thinking; 3) re-check for conceptual learning using discussion about related ideas or examples to increase the students' use of language for deeper conceptual thinking; 4) add more conceptual depth by providing more complex scenarios, thereby increasing the use of language for better recall and retention. Understanding of the content and concepts related to nursing pharmacology was rechecked later in the course by conducting an extensive review of course content using a large bank of questions answered via clickers.

Action research design allowed for the continuity of assessment and reflection by the faculty. But, higher order conceptual student learning is also based on how well the faculty is able to provide feedback for the scaffolding of layers of information. Therefore, faculty examined the types of questions for what students would have to understand in order to answer the questions. In this way, the developmental level of the questions were arranged in a hierarchy of difficulty: 1) Prior course content questions were simple preoperational questions from a previous lecture designed to be sure that students were starting at the same level of background conceptualization (see Table 1). 2) Immediate recall questions covered content in the same lecture to determine if the class understood the content or would require students to use their nursing drug book to find the answers to questions. In this way, students were actively layering prior knowledge with current knowledge to raise their levels of thinking. 3) Memory recall of pharmacotherapeutics content questions were given to see if the students recalled the material. These questions were more difficult than pure recall because students were asked to make connections among past classes. 4) Student application questions began with simple application of pharmacotherapeutics knowledge to a client situation. This type of question took the students' past knowledge (preoperational) and layered their simple application (preoperational to concrete) with more connections (concrete) for higher thinking. 5) Standard formal questions similar to those on the NCLEX-type question format of the Registered Nurse board exam were used. And, finally, 6) Review questions that asked for formal or comprehensive applications across classes were part of a comprehensive final exam.

IV. RESULTS

The student responses gave immediate feedback to the faculty as to whether the students understood the targeted concepts or knowledge. The faculty could then respond to the information gained from the student responses to clarify a concept or add information and improve conceptual learning. Overall learning outcomes were measured by quantitative scores on a nationally-normed exam and by qualitative comments students made in the course evaluations.

A. Quantitative test scores

Student outcomes in pharmacotherapeutics were determined by the class scores on a nationally-normed online exam of pharmacotherapeutics content. This outcome was used because students had traditionally done poorly on the nationally-normed ATI (Assessment Technologies Institute) exam and it was seen as an external evaluation of student learning.

The use of clickers was implemented Fall semester 2007, and outcomes were measured through Fall semester 2010, for a total of ten semesters of data collection. Pre-intervention ATI scores for the academic year prior to implementation of clickers were used as a comparison. Class sizes ranged from 36 students (Summer 2010) to 62 students (Fall 2008) during the data collection period. Pre-intervention scores for the students taking the pharmacology ATI were at the 19th percentile on the national ranking. ATI scores post-intervention ranged from 39th percentile to the 80th percentile. The lowest score measured after the clickers were

implemented was the first semester of implementation, Fall

Students in the Spring cohort are generally several years older,

TABLE 1: TYPES OF QUESTIONS USED IN COURSE AND EXAMPLES OF EACH TYPE OF QUESTION.

Question Type	Examples
Knowledge recall	Which pregnancy category should not be given to any pregnant woman? 1. A 2. B 3. C 4. X
Application (early in semester) Students use their nursing drug book to answer to learn how to use the resource.	You are the nurse caring for an elderly patient with a seizure disorder. The patient is on phenytoin (Dilantan) What drug classification is phenytoin (Dilantin)? A) D B) anticonvulsant C) prototype Phenytoin is poorly absorbed from the GI tract • True • False Phenytoin is totally safe during pregnancy • True • False
Knowledge (later in semester)	Mr. Jones, age 68 yrs, takes nitroglycerine occasionally for angina. What comorbid conditions should the nurse assess for when doing medication teaching? A) Type II Diabetes B) Erectile dysfunction C) Asthma D) Thrombocytopenia A client with a history of alcoholism has just been diagnosed with type 2 diabetes mellitus and placed on sulfonaurea glipizide (Glucotrol). The nurse explains that which one of the following reactions may occur if the client drinks alcohol while taking this medication? A) Decreased diuresis B) Disulfiram-like reaction C) Anaphylaxis D) Increased tolerance to the medication
Application (multiple right answers)	The nurse is caring for a patient who has suspected septicemia. The physician has ordered ciprofloxacin (Cipro) as one of the antibiotics the patient will be treated with. What nursing care would you anticipate: A) Cultures should be obtained after starting the antibiotic B) Monitor for diarrhea C) Monitor temperature D) Monitor CBC E) Monitor for ototoxicity

2007, with students scoring in the 39th percentile.

The ATI scores are presented as national percentile rank. The ATI national percentile rank refers to the proportion of groups from all types of RN nursing programs (within a specified sample from the ATI data pool) whose scores are the same as or lower than the school group score (Assessment Technologies Institute). ATI percentile rank scores are reported as a group score and are not broken down by gender or ethnic group. The class composition of nursing students taking pharmacotherapeutics in the Fall differs from students who take pharmacotherapeutics in the Spring Semester.

some have a previous degree, and all have work experience compared to students who take pharmacotherapeutics in the Fall who are traditional college students typically under 21 years of age. Therefore, fall student data were separated from the spring student data and graphed accordingly (see Figure 2).

B. Qualitative Comments

Anonymous end-of-semester course evaluations were used to gather qualitative data regarding the use of clickers in

the pharmacotherapeutics course. Standard course evaluations use of the clickers in the course, but there was a question were
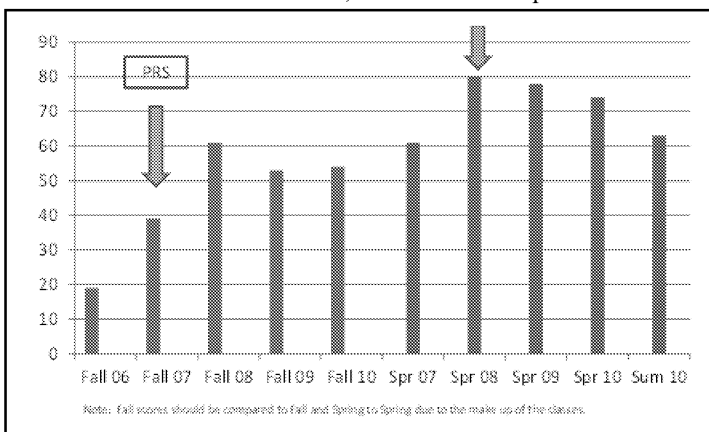

Fig. 2 Results on Assessment Technology (ATI) exams in national percentile rank

used and there was not a specific question related to the regarding strengths of the course. Students spontaneously answered: "Loved the clickers!" "Clicker questions were great review." and "Clickers helped with practicing and reiterating information from the previous lecture." Repeatedly students identified clicker questions as a strength of the course and requested more clicker questions in the class. It should be noted that while this faculty member had success with the use of clickers, other faculty at the same school of nursing did not have similar positive results and either abandoned the use of clickers or did not report positive student learning.

V. DISCUSSION

Learning, cognition and translational neuroscience are the theories used to interpret and analyze the results and explore how clickers improve student conceptual learning. There are cognitive language reasons as well as social reasons why the use of clickers increased student learning in this study. These cognitive and social reasons are rooted in neuroscience and include: 1) the use of a clickers activates the areas of the brain that processes the professor's language and therefore helps maintain the level of student engagement that facilitates attention to detail; 2) the motor action of the fingers clicking on the device activates visual-spatial sensory input in the brain which helps maintain attention for later recall; and 3) the use of scaffolded language questions by the professor offers learners the opportunity to acquire concepts at a deeper level of understanding that results in higher order thinking.

The use of any method that asks learners to remain engaged in order to be a part of the class should show some improvement in immediate memory. The use of clickers necessitates engagement between the processing of the professor's words and mental graphics with some immediate recall. The prefrontal cortex assists with successful memory retrieval of words by increasing the blood flow in this area of the brain which contributes to maintaining attention ([14]; [40]). Attention is the ability to sort out information that must be recognized from information that is old or not needed. So,

the mere use of a system that asks the learner for a response activates the portion of the brain that coordinates neural networks that are related to the processing of ideas [26]. Furthermore, such activation of the prefrontal cortex is not modality but sensory specific [36] which suggests that changes in sensory input such as having to push the clicker button would stimulate the part of the brain that helps with maintaining attention and organizing the neural networks for responding. Pushing a button in response to the professor's questions utilizes a motor movement of the hand in a visual-spatial task. Visual-spatial tasks activate the neural networks between the prefrontal cortex and the right anterior cingulate gyrus (Brodmann area 24), known for processing language ([4]; [23]; [35]).

The use of language by the learner to answer the professor's questions activates very large neural networks [1] that connect the left hemisphere of the cortex to the medial prefrontal cortex and the anterior cingulate gyrus. The professor in this study spent time arranging the questions in a hierarchy of language difficulty that would build the meaning (semantic memory) from easier concepts to more difficult concepts, thus increasing the likelihood of learners being able to recall material at a later date. Increasing the use of semantic memory activates the left lateral prefrontal cortex, and perhaps the anterior temporal cortex, which may have distinct roles in retrieving, maintaining and selecting semantic information [30]. At this point, both the left and right hemispheres are engaged as well as the interconnections between the memory systems of the sub-cortical regions. For these regions to remain active, the prefrontal cortex must be involved in the circuitry.

Most educators would translate the findings of this study to mean that the professor made use of best teaching practices. But, in examining the way this educator's practices affected the synergy of the learners' brains, the effectiveness appears to be about learning, not just teaching. In other words, the professor arranged the learning environment to activate not only the "fun" sub-cortical aspects of memory but the cognitive aspects of higher order thinking through considering the type of response and the level of language for the questions.

By consciously attending to the cognitive linguistic level of the questions, the professor not only assisted the students in their long term or semantic memory of the pharmacotherapeutics concepts; but, the professor socially helped provide a safe learning environment by allowing for anonymous student response.. Most learners want to represent their ability by correctly answering the professor's questions. Such desire activates the medial prefrontal cortex to attenuate any emotional connection with being incorrect that might be activated at a lower amygaloid process level [22]. By providing a safe anonymous way for answering the questions, the professor allowed the students the opportunity to learn the content at a higher order level of thinking.

The use of clickers could be a fun novel device that would show some immediate gains but not long term conceptual or cognitive learning unless upper cortical

processes are activated. The lower processes of the amygdala that last a long time but do not address higher order thinking.

Table 2. Language learning implications of this study.

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1). **Professor arranged the cognitive language level of the questions**
e.g., early questions that require straight knowledge of facts or pattern recognition, such as "which pregnancy category should be given to women with a specific health problem and others not be given to any woman. Later questions addressed actions nurses must take or not take that are based on a higher order knowledge of the interaction of the medication with other medications or medical problems such as "David, age 78, using the inhaled anticholinergic ipratropium (Atrovent) for his COPD. Other questions address nurses teaching patients about their medications which represent a concrete level of thinking as the student must apply knowledge, analyze options in the possible answers, and synthesize past knowledge into determining the correct answer. Questions towards the end of the semester represented more complex abstract application , which means it was at a formal developmental level, in that the nurse needed to understand the relationship between several biological systems and medications in order to take action or determine the best action for the nurse to take, therefore the student's decision was based on inferred meaning. For example, "Donald Bloomberg has recently been diagnosed with hyperlipidemia. Because of his lipid profile, atorvastatin (Lipitor), a HMG-CoA reductase inhibitor, has been prescribed, Rhabdomyolysis is a rare but serious adverse response to drugs in this class. Mr. Bloomber should be told to:" and the answer choices require not only knowledge of the drug, the patient, and the disease but the student must decide what information the patient needs to know. This requires the student to sort out what information that the patient does not need to know.

2). **The professor used rich language in giving feedback regarding different answers**. This provided the students with more information about their choices of answers which increases the meaning (semanticity).

3). **The professor used scaffolding in arranging how the developmental level of the questions increased over time** while providing immediate feedback. Scaffolding of knowledge increases the level of student conceptualization.

In this study, the professor spent extra time setting up the situation so that students would feel safe using the clickers to increase higher order thinking in a safe environment. Even though research studies show emotional memory is more lasting than working or episodic memory; emotional memories are rooted in smells, tastes, touches, visions, and acoustic parameters, not in thoughts or higher cortical language functions [2]. The professor wanted the students to learn the content at a conceptual level so that they could apply the course content to patients and provide safe care. These concerns required careful attention on the part of the faculty member to the developmental level of questions asked, as well as the student engagement through clickers that created a safe learning environment. The professor reactivated the students' learning systems with more meaning by carefully explaining the differences in correct and incorrect answers. This feedback process [27] provided by the continual linking of past to present learning activates the larger neural networks in the brain required in higher order thinking processes of the brain. Socially and cognitively, the professor arranged the learning environment to capitalize on acquiring concepts for higher order thinking through cognitive and social learning. Table 2 discusses the learning implications of this study.

VI. LIMITATIONS

This study is limited to the one faculty member and the particular class that was taught. Data was not collected regarding the gender of the students who took the ATI, nor were socioeconomic differences in students measured. The concept of a "master" teacher using clickers versus a novice

teacher needs to be recognized. Would a novice teacher have the same results as the faculty who conducted the study? Likewise, the student sample is from a private university with high admission standards and would there be the same results in a different student demographic group?

The authors propose neuroscience theory as a reason the clickers enhance learning in the classroom. More studies with perhaps some brain imaging during and after questioning would provide support to this data. As more neuroscience is used to interpret learning methods, more knowledge about how to interpret the data will emerge.

VII. CONCLUSIONS

Personal Respone Systems or clickers by themselves do not necessarily create better learning. However, when such systems are thoughtfully integrated into a learning environment that makes use of engagement principles of learning along with linguistic parameters for higher order thinking, there is an improved opportunity for learners to receive feedback that helps maintain attention, focus energy on assigning meaning to the questions through language, and provide for deeper conceptual learning. As with any technology, it is not the device that makes a difference in learning; it is the application of learning theory by the teacher based on neuroscience that improves conceptual learning.

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