THE IMPACT OF COLLABORATIVE AND INDIVIDUALIZED STUDENT RESPONSE SYSTEM PEDAGOGY ON LEARNER MOTIVATION, METACOGNITION, AND TRANSFER

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CHAPTER I

INTRODUCTION

There has been a recent and widespread call for reform in undergraduate instruction to increase meaningful learning (Jenkins, Breen, Lindsay, & Brew, 2003; Ramsden, 2003; Reigeluth, 1999; Spiro, Collins, Thota, & Feltovich, 2003). Meaningful learning is that which results in the ability of learners to recall and apply what has been learned, and therefore requires more focus on developing a deep understanding of concepts as well as the interconnections among concepts, as opposed to a focus on memorization of facts (DeHaan, 2005; Jonassen, 2007). Research in recent decades has shown that deep understanding requires instruction that does more than passively disseminate information to learners (Bransford, Brown, & Cocking, 2000). However, "many university teachers implicitly or explicitly define the task of teaching undergraduates as the transmission of authoritative content or the demonstration of procedures" (Ramsden, 2003, p. 108).

Chickering and Gamson's (1987) landmark article proclaimed seven principles of good practice in undergraduate education. Among these principles were such activities as encouraging student-faculty contact, promoting active learning, and providing prompt feedback. Unfortunately, twenty years later most university instruction has not found a way to successfully implement these principles, especially in the large undergraduate classroom (Ramsden, 2003).

Large university classrooms are particularly susceptible to passive learning pedagogy, despite evidence that this type of instruction is inferior to active strategies for many aspects of learning such as retention, transfer, problem solving, and motivation (Jenkins, 1992; McKeachie, 1986). John Keller, a prominent researcher in learner motivation, proposed that there is no better example of "distance education" than the large undergraduate classroom (Keller, 2007).

Overcoming the use of uninterrupted lecture in higher education is largely due to the difficulty of implementing active learning strategies in these large enrollment settings (Allen & Tanner, 2005; Bonwell & Eison, 1991). Other reasons cited for maintaining this form of instruction are the amount of material that must be covered in the time allotted, as well as a feeling by many faculty that learning for university students is the students' responsibility, not the instructor's; therefore, many faculty are not concerned with the effectiveness of their instruction beyond exam performance (Ramsden, 2003). Yet, exam performance often says little about students' actual understanding (Wiggins & McTighe, 1998). Decades of research have shown that "students often *know* far more than they *understand* about subjects they have studied" (Perkins & Unger, 1999, p. 95).

Since implementing active learning is logistically challenging in large classroom settings, recent research in education has focused on seeking solutions to this problem (Smith, Sheppard, Johnson, & Johnson, 2005). A form of classroom technology, known as a student response system (SRS), offers great promise for enabling the obstacles to active learning in large classrooms to be overcome (Hoffman & Goodwin, 2006).

A student response system consists of handheld devices that allow all students in a class to simultaneously respond to a question from the instructor. The responses are collected by a computer-connected receiver, aggregated, and then displayed for the entire class to see.

SRS technology was introduced in education in the 1960s, and was mainly used as a drill-and-practice tool for large classrooms (Judson & Sawada, 2002). Therefore, much of SRS research has focused on learner achievement comparisons between students using or not using the technology, (Judson & Sawada, 2002). However, meaningful learning is much more complex than can be adequately understood and measured solely by exam scores (Perkins & Unger, 1999). Thus, there is a need for more research on the kinds of pedagogies that SRS facilitates as well as how SRS-augmented pedagogies impact learners in more ways than just exam performance. Motivation, metacognition, and transfer are three examples of important aspects of meaningful learning (Bransford, et al., 2000) that are in need of investigation.

Human learning is a complex process that involves the interaction of many aspects of human behavior (Mayer, 2008). This is analogous to biological systems that have been referred to as irreducibly complex machines (Behe, 1996). These systems involve a number of parts that function in unison to a degree that the system cannot be reduced by any one of those parts and still function effectively. The human eye is one example of this kind of system (Behe, 1996). Similarly, it seems appropriate to use this metaphor to describe meaningful learning.

The irreducibly complex system of meaningful learning is comprised of many aspects. Most of them appear to be cognitive in nature, such as knowledge acquisition and retention (Driscoll, 2005). However, there are many more aspects that go beyond cognition, such as motivation, metacognition, and transfer that are equally important to learning as cognition (Bransford, et al., 2000; Driscoll, 2005; Mayer, 2008). A major difference between meaningful learning and tangible systems, such as the human eye, is that constructs such as motivation, metacognition, and transfer cannot be observed and measured directly. As a result, pedagogical research must rely on indirect measures to compare effectiveness of pedagogical strategies (Kirk, 1995). This is especially true of research on technology-facilitated pedagogies. If a concerted effort is not made to effectively evaluate the impact of new technologies used in instruction on more than simply changes in exam scores, then we run the risk of using technology for technology's sake (Cuban, 1986). Therefore, the goal of this study is to specifically explore the implications of SRS-based pedagogy on learner motivation, metacognition, and transfer.

Theoretical Framework

The theoretical framework that informs this study includes both instructional and learning theories. It is at the intersections, as well as overlaps between these theoretical foundations that SRS pedagogy will be investigated.

Only recently has the focus of SRS research shifted to pedagogical strategies (Draper & Brown, 2004; Fies & Marshall, 2006; Montplaisir, 2003). One of the most prominent of SRS-based pedagogies is Mazur's Peer Instruction (Mazur, 1997a). This approach goes beyond simply having students respond to questions using SRS. Instead, the attributes of SRS are exploited to facilitate a collaborative learning environment, even in large classrooms. Through Mazur's Peer Instruction, students not only respond to carefully designed questions that encourage higher-order thinking and reflection, but they also discuss their responses in small groups, and then respond again to the question being considered. Several studies have shown that this strategy fosters significant gains in student performance (Mazur, 1997b), however there is a lack of research into other aspects of meaningful learning. The constructs of meaningful learning that are investigated in this study include motivation, metacognition, and transfer. These three aspects of learning have been noted as the *trifecta* of meaningful learning (Mayer, 2008; Short & Weissberg-Benchell, 1989).

While there are numerous approaches to learner motivation, this study will use Keller's ARCS model for the definition and measurement of this construct due to the extensive empirical research that has supported the validity of this model of learner motivation (Keller, 1979, 1983, 1987a). ARCS is an acronym formed by the four primary components that represent a learner's situational motivation: attention, relevance, confidence, and satisfaction. Instruction can be motivating, or non-motivating, to learners in any combination of these four dimensions. Therefore, if meaningful learning is to occur, instruction should be designed to target each of these motivational components (Keller, 1987b).

Metacognition is the process by which an individual monitors and regulates their own cognition (Flavell, 1979). The ability to perform these processes effectively has a significant impact on learners' self-regulation of learning (Pintrich, 2004). Metacognitive awareness can be developed by a number of strategies, such as embedding metacognition skills instruction within regular instruction (de Bruin, Rikers, & Schmidt, 2007), having learners perform self-explanations (Ainsworth & Th Loizou, 2003), and having learners perform problem solving activities (Davidson & Sternberg, 1998). It has been noted that a key to the development of metacognitive skills in learners is to provide timely, continuous formative feedback (Nicol & Macfarlane-Dick, 2004).

Transfer is the process of applying prior knowledge to new situations or to new learning (Mayer, 2008). Transfer is representative of the "adaptive expertise" that sets experts apart from novices in a particular knowledge domain (Bransford, et al., 2000). Thus, transfer is the quintessential goal of all instruction (Haskell, 2001).

Statement of Purpose

The purpose of this study is to compare the impact of two SRS strategies on learner motivation, metacognitive awareness, and transfer in a large undergraduate science course for non-majors. The SRS strategies will both serve to engage all students, however one strategy will implement Mazur's Peer Instruction method (Mazur, 1997a) while the other strategy will involve students responding to questions individually.

Investigating the pedagogical impact of SRS through strategies such as Peer Instruction on aspects of learning beyond achievement is at an initial, exploratory stage. The few examples found in current literature are anecdotal at best. Most use rudimentary methods to measure any impact on these constructs. These studies are often methodologically flawed through an oversimplification of the constructs being investigated. For example, a study published in the summer of 2007 used a six-item questionnaire to determine student benefits of using SRS (Poirier & Feldman, 2007). This instrument included questions such as, "Using clickers was fun and made the class more enjoyable". Measuring student attitudes is difficult enough (Keller, 1978), but the problems inherent in using questions such as this as indicators of student attitudes are apparent. The present study will attempt to explore this gap in the SRS literature by measuring the impact of SRS pedagogies on aspects of learning beyond exam performance through the use of instruments that are more psychometrically valid and reliable.

Research Questions

The research questions investigated in this study are:

(1) Is there a significant change in motivation for students experiencing SRS-based instruction, relative to students engaged in Peer Instruction versus students engaged in individualized SRS-based instruction?

(2) Is there a significant change in metacognitive awareness for students experiencing SRS-based instruction, relative to students engaged in Peer Instruction versus students engaged in individualized SRS-based instruction?

(3) Is there a significant difference in the ability to perform entomology content knowledge transfer for students experiencing SRS-based instruction, relative to students engaged in Peer Instruction versus students engaged in individualized SRS-based instruction?

Significance of the Study

The adoption of SRS in university classrooms is growing at an exponential rate. One of the leading SRS companies, eInstruction, reports that “millions of students, teachers and professors use eInstruction technology in 250,000 K-12 classrooms and more than 1,000 higher education institutions around the world” (eInstruction, 2008). This company has only been in business since 1980, which demonstrates the rapid rate of diffusion of this instructional technology.

So far, there has been little empirical research on SRS pedagogy, as well as impact of SRS-augmented instruction on aspects of learning beyond learner performance.

Thus, this study is an exploratory investigation into these uncharted waters. The findings of this study will add to the small but growing body of knowledge on the pedagogical implications of SRS technology for learning. Additionally, it is hoped that this study will encourage more SRS research to focus on innovative pedagogical uses of SRS technology.

Chapter II

REVIEW OF LITERATURE

This chapter presents a review of instruction and learning theory and research from which this study is based. First, active learning will be discussed as an important instructional framework for eliciting meaningful learning, along with the barriers that make implementing active learning difficult in large university classrooms. Next, student response systems (SRS) will be introduced as a tool that serves to overcome these barriers. Finally, Mazur's Peer Instruction strategy to promote engaging and collaborative instruction in large classrooms (Mazur, 1997a) will be examined, along with how this strategy targets three important aspects of meaningful learning: motivation, metacognition, and transfer (Bransford, et al., 2000).

Learner-centered Instruction and Active Learning

Instruction that is learner-centered recognizes the fact that each individual learner is unique and does not enter the learning setting as a blank slate (Bransford, et al., 2000). The principles of learner-centered instruction include cognitive and metacognitive factors, motivational and affective factors, developmental and social factors, and individual differences factors (McCombs & Miller, 2007). By making instruction focused around learners' needs, interests, and cultural context, instruction not only becomes more appealing, but it also becomes more effective to accommodate and assimilate new knowledge into the learners' existing schema of understanding

(Piaget & Inhelder, 1969). Implementing the principles of learner-centered instruction inherently requires learners to be active participants, not passive recipients, of information in the learning process (McCombs & Miller, 2007).

Active learning is an umbrella term used to describe pedagogical strategies that move students from a passive role in learning to one where they actively engage and interact with the knowledge and skills being learned (Browne & Keeley, 2001; McConnell, Steer, & Owens, 2003). Active learning involves more than listening and writing notes. For learning to truly be active, students must be involved in higher-order thinking and interaction through tasks such as reading, writing, discussing, or other forms of engagement (Bonwell & Eison, 1991). The following are characteristics that exemplify an active learning environment:

- Students are involved in more than passive listening;
- Students are engaged in activities;
- Students are focused more on developing skills as opposed to memorizing facts;
- Students are more motivated;
- Students receive immediate feedback from their instructor;
- Students are involved in higher-order thinking (such as analysis, synthesis, evaluation) (Bonwell & Eison, 1991, p. 2).

Students consistently report a preference for active learning over lecture-only environments (Beekes, 2006; Bonwell & Eison, 1991; Cutts, Carbone, & van Haaster, 2004; Dufresne, 1996; Fies, 2005; Martyn, 2007; Meltzer & Manivannan, 2002; Meyers & Jones, 1993). Therefore, since course satisfaction is an important aspect of learner motivation (Keller, 1987a), active learning environments understandably increase students' willingness to exert effort towards learning. Effort, or learner volition, has been shown to be a key factor to successful learning (Deimann & Keller, 2006). The benefits of active learning are well documented, however the difficulties of implementing this type of instruction in large undergraduate courses limits the ability or willingness of instructors to use active learning in their courses.

Barriers to Active Learning in Large Classrooms

Implementation of active learning faces significant hurdles in large undergraduate classrooms. A primary hurdle is the logistical difficulty of teaching and assessing in a learner-centered manner when instructors are dealing with large numbers of students (Bonwell & Eison, 1991; Michael, 2007). Other barriers to active learning in higher education include concerns about limited class time, increased preparation time, lack of resources, and lack of support (Bonwell & Eison, 1991). In addition to these barriers is the instructor's willingness to overcome the fear that students will be unwilling to participate or will not learn the content sufficiently from active learning methods (Michael, 2007). Faculty are also often fearful of the loss of control over the direction of the classroom, lack confidence in their ability to successfully teach in this format, and fear that they might be criticized for breaking from the traditional lecture method for university teaching (Bonwell & Eison, 1991).

Some faculty may be concerned that taking time away from lecturing will result in decreased learning of content due to spending less time on explaining the material to students (Ramsden, 2003). However, studies show this is not the case, as students in active learning classrooms perform equally well in content mastery compared to lecture-based classrooms, and outperform in the ability to think and write about the content

(Bluestone, 2007; Bonwell & Eison, 1991; Gulpinar & Yegen, 2005; Poirier & Feldman, 2007). It has been proposed that there is sufficient research evidence to confidently support the notion that active learning strategies are superior to traditional lecture for facilitating learner retention and transfer (DeHaan, 2005).

The barriers to active learning in large classrooms can be overcome in a number of ways. Two important factors to address these barriers are (a) show that learning theory and research support the processes that are facilitated by active learning, and that make active learning superior to passive learning, and (b) show that through the use of classroom technology, engaging every student, even in large classrooms, is viable (Bransford, et al., 2000). Among the abundance of research supporting active learning, student response systems have been particularly cited as a technology for successfully implementing active learning in large classrooms (Allen & Tanner, 2005; Beekes, 2006; Bransford, et al., 2000; Martyn, 2007).

Student Response Systems

A Student Response System (SRS) is a form of instructional technology that enables all students to become active participants during instruction, even in large classrooms (Greer, 2004; Herreid, 2006). SRS varies little from one vendor to another. In general, SRS works by providing some mechanism for an instructor to ask a question and then for all students to respond to the question via an electronic device. SRS is known by many names, including electronic response systems (ERS), personal response systems (PRS), audience response systems (ARS), classroom communication systems (CCS), among others (Hall, Collier, Thomas, & Hilgers, 2005). In the United Kingdom, SRS is referred to as handsets or zappers (Simpson & Oliver, 2007).

The use and evaluation of SRS technology in classrooms has been documented since the 1960s (Hall, et al., 2005). These systems have evolved from hardwired units with switches, knobs, or buttons on the student end and gauges on the teacher end, to the wireless pads in use today.

Despite the array of terminology, as well as the variety in brands available, the function of SRS is very simple. SRS allows an instructor to ask a question and to immediately receive a response from all students simultaneously (Poulis, Massen, Robens, & Gilbert, 1998). When a question is presented, students submit an answer with their SRS pad. Each student's response is instantly transmitted to a receiver connected to the instructor's computer. When student responses have been received, software aggregates the students' responses, and then displays the results, either by total count, percentage, a chart, or a combination of these options (Judson & Sawada, 2002).

SRS-based instruction has shown to have a positive impact on learner achievement and performance (Conoley, 2005; Conoley, Moore, Croom, & Flowers, 2006; Fies, 2005; Garvin-Kester, 1990; Meltzer & Manivannan, 2002; Preszler, Dawe, Shuster, & Shuster, 2007; Roschelle, Penuel, & Abrahamson, 2004). For example, a large-scale study of SRS on physics learning that involved over 6,500 physics students in 62 physics courses, including high school, community college, and university settings, found that students in courses implementing SRS-based instruction experienced performance gains on the Force Concept Inventory exam nearly two standard deviations higher than students in traditional courses (Hake, 1998). Additionally, a long-term study of physics courses spanning 13 years demonstrated a nearly 50% higher pass rate for students in SRS-using sections over students in non-SRS sections (Poulis, et al., 1998).

Students in SRS classes have also shown better conceptual understanding of content (Montplaisir, 2003). Students in an undergraduate human anatomy and physiology course demonstrated through interviews and pre/post-tests a deeper understanding of course topics after SRS-based instruction (Montplaisir, 2003). Additionally, students reported an increase in in-class thinking about content as well as more discussions with peers about content, and more opportunities in class for deeper learning (Montplaisir, 2003).

While there are many studies that have investigated the impact of SRS technology in general, there is yet to be sufficient research into how the various ways that SRS can be used has an impact on various aspects of learning. However, there has recently been more attention given to SRS pedagogical strategies, such as Peer Instruction (Mazur, 1997a).

SRS and Active Learning

When used appropriately, SRS technology enhances the ability of instructors to implement the principles of active learning, especially in large classrooms (Martyn, 2007). As one of the primary barriers to active learning is the ability to effectively engage all learners, SRS allows all students to simultaneously respond to questions posed by the instructor. Thus, SRS-based instruction leads to increased student participation and enhanced discussion in large classes (Beekes, 2006; Conoley, et al., 2006; Fies, 2005; Montplaisir, 2003; Roschelle, et al., 2004; Shapiro, 1997), both of which are key features of an active learning classroom (Browne & Keeley, 2001; Meyers & Jones, 1993). Researchers have often attributed the positive impact that SRS has on learner performance and attitudes to the fact that SRS classrooms are more reflective of active learning environments (Dufresne, 1996; Greer, 2004; Hoffman & Goodwin, 2006; Martyn, 2007; Presby & Zakheim, 2006; Robertson, 2000).

Benefits of Increased Feedback

A key attribute of SRS technology is the ability to provide instructional feedback to all learners simultaneously during the instructional sequence. Receiving feedback during learning is one of the most important elements of effective instruction (Draper, 2002). Opportunities for practice and feedback are key points in Gagne's nine events of instruction (Gagné & Driscoll, 1988). Instructional feedback is paramount to learners being able to determine if they are accurately understanding concepts being learning (Mory, 2004). This is important not only to avoid misconceptions, but also for other aspects of learning such as building confidence and increasing self-regulation (Draper, 2002).

There are a number of strategies for incorporating formative feedback in large classrooms. The common thread to these strategies is an attempt to increase the level of student engagement through effective questioning (Steinert & Snell, 1999). Some strategies that have been recommended for larger classrooms include using questions at 10-15 minute intervals throughout the lecture, and beginning and ending a lecture session with questions (Allen & Tanner, 2005). However, not just any questions will effectively engage students in higher-order thinking processes necessary to promote meaningful learning. It has been shown that complex, ill-structured questions that facilitate discussion stimulate more meaningful learning than primarily using simple, lower-order questions (Allen & Tanner, 2005).

The importance of good questioning in instruction is underwritten by the importance of feedback in the learning process. It is through proper instructional feedback that learners develop the ability to move beyond the guidance of the instructor and move towards independence (Pintrich, 2002), which is congruent with Vygotsky's zone of proximal development (Driscoll, 2005). Preparing students to be lifelong learners requires that they have ample opportunities to develop internal feedback skills (Nicol & Macfarlane-Dick, 2006). Quality feedback is that which helps students develop metacognitive awareness by:

> (1) Helping clarify what good performance is (goals, criteria, expected standards);
> (2) Facilitating the development of self-assessment (reflection) in learning;
> (3) Delivering high quality information to students about their learning;
> (4) Encouraging teacher and peer dialogue around learning;
> (5) Encouraging positive motivational beliefs and self-esteem;
> (6) Providing opportunities to close the gap between current and desired performance;
> (7) Providing information to teachers that can be used to help shape teaching (Nicol & Macfarlane-Dick, 2006, p. 205).

According to Nicol and Macfarlane-Dick's model of self-regulated learning and the feedback principles that support and develop self-regulation in students (Nicol & Macfarlane-Dick, 2006), providing instructional feedback based on these guidelines results in enhanced student motivation and metacognition. Sources of this formative feedback can include the learners themselves, the environment, and the instructor (Draper, 2002).

Benefits of Increased Collaboration

Research has widely supported that articulation and social negotiation are critical to the learning process (Ghefaili, 2003; Prawat, 1989; Rogoff, 1990; Wertsch, 1991). As Driscoll stated, “What people perceive, think, and do develops in a fundamentally social context” (Driscoll, 2005, p. 157). Thus, learning is inherently a social process, and recognizing the social nature of learning is paramount to effective instruction. This is one of the greatest challenges to fostering meaningful learning in large classrooms (Bonwell & Eison, 1991; Ramsden, 2003).

The role of collaboration in learning has been a prominent focus of educational research for decades (Driscoll, 2005). Vygotsky viewed higher-order cognition as being rooted in social processes (Vygotsky & Cole, 1978; Wertsch, 1991). Piaget focused on the role of cognitive disequilibrium through encounters with the environment (including people) that stimulates accommodation or assimilation in individuals (Piaget & Inhelder, 1969).

Meaningful learning is enhanced through increased learner collaboration (O'Donnell, 2006). As Bender (2003) states, “Collaboration is vital to learning so that students understand questions, develop arguments, and share meaning and conclusions among a community of learners” (p. 8). Through dialogue with other learners and the instructor in a community of practice, learners communally build on each others’ understandings through distributed cognition (Ghefaili, 2003). “Learning becomes a process of reflecting, interpreting, and negotiating meaning among the participants of a community. Learning is the sharing of the narratives produced by a group of learners” (Ghefaili, 2003, p. 7).

Research has supported the notion that increased collaboration enhances learning. For example, in a study of tenth-graders learning classical mechanics, half were taught quantitative concepts and the other half were taught qualitative concepts (Kneser & Ploetzner, 2001). Students were then paired to solve problems that required both quantitative and qualitative knowledge to solve. As the student dyads collaborated, the students who learned the most from their peer more frequently performed reflective activities. This outcome may be interpreted as meaning that student collaboration facilitates metacognition, especially for weaker students.

In another study, students worked alone or in pairs while solving Tower of Hanoi problems (S. Brand, Reimer, & Opwis, 2003). Also, students either did or did not receive instruction on metacognitive skills. The study found that the students who worked in pairs performed better at the learning tasks, and this was enhanced even more by the metacognition instruction. Therefore, collaboration works in tandem with instruction that facilitates metacognition and as a result, learning is amplified.

SRS has great potential for facilitating learner collaboration in large classrooms, however the impact depends heavily on how the tool is implemented by the instructor (Judson & Sawada, 2002). SRS strategies range from only having students individually respond to each question to strategies that foster collaboration between learners on each question. As SRS pedagogical strategies evolve as a result of experience and research, the strategies that intentionally foster learner collaboration are growing in popularity (Abrahamson, 1999; Crouch & Mazur, 2001).

SRS Pedagogy

Consistent with the popularity of operant conditioning during the 1960s and

1970s (Skinner, 1965), the main focus of early response system research was on student performance, with the use of the SRS primarily providing a stimulus-response effect. Results of these early studies showed little or no learning gains (Judson & Sawada, 2002). For example, both Bessler (1969) and Brown (1971) found no significant differences in achievement between classes using SRS and classes not using the systems. However, students did feel more engaged with the use of these systems.

A large body of evidence that supports the use of SRS to improve learner achievement has overturned the lackluster results from these earlier studies. While the nature of the tool has remained virtually constant, its benefits to learners appear to have increased over decades of use (Judson & Sawada, 2002). One might infer that a possible cause of this improvement could be due to the radical differences in characteristics of today's students as compared with the students of the 1960s and 1970s. As compared with previous generations of learners who were acquiescent to more teacher-centered pedagogies, today's learners, referred to as Millenials , thrive on interaction and desire to have more control of their own learning (McGlynn, 2005; Tapscott, 1998). SRS can foster engagement and interaction, especially in large classrooms that are typically non-interactive by nature (Hoffman & Goodwin, 2006; Martyn, 2007; Presby & Zakheim, 2006). These attributes of SRS accommodate the needs and expectations of today's learners (Tapscott, 1998), therefore enhancing the appeal and effectiveness of SRS-based instruction for these students.

Another boost to SRS has been the shift in SRS research towards a focus on pedagogy rather than the technology. A comprehensive review of SRS studies found a clear difference between SRS research published before and after 2002 (Simpson &

Oliver, 2007). SRS research published after 2002 demonstrated a significant pedagogical maturing of the use of the tool. While pre-2002 studies looked generically at comparing samples with or without the tool, recent studies considered more distinct pedagogical strategies that the tool enables (Simpson & Oliver, 2007).

The recent focus on SRS pedagogy is encouraging since several researchers have noted that SRS benefits are greatest when attention is placed on pedagogy, and not on the tool (Fies & Marshall, 2006; Simpson & Oliver, 2007). This conclusion is not surprising because a SRS, like any form of instructional technology, is only a tool that in and of itself does not improve learning (Jonassen, 2003). How SRS is used is what determines the impact on learning (Draper & Brown, 2004). A pioneer of SRS-based instruction, Louis Abrahamson, stated:

> The technology, in itself, does not offer some wonderful new “magic bullet” that will offer learning gains simply by its adoption. It can certainly provide novelty and fun for all participants, but must be used within the context of teaching and learning processes for its full promise to be achieved. (2006, p. ix)

Several examples of SRS-based pedagogies were found in the literature, including Peer Instruction (Crouch & Mazur, 2001), ClassTalk (Dufresne, 1996), Interactive Engagement (Draper & Brown, 2004), and Contingent Teaching (Draper & Brown, 2004). While these strategies vary in the implementation of SRS technology, they all share a common goal of facilitating student engagement and interaction through the use of SRS. While these strategies can be implemented without SRS, their effectiveness is amplified when coupled with SRS technology. Peer Instruction is particularly enhanced when SRS is used to facilitate the strategy in large courses (Mazur, 1997b).

Mazur's Peer Instruction Strategy

Peer Instruction (PI) is one of the most prominent forms of SRS-based pedagogy specifically designed to target meaningful learning (T. Anderson & Soden, 2001; Cortright, Collins, & DiCarlo, 2005; Crouch & Mazur, 2001; Lasry, 2007; Mazur, 1997a; McConnell, Steer, Owens, Knott, & al, 2006; Pilzer, 2001; Rao & DiCarlo, 2000; Slavin, 2001; Smith, et al., 2005). Similar to all uses of SRS, PI engages all students in responding to course questions and gaining instant feedback. However, PI also has a collaborative element in that students engage in discussions about the questions in small groups. It is the collaborative aspect that amplifies the effectiveness of this SRS strategy (Crouch & Mazur, 2001; Mazur, 1997b).

Mazur's PI strategy involves three steps (Duncan, 2005; Mazur, 1997a). First, a challenging conceptual question is presented to the class, and the students individually respond to the question using SRS. Second, after the results have been displayed, the students are asked to spend two to three minutes discussing their answers in groups of two or three with the goal of convincing others that their own answer is correct. Third, students again individually respond to the question using SRS. The differences between the first and second responses provide the instructor with many instructional options, depending on the results. For example, if the second round of responses shows an increased selection of a particular incorrect response, then there are convincing misconceptions among the students that can be brought to light and addressed.

A key to the PI strategy is the type of questions used. These questions are referred to as ConcepTests, and are designed to strategically draw out student misconceptions (Mazur, 1997a). ConcepTest questions are most effective when the level of difficulty achieves around 50% accuracy rate at the initial response to the question (Duncan, 2005).

Another key to the PI strategy is the collaborative element in the process (Mazur, 1997a). SRS technology has been noted as a tool that increases student engagement, yet most implementations of SRS only have students respond to questions independently. It is the collaborative element that sets Mazur’s Peer Instruction method apart from individualized methods of using SRS technology (Mazur, 1997a).

Peer Instruction and Learner Motivation

Many benefits of Peer Instruction have been documented over the last ten years (Cortright, et al., 2005; Crouch & Mazur, 2001; Fagen, Crouch, & Mazur, 2002; Lasry, 2007; Nicol & Boyle, 2003). For example, PI research has shown consistently that students receiving this form of instruction outperform students in lecture-only courses on measures such as the Force Concept Inventory in Physics (Mazur, 1997b) and the Astronomy Diagnostic Test in Astronomy (Duncan, 2005). A study that compared PI with class-wide discussion found that students reported that they learned better from the PI method (Nicol & Boyle, 2003). It has also been shown that 80% of students receiving PI in a science course for non-science majors consistently reported improved attitudes towards science over four years of data collection (Duncan, 2005), which implies increased learner motivation.

The improvement to student motivation in PI-based instruction is congruent with recent literature on the use of SRS that has broadened in scope and has provided evidence of benefits to learners beyond performance (Burnstein & Lederman, 2001; Draper & Brown, 2004; Herreid, 2006; Owens, Demana, Abrahamson, Meagher, & Herman, 2002;

Poulis, et al., 1998; Van Horn, 2004). One of the additional benefits cited is a better student attitude towards both the content (Conoley, 2005; Fies, 2005; Preszler, et al., 2007) as well as the course as a whole (Beekes, 2006; Fitch, 2004; Trees & Jackson, 2007). For example, a study involving 550 students in both lower- and upper-division biology courses showed that most students viewed the use of SRS as helpful for course interest, attendance, and overall understanding of the content being learned (Preszler, et al., 2007). These results were most pronounced for lower-division courses, so the impact of SRS appears to be greatest for students in the earliest courses.

The increased appeal of SRS-based instruction is largely credited to the anonymous responding feature that is possible with most versions of the tool (Fies, 2005; Woolley, 2006). Use of SRS in anonymous mode guarantees near or total participation by students in a low-stakes manner (Martyn, 2007). Anonymous responding allows students to try out their understanding with no fear or embarrassment for being wrong. A study involved 139 students in an introductory management accounting course to a variety of questioning methods that varied in the degree of anonymity, and then surveyed the students in regards to the impact of these strategies (Freeman, Blayney, & Ginns, 2006). The results indicated that the more anonymous the students are in responding, the more likely they were to engage in the class exercises, and that of the questioning methods used, only SRS technology afforded this level of anonymity. Providing opportunities for success in learning, without the risk of public failure, is potentially the key to improved attitudes of learners in SRS-based instruction, and this may point to enhanced learner motivation.

Motivation Theory

Motivation is one of several hypothetical constructs that is used to explain human attitudes (Wlodkowski, 1999). Researchers since the 1980s have recognized that successful learning requires both cognitive skill and motivational will (Pintrich & Schunk, 2002). Research has shown that a learner's mood moderates both learner performance and transfer (Serge Brand, Reimer, & Opwis, 2007). Bloom proposed that there are three domains of knowledge: cognitive, psychomotor, and affective (L. W. Anderson, Krathwohl, & Bloom, 2001). Focusing only on cognitive aspects of instruction while ignoring affective aspects is akin to leading a horse to water but not being able to make the horse drink. Nonetheless, the motivational aspect of instruction is often overlooked in instructional design models (Keller, 1983). Particularly, science education research has largely ignored the importance of motivation in learning (Zusho, Pintrich, & Goppola, 2003).

Teachers often diagnose lack of student motivation towards learning as apathy (Driscoll, 2005). However, there are many factors, both internal and external, that influence a learner's motivational state (Donald, 1999; Keller, 1983; Pintrich, 2004; Schunk, 1991; Wlodkowski, 1999). For example, a survey of 646 fifth-graders demonstrated that a focus on relative ability was positively correlated with handicapping strategies such as procrastination and misbehavior (Urdan, Midgley, & Anderman, 1998). This result was significant for both teachers' use of strategies that focus on relative ability and for students' perceptions of a focus on relative ability, and the results were more pronounced for males than females. In another study, students' ratings of self-efficacy in an undergraduate chemistry course were able to predict final exam performance better that the students' SAT-mathematics scores (Zusho, et al., 2003). Thus, how both teachers and students approach instruction has an impact on behaviors that are often dismissed as learner apathy. Previous successes or failures in learning can also have an impact on students' level of engagement and motivation in later attempts at learning (Pintrich & Schunk, 2002).

Internal and external factors of learner motivation are also represented by Weiner's attribution theory (1985). Weiner proposed that individuals perceive success or failure as being the result of either internal or external causes. Which view an individual ascribes to has an impact on the motivation of a learner. An attribute which is unstable but under the control of the learner is that of effort (Weiner, 1985). Therefore, without sufficient motivation towards instruction, the learner may lack the willingness to exert sufficient effort to be successful at learning.

Thus, the idea of motivation should not be oversimplified or dismissed as a student's own responsibility. A social cognitive model of motivation views motivation as dynamic and multifaceted (Linnenbrink & Pintrich, 2002). Further complicating this is the fact that motivation is not a stable trait characteristic, but instead is "situated, contextual, and domain-specific" (Linnenbrink & Pintrich, 2002, p. 314). This was demonstrated by a study of 458 undergraduate chemistry students that showed that through the duration of the course, students' motivation and use of learning strategies (such as rehearsal and elaboration) declined, however organizational and self-regulatory strategies were found to increase (Zusho, et al., 2003). Changes in motivation also differed for low versus high achievers. While motivation decreased for low achievers, it was found to increase for high achievers. These results demonstrate the complexity of learner motivation.

This complexity must be considered in measurements of motivation (Linnenbrink & Pintrich, 2002). "Direct measures [of learner motivation] are needed, because they will assist in the process of identifying specific motivational problems and the effects of instructional techniques on motivation" (Keller, 1983, p. 389). John Keller's work has helped considerably by developing measures of learner motivation that account for this complexity.

ARCS Model of Motivation

While there are several frameworks of learner motivation (e.g., Hardre & Miller, 2006; Keller, 1987a; Wlodkowski, 1999), one of the most researched and implemented motivational design models is Keller's ARCS model (Hardre & Miller, 2006; Small, 2000). ARCS, which is an acronym for attention, relevance, confidence, and satisfaction, is a theory of learner motivation developed by John Keller (Keller, 1983). The goal of Keller's work was two-fold: 1) to synthesize a macro-theory from the wide range of work in human motivation from a variety of fields, and 2) to develop a model for practical application of the macro-theory to improving the motivational quality of instruction (Keller, 1987a).

Keller's work resulted in a model made up of four conceptual categories that subsume the various aspects of motivation previously identified by researchers. The ARCS categories have been summarized as:

- Attention strategies for arousing and sustaining curiosity and interest;
- Relevance strategies that link to learners' needs, interests, and motives;

- Confidence strategies that help students develop a positive expectation for successful achievement;
- Satisfaction strategies that provide extrinsic and intrinsic reinforcement of effort (Small, 2000).

The ARCS categories consist of several subcategories of respective elements that are important to the motivational quality of the instruction, and are various aspects of human motivation that are supported in previous motivational research (Keller, 1987b). These subcategories represent strategies that can be employed to increase learner motivation in each area of ARCS.

Attention includes subcategories of perceptual arousal, inquiry arousal, and variability (Keller & Kopp, 1987). Keller suggests that these subcategories can be targeted in instruction by strategies such as incongruity or conflict, concreteness, variability, humor, inquiry, and participation (Keller, 1987a).

Relevance includes subcategories of familiarity, goal orientation, and motive matching (Keller & Kopp, 1987). Keller suggests that these subcategories can be targeted in instruction by strategies such as experience, present worth, future usefulness, need matching, modeling, and choice (Keller, 1987a).

Confidence includes subcategories of expectancy for success, challenge setting, and attribution molding (Keller & Kopp, 1987). Keller suggests that these subcategories can be targeted in instruction by strategies such as learning requirements, difficulty, expectations, attributions, and self-confidence (Keller, 1987a).

Satisfaction includes subcategories of natural consequences, positive consequences, and equity (Keller & Kopp, 1987). Keller suggests that these subcategories can be targeted in instruction by strategies such as natural consequences, unexpected rewards, positive outcomes, negative influences, and scheduling (Keller, 1987a).

Several studies have supported the use of the ARCS model for making the design of instruction more motivational. For example, a study of teachers' perceptions of ARCS in terms of its comprehensibility, usability, and that it will result in more motivational instruction showed that most teachers agreed with these tenets (Keller, 1987a). However, the ratings were more positive from the group of teachers who had received more professional development experiences in instructional design, therefore were better able to integrate aspects of ARCS motivation design into their preexisting knowledge of instructional design (Keller, 1987a).

Multiple studies in a variety of areas have employed the ARCS model as the theoretical framework of learner motivation, including distance education, computer-based instruction, multimedia learning, and self-directed learning (Alfassi, 2003; Gabrielle, 2003; Huett, 2006; Keller, 1999; Keller & Suzuki, 2004; Oh, 2006; Wang, 2000). The present study will extend the application of the ARCS model to understanding the impact of individualized versus collaborative SRS instructional strategies on learner motivation.

The combination of activity, feedback, and collaboration in Mazur's PI should provide an amplified impact to learner motivation in all components of ARCS. These characteristics of PI-based instruction also have the potential to positively impact learners in other ways, such as enhanced metacognitive awareness.

Peer Instruction and Metacognition

An important aspect of the PI strategy is that during peer discussions, students are to explain and justify their answer choices to each other, with the goal of convincing others of their selection (Mazur, 1997a). This "self-explanation" that occurs through peer discussions during Mazur's PI method may facilitate both metacognition and transfer.

"Self-explaining is an effective metacognitive strategy that can help learners develop deeper understanding of the material they study" (Ainsworth & Th Loizou, 2003). Gagné and Smith Jr. (1962) performed a study that involved 28 ninth and tenth-grade boys to determine the impact of requiring subjects to self-explain during practice exercises. The results of this study showed that verbalizations caused students to consider new reasons for their decisions, which facilitated "both the discovery of general principles and their employment in solving successive problems" (Gagné & Smith Jr, 1962, p. 12).

Another study examined the impact of self-explanations on ten college students who ranged in achievement levels, based on ACT scores and GPA (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). During a physics problem-solving task, the good students demonstrated self-explanations that showed they were learning with understanding, while the poor students demonstrated self-explanations that showed they were not accurately monitoring their learning, and they relied much more heavily on worked examples (Chi, et al., 1989). The findings of this study highlight that the Mazur PI strategy provides an opportunity to bring these self-explanations out in large classrooms where under normal conditions they are never observed. Through the process of revealing students' self-explanations, lower achieving students can be assisted with their metacognitive and cognitive strategies.

Additionally, a series of four studies explored what is responsible for the positive impact of verbalizations on learner performance and transfer (Berardi-Coletta, Buyer, Dominowski, & Rellinger, 1995). Three of the experiments demonstrated that it was not the verbalizations, but was actually the level of metacognitive processing that determined enhanced performance and transfer. In the fourth experiment, the higher metacognitive processing group formed more "sophisticated problem representations and developed more complex strategies" (Berardi-Coletta, et al., 1995, p. 205). Based on these results, the collaborative environment of Mazur's PI should foster metacognitive activity and therefore enhance metacognitive awareness.

Metacognition Theory

In 2001, a revision of Bloom's taxonomy of knowledge included metacognition as one of the general knowledge categories (L. W. Anderson, et al., 2001; Pintrich, 2002). "Metacognitive knowledge involves knowledge about cognition in general, as well as awareness of and knowledge about one's own cognition" (Pintrich, 2002, p. 219). Succinctly, metacognition is thinking about thinking (Kuhn & Dean, 2004, p. 270).

Metacognition is the process by which an individual monitors their own understanding, and makes decisions for action based on self-assessment (Bransford, et al., 2000; Flavell, 1979; Phye & Andre, 1986). In terms of learning, metacognition is akin to study skills (Phye & Andre, 1986, p. 208).

One of the pioneers of metacognition theory and research, Flavell, viewed metacognition as occurring across four classes: metacognitive knowledge, metacognitive experiences, goals (or tasks), and actions (or strategies) (1979, p. 906). Flavell's work in metacognition was in tandem with Piaget's work in cognitive development, and much of the early research focused on children's ability to develop metacognitive skills (Hacker, Dunlosky, & Graesser, 1998).

Metacognition has two primary operations, knowledge and control (Flavell, 1979). A person's understanding of their own cognitive operations is metacognitive knowledge, whereas a person's understanding of how to adjust their own cognition refers to metacognitive control (Otani & Widner, 2005, p. 330).

Flavell felt that metacognitive strategies could be taught. He stated, "I can also at least imagine trying to teach children and adolescents to monitor their cognition in communication and other social settings" (Flavell, 1979, p. 910). Decades later, there is a large body of research that supports the embedding of teaching metacognitive strategies along with subject area instruction (Bransford, et al., 2000). As Bransford et al. state, "Teaching practices congruent with a metacognitive approach to learning include those that focus on sense-making, self-assessment, and reflection on what worked and what needs improving. These practices have been shown to increase the degree to which students transfer their learning to new settings and events" (Bransford, et al., 2000, p. 12).

Metacognition skills of learners have a great deal of impact on conceptual development, in both individual and group learning (D. Anderson & Nashon, 2007; Haidar & Naqabi, 2008). Pintrich (2002) discussed three roles of metacognitive knowledge in learning: (1) Metacognitive knowledge of strategies and tasks, as well as self-knowledge, is linked to how students will learn and perform in the classroom, (2) Metacognitive knowledge of all these different strategies seems to be related to the transfer of learning, and (3) Self-knowledge can be either a facilitator or a constraint. (Pintrich, 2002, p. 222) The implication of these roles is the need for addressing metacognitive skill development explicitly while teaching other content (Haidar & Naqabi, 2008; Pintrich, 2002).

Metacognition has been shown to mediate between test anxiety and exam studying strategies (Spada, Nikcevic, Moneta, & Ireson, 2006). If learners did not receive assistance in metacognitive skills, test anxiety resulted in a more surface level approach to studying, even if learners are discouraged from using this strategy (Spada, et al., 2006). This demonstrates the link between metacognition and emotional factors of learning that also impact motivation.

In addition to mediating test anxiety, there is also a link between metacognition and motivation. Self-efficacy is the measure of confidence one has in oneself to be successful in something, and is a component in Bandura's Social Cognitive Theory (Bandura, 1989). Research has shown that while self-efficacy and metacognition are independent constructs, they are closely related to each other (Moores, Chang, & Smith, 2006). The research model tested in this study proposed that metacognition and self-efficacy both influence procedural knowledge directly as well as indirectly as mediated by influences on declarative knowledge (Moores, et al., 2006). Findings supported this path for self-efficacy, but suggested that metacognition more directly influences procedural knowledge. In summary, both metacognition and self-efficacy are extremely important processes in learning and are intricately linked together.

Integrating SRS-based PI into instruction provides learners with opportunities to reflect on their understanding of course concepts. Cognitive monitoring is an aspect of self-regulation of learning (Hacker, et al., 1998). Metacognitive awareness is a learner's ability to perform monitoring activities, such as comparing an actual result to the expected result (Carr & Biddlecomb, 1998). Many studies have shown that effective learning is highly correlated with the ability to perform self-regulation (Hacker, et al., 1998). Effective self-regulation is contingent on the ability to perform an accurate assessment of one's own knowledge (Schoenfeld, 1987).

SRS involves learners in a community of practice (Lave & Wenger, 1991), and Mazur's PI capitalizes on this by having students discuss their responses with each other. These social interactions can serve as sites to perform cognitive monitoring activities (Carr & Biddlecomb, 1998). A study involving instruction that focused on peer interactions demonstrated that students in those classrooms had better organization and understanding of the course concepts (Vye, Schwartz, Bransford, Barron, & Zech, 1998), which points to enhanced metacognitive monitoring and regulation during learning.

Use of SRS questions often stimulates class discussion based on the group's responses. This verbalization plays a key role in metacognition. Having a learner explain or justify choices and actions has been shown to improve task performance and transfer (Dominowski, 1998). Metacognition is facilitated by internalization of processes that begin as social, such as asking questions like "Why did you choose that?" (Kuhn & Dean, 2004). As learners make these kinds of questions internal, their reflection and self-monitoring abilities increase (Kuhn & Dean, 2004).

A strategy for using SRS questions is to present paths towards solving a problem that involves the concepts being learned. In problem solving, "metacognitive skills help the student (a) strategically encode the nature of the problem and form a mental model or representation of its elements, (b) select appropriate plans and strategies for reaching the goal, and (c) identify and conquer obstacles that impede progress" (Davidson & Sternberg, 1998, p. 48). Thus, it should be beneficial for developing metacognitive awareness if SRS questions focus on ill-defined authentic problems.

Learning achievement has shown to be a factor in the ability of learners to develop metacognitively (de Bruin, et al., 2007). In a study involving teaching an end game to novice and experienced chess players, experienced players were both able to perform the end game better, but more importantly were much better at utilizing metacomprehension and self-regulation than the non-experienced players (de Bruin, et al., 2007). In fact, the novices' metacomprehension accuracy was nearly zero. Repetitive practice in assessment has been shown to increase metacognitive accuracy, with higher achieving students enjoying better recall, less overconfidence, and were better able to adjust metacognitive predictions more accurately (Kelemen, Winningham, & Weaver, 2007). The metacognitive advantages have been shown to apply to learning of psychomotor tasks as well (Castel, 2008; Martini & Shore, 2008). Therefore, it is a necessity for lower achieving students to have more feedback in order to develop sufficiently in metacognitive monitoring throughout a course.

Research has demonstrated a quandary in regards to metacognition and learning. This dilemma results from the need for metacognitive skills in order to develop deep understanding, however a depth of understanding is in large part a prerequisite to performing effective metacognition (Vye, et al., 1998). This demonstrates the need to provide metacognitive support while learning content, so that both can be developed simultaneously. Using SRS technology can provide the real-time feedback for all learners simultaneously that is necessary for both cognitive and metacognitive growth.

Formative feedback helps learners perform metacognitive tasks such as monitoring their level of success in learning (Nicol & Macfarlane-Dick, 2004). Also, formative feedback provides opportunities for the instructor to target motivation and self-regulation (Pintrich, 2003), as well as provides the instructor with information necessary for adjusting instruction to maintain an appropriate level of challenge, such as that proposed by Vygotsky's zone of proximal development (Driscoll, 2005; Vygotsky & Cole, 1978). A primary function of SRS technology is to facilitate formative feedback for all learners simultaneously, even in large classrooms (Abrahamson, 1999).

Peer Instruction and Learner Transfer

Questions that engage learners in lower-order thinking are those that ask about facts or details (Ramsden, 2003). These questions are an important part of instruction, however they do not ensure that learners truly understand how the facts or details connect with other facts or details (Wiggins & McTighe, 1998). Questions that engage learners in higher-order thinking "are those that ask how or why something happens, or how one event, object, or idea might be related to other events, objects, or ideas" (Crawford, Saul, Mathews, & Makinster, 2005, p. 5). These questions require the learner to recall and relate multiple concepts from memory in order to effectively answer. Accordingly, the learner is required to engage both conceptual and structural knowledge. The learner is "actively asserting some position about causes or relationships" (Crawford, et al., 2005, p. 5).

One of the dimensions of student self-explanations in PI-based instruction is the ability to articulate and argue a point of view. Development of argumentation skills has been shown to enhance understanding of science concepts as students apply concepts in the formation and articulation of positions (Zohar & Nemet, 2002). Specifically incorporating instruction about scientific argumentation may result in students being able to more accurately apply biological concepts to human genetics dilemmas (Zohar & Nemet, 2002). These results were tied to the increase in metacognitive thinking, as well as changing students' view of what kind of knowledge was valued in the course (Zohar & Nemet, 2002), which demonstrates the possibility of PI to enhance not only motivation and metacognition, but also learner transfer.

While motivation and metacognition are two important aspects of meaningful learning, transfer is also an important outcome. Transfer is the application of previous learning to new situations (Haskell, 2001; Mayer, 2008). "It is important to view transfer as a dynamic process that requires learners to actively choose and evaluate strategies, consider resources, and receive feedback" (Bransford, et al., 2000, p. 66). Thus, learner transfer is reflective of higher levels of Bloom's taxonomy, such as application, evaluation, and synthesis (Bloom, 1956).

The importance of transfer as an instructional outcome cannot be overstated. "Transfer of learning is the very foundation of learning, thinking, and problem-solving" (Haskell, 2001, p. xiii). The nature of our society becoming increasingly dynamic increases the necessity that learners acquire the ability to effectively perform transfer of knowledge to situations completely foreign of the context in which the knowledge was acquired (Haskell, 2001; Reigeluth, 1999).

The concept of learner transfer originated in the doctrine of formal discipline (Mayer, 2008). It was believed that learning subjects such as Latin and geometry would result in general transfer to other behaviors, such as mental discipline and orderly thinking. The concept of general transfer was disproved by the research of Thorndike in the early 1900’s (Mayer, 2008).

The alternative for general transfer is specific transfer, in which a learner can only apply knowledge to solve problems that have been experienced before. For example, understanding how a car engine works would not transfer to understanding how a lawnmower engine works. This view presents a dilemma, because it implies that teaching for transfer requires presenting solutions to every situation possible.

The best alternative view then becomes the specific transfer of general principles or strategies (Mayer, 2008). This view may also be thought of as adaptive expertise (Bransford, et al., 2000), which is what sets apart experts from novices in a particular knowledge domain. Experts have the ability to selectively and efficiently retrieve knowledge and apply it appropriately to solve new problems (Bransford, et al., 2000; Glaser, 1992). Thus, providing students with opportunities to apply concepts to new contexts helps to develop from novice to more expert-like users of knowledge. The consistent engagement of all students in SRS questions that provide opportunities apply concepts to a variety of context-based questions should enhance learner transfer. The collaborative aspect of PI instruction may amplify these benefits.

Transfer is commonly thought of in two dimensions: near and far. However, Haskell (2001) proposed a six level taxonomy of transfer. Level One is nonspecific transfer and is the simplest form of transfer. Nonspecific transfer involves connecting new learning to prior learning. Level Two is application transfer, and involves applying prior learning to a similar situation. An example of this is learning to shoot a basketball, and then successfully making a shot during a game. Level Three is context transfer, and involves applying prior learning to a slightly different situation, such as applying math skills to physics problems. The task stays the same but the context in which to apply the task has changed. Level Four is near transfer, and involves transferring prior learning to slightly different situations. This form of transfer is the epitome of applying school learning to real world situations. Level Five is far transfer, which involves applying prior learning to situations that are quite different. Far transfer is analogic reasoning, and is applied in developing inventions and product development. Level Six is referred to as displacement or creative transfer, and is the highest form of transfer. This level of transfer results in the creation of something new from the application of prior learning to very different learning (pp. 29-30). Similar to the need for instruction to strive for higher-order thinking, instruction should also strive to foster higher levels of transfer in students. By engaging students in questioning activities with SRS, along with appropriately constructed questions, these higher levels of transfer should be more likely to result as compared to passive lecture strategies.

Instruction that promotes the ability to perform transfer, or cognitive flexibility, requires more than passive learning pedagogy (Jonassen, 2003). Cognitive flexibility has been proposed as a theory of how individuals adapt their structure of knowledge in order to effectively deal with a unique situation (Spiro, et al., 2003). In addition, instruction that targets transfer also enhances metacognition (Cormier & Hagman, 1987). "Transfer can be improved by helping students become more aware of themselves as learners who actively monitor their learning strategies and resources and assess their readiness for particular tests and performances" (Bransford, et al., 2000, p. 67).

Effective implementation of SRS technology such as through the PI strategy, may serve as a catalyst for learner transfer in large classrooms. It also makes this aspect of learning more visible. Without SRS, the instructor can only hope that the learners are each internally performing the processes that promote metacognition and transfer, along with wondering if students are performing motivated behaviors such as mentally attending to instruction and building confidence in their understanding of concepts.

Facilitating students' ability to construct explanations and to effectively participate in argumentative discourse hinges on three goals for students: sense-making, articulating, and persuading (Berland & Reiser, 2008). For example, students have recently been shown to struggle to perform the goal of persuading others, which was credited to the limited social interactions in classrooms that are necessary to develop this skill (Berland & Reiser, 2008). Mazur's PI method deliberately involves students in negotiating positions through the PI process, and therefore may result in enhanced meaningful learning, as represented by enhanced motivation, metacognitive awareness, and transfer.

Summary

While PI has been one of the most prominent forms of SRS pedagogy represented in the literature, there is a lack of investigations into the impact of PI on aspects of learning beyond exam performance. What evidence exists in regards to learner attitudes is based on rudimentary, non-validated measures (e.g., Crouch & Mazur, 2001; Fagen, et al., 2002; Rao & DiCarlo, 2000). Thus, the goal of this study is to explore this gap in SRS research.

This literature review has examined how active learning in large classrooms can be facilitated by SRS-based instruction. This is possible due to the ability to enhance feedback and collaboration through strategic pedagogical implementations of the technology. Literature was presented to provide a foundation from which to compare an individualized versus collaborative strategy for SRS. This comparison focused on the possible differences in the impact of these two SRS pedagogies on learner motivation (Keller, 1987a), metacognitive awareness (Flavell, 1979; Schraw & Dennison, 1994), and ability to perform transfer of conceptual knowledge (Haskell, 2001; Spiro, et al., 2003).

Chapter III

METHODOLOGY

Research Questions

The research questions investigated in this study were:

(1) Is there a significant change in motivation for students experiencing Student Response System (SRS)-based instruction, relative to students engaged in Peer Instruction versus students engaged in individualized SRS-based instruction?

(2) Is there a significant change in metacognitive awareness for students experiencing SRS-based instruction, relative to students engaged in Peer Instruction versus students engaged in individualized SRS-based instruction?

(3) Is there a significant difference in the ability to perform entomology content knowledge transfer for students experiencing SRS-based instruction, relative to students engaged in Peer Instruction versus students engaged in individualized SRS-based instruction?

Hypotheses

The following null hypotheses were used to test each of the research questions:

$H_0$1: There will be no significant change in learner motivation for SRS-based instruction in general or for Individual Responding (IR) versus Peer Instruction (PI) strategies.

$H_0$2: There will be no significant change in metacognitive awareness for SRS-based instruction in general or for IR versus PI strategies.

$H_0$3: There will be no significant difference in the ability to perform entomology content knowledge transfer for SRS-based instruction in general or for IR versus PI strategies.

Research Design

This study employed a quasi-experimental comparative design that used a convenience sample of intact groups of students enrolled in an introductory undergraduate Entomology course for non-science majors. One section of the course served as the treatment group while another section served as the control group.

The independent variable in this study was the SRS strategy implemented in the course instruction. For this study, Mazur's PI strategy was the treatment (Mazur, 1997a) and individualized SRS-based instruction was the control. Other than the different SRS strategies, there was no variation in the content, methods, or instructors between the treatment and control sections of the course.

The three dependent variables in this study were (a) learner motivation, (b) metacognitive awareness, and (c) ability to perform transfer of course concepts. Learner motivation was measured by the Course Interest Survey (CIS, Keller, 2006), metacognitive awareness was measured by the Metacognitive Awareness Inventory (MAI, Schraw & Dennison, 1994), and transfer was measured by a custom-designed instrument referred to as the Entomology Concepts Transfer Assessment (ECTA).

The treatment was administered for the duration of Unit One of the course, which lasted approximately four weeks. The instruments were combined into a single questionnaire. The pre-test was administered at the beginning of the course and included a brief set of demographic questions, the CIS, and the MAI. The post-test included the CIS, the MAI, and the ECTA.

Participants

Participants in this study were 194 students enrolled in a large undergraduate science course at a large Midwestern university. This course was an introduction to entomology that is taken by non-science majors to satisfy the university's natural science general education requirement. The course was selected for several reasons. First, students that take the course are not pursuing a science degree and therefore most of them are not inherently interested in the course. This provided a course interest baseline from which to measure any impact to learner motivation. Second, the course had multiple sections with similar demographics, and each section having similar sized enrollment: 99 students in the treatment section and 95 students in the control section. This provided a large, homogenous sample for each group.

As is common in behavioral studies, small to medium effect sizes were expected, so a large sample size was necessary to detect this level of effect while maintaining sufficient power (Stevens, 1996). The size of the sample provided in this course allowed statistical tests to be performed at nominal Type I error rates while maintaining sufficient power to detect a treatment effect if one existed.

Homogeneity between the groups was important to be able to control as many nuisance variables as possible. To ensure homogeneity of the learners between the two sections, demographic data from a pilot study was analyzed with regard to gender, ethnicity, high school GPA, and high school science course grades, and science ACT scores. ANOVA tests showed no significant differences among students in different sections in regards to demographics as well as in motivation towards the course at the point of data collection, which was near the end of the course. ANOVA tests showed that the subjects in the present study were not statistically different based on demographic variables.

Third, the same instructor taught both sections of the course. This instructor has used SRS in the course for several semesters. The SRS strategy that has been used in previous semesters –that is, the individualized responding method, was maintained for the control group in this study.

Treatment

The treatment for this study was Mazur's PI strategy for SRS-based instruction (Mazur, 1997a), as compared with individualized SRS-based instruction. According to the PI strategy, students were presented with a conceptual question, given time to reflect on the question and then responded with their SRS pad.

The histogram of responses was displayed to all students, and then students discussed their responses in self-selected peer groups of two or three. The groups were selected based on student proximity. The students participated in the question discussion with the intention of convincing others that their response is correct. Finally, students again responded to the question individually, and the histogram of responses was displayed. The instructor then discussed the question and responses with the whole class.

Mazur's PI strategy normally utilizes developed question sets, referred to as ConcepTests, that are specifically written to draw out student misconceptions as well as target for a 50% accuracy rate for best discussion to occur (Mazur, 1997a). Since there was not a set of ConcepTests available for the Entomology subject area, the questions used previously in this course were evaluated by three independent experts and adapted to best meet the guidelines for use in the PI method. For example, one question was:

> What might help to explain the higher incidence of Lyme disease in the northern states vs. the southern states?
>
> (a) There are more ticks in the north than in the south
>
> (b) There are more small reptiles in the southern states
>
> (c) Northern people are less resistant to Lyme disease
>
> (d) There is just as much Lyme disease in the south but people do not report it

Both the IR and PI sections used the same questions during each Unit One class session (Appendix E).

Instruments

Each of the dependent variables used in this study involves complex constructs of learner characteristics. These constructs can be difficult to validly and reliably measure. Therefore, previously developed and validated instruments were used for measuring motivation and metacognitive skills. Measurement of the ability to perform transfer of the Unit One concepts required that a custom assessment instrument be used.

Course Interest Survey

The Course Interest Survey (CIS, Appendix B) is a situational measure of students' motivation towards a particular instructional setting (Keller, 2006). The CIS consists of 34 items that measure each of the four components of the ARCS model of learner motivation: attention, relevance, confidence, and satisfaction (per Keller, 1987a). Subjects rate statements using a Likert scale ranging from Not True (1) to Very True (5).

For example, an Attention statement is “The students in this class seem curious about the subject matter.” A Relevance statement is “The things I am learning in this course will be useful to me.” A Confidence statement is “Whether or not I succeed in this course is up to me.” A Satisfaction statement is “I enjoy working for this course.” From these ratings, a total motivation scores can be calculated, as well as a score for each of the ARCS components.

Of the 194 students enrolled in the two section of the course, 116 responded fully to the both the pre- and post-CIS. In the control group, 61 students out of 95 completed the CIS, with 33 being male and 28 being female. In the treatment group, 55 students out of 99 completed the CIS, with 20 being male and 35 being female.

Prior psychometric testing of the CIS on 200 undergraduate and graduate students produced Conbach’s alpha reliability estimates for Attention (α=.84), Relevance (α=.84), Confidence (α=.81), Satisfaction (α=.88), and Total score (α=.95) (Keller, 2006). During pilot testing, 78 students in two sections of this entomology course completed the CIS by use of SRS following the procedures that were later used to collect data in this study. Cronbach’s alpha scores were produced for Attention (α=.77), Relevance (α=.74), Confidence (α=.73), Satisfaction (α=.85), and Total score (α=.92). Table 1 summarizes the reliability estimates from the pre- and post-administration of the CIS in the present study. These results show that the CIS is a reliable measure of the construct of motivation as represented by the ARCS model, and the reliability is maintained with use of SRS for responding to the instrument.

Table 1

Chronbach's Reliability Estimates for Course Interest Survey Responses

	Pre α			Post α		
	IR	PI	Combined	IR	PI	Combined
Attention	.79	.77	.78	.77	.81	.79
Relevance	.74	.72	.73	.68	.79	.74
Confidence	.60	.68	.64	.55	.70	.62
Satisfaction	.84	.78	.81	.77	.77	.77
Overall	.91	.89	.90	.90	.92	.91

Note: IR = Individually Responding Group; PI = Peer Instruction Group.

The data from the CIS were checked for each of the assumptions necessary for the repeated measures MANOVA, and were found to satisfactorily meet all assumptions. These methods included evaluation of histograms, Levene's test for normality, multivariate Box's M, as well as homogeneity across groups based on demographic variables.

Metacognitive Awareness Inventory

The Metacognitive Awareness Inventory (MAI, Appendix C) contains 52 items and is used to assess an individual's metacognitive skills according to two factors: knowledge of cognition and regulation of cognition (Schraw & Dennison, 1994). Subjects respond to a statements with a Yes or No response. One point is given for each Yes response. Knowledge of cognition is measured with 17 statements such as "I understand my intellectual strengths and weaknesses." Regulation of cognition is measured with 35 statements such as "I think about what I really need to learn before I begin a task." Factor analysis has supported the validity of the instrument to measure these two factors with a high degree of internal consistency (α=.95, Schraw & Dennison, 1994). Table 2 summarizes the reliability estimates from the present study.

Table 2

Chronbach's Reliability Estimates for Metacognitive Awareness Inventory Responses

	Pre α			Post α		
	IR	PI	Combined	IR	PI	Combined
Knowledge of Cognition	.69	.76	.73	.76	.82	.80
Regulation of Cognition	.83	.82	.83	.89	.88	.89
Overall	.85	.87	.86	.90	.91	.90

Note: IR = Individually Responding Group; PI = Peer Instruction Group.

Of the 194 students enrolled in the course, 108 responded fully to the MAI. In the IR section, 54 students out of 95 completed the CIS, with 29 being male and 25 being female. In the PI section, 54 students out of 99 completed the CIS, with 19 being male and 35 being female.

The data from the MAI were checked for each of the assumptions necessary for the repeated measures MANOVA using the same procedures as the evaluation of CIS data, and were found to satisfactorily meet all assumptions.

Entomology Concepts Transfer Assessment

The ability of students to apply Unit One concepts to novel situations was measured by a twenty-item assessment, referred to as the Entomology Concepts Transfer

Assessment (ECTA, Appendix D). The researcher, the course professor, and the course graduate assistants collaboratively developed this assessment. The process of developing the assessment questions followed a specific sequence: (1) identify the core concepts to be learned in Unit One, (2) design questions that involve the application of those concepts to unique situations, with degree of difficulty delineating near and far transfer, and (3) create multiple choice options that require near or far transfer skills to answer the questions. For example, a near transfer item is "The 4 largest insect orders have what in common? (a) chewing mouthparts; (b) 2 pairs of wings; (c) complete metamorphosis; (d) gradual metamorphosis". A far transfer item is "What could be one potential consequence of all millipedes disappearing? (a) less incidence of vector-borne disease; (b) certain insects might flourish from lack of predation; (c) large build-up of decaying plan matter; (d) many plants would go unpollinated". One point was given for each correct response, and these points were summed according to category to form near and far transfer scores.

Three entomology experts and three education experts independently reviewed the ECTA questions to assess the face-validity of the knowledge transfer instrument. This process has been supported as a means for instrument content validation (Gage & Berliner, 1998). The reviewers unanimously agreed that the questions were valid for measuring discriminately between performance of near and far levels of transfer. Table 3 provides a summary of the reliability estimates calculated from the responses to the ECTA.

Table 3

Chronbach's Reliability Estimates for Entomology Concepts Transfer Assessment Responses

	IR	PI	Combined
Near Transfer	.40	.09	.29
Far Transfer	.47	.55	.50
Overall	.64	.47	.58

Note: IR = Individually Responding Group; PI = Peer Instruction Group.

Materials

The SRS used in this study are the Classroom Performance System Radio Frequency™ (CPS RF), which is produced and marketed by eInstruction™. The CPS RF™ system consisted of student units, an instructor's receiver, and CPS™ software, as shown in Figure 1. The instructor's receiver connects to the computer by Universal Serial Bus (USB) port. The student units are handheld pads that are the size of a small television remote control. These pads communicate by RF with the instructor's receiver. Since the pads use RF, no line of site is necessary between the pad and the receiver. The pads have a range of about 200 feet, and can support a classroom of up to 1,000 students.

Figure 1. CPS RF Receiver and Response Pad.

(Source: eInstruction.com. Reprinted with permission.)

The CPS RF™ pad allows numeric entries of up to 12 characters. The input can be viewed on a three-line LCD screen, as well as confirmation that the response was received. Students also see a visual confirmation on the CPS™ software screen projected to the class that their response was correctly received. As the students respond to a multiple choice question, the CPS™ software collects and aggregates the student responses, then displays a histogram of the results. This result is usually projected for the entire class to see.

Three features of the CPS RF™ allow it to be used as a data collection instrument. First, student responses can be collected anonymously. The pads allow the student to enter up to 12 numeric digits, which will allow the participants in this study to enter the last five digits of their Social Security numbers, thereby allowing the pre and post questionnaire responses to be linked together for each participant. Second, student managed assessment (SMA) mode allows each student to respond to the research questionnaire at his or her own pace. When an SMA session is started, the transmitter sends the number of questions for the set to the student pads. Then the students use a paper copy of the research questionnaire and respond to each item individually on their own pad. As the students respond at their own pace, the CPS™ software displays the responses on the instructor's screen as they are received. When an anonymous session is started in SMA mode, the screen does not show the student names, as Figures 2 and 3 demonstrate. Third, the raw data for each CPS session was easily exported to a spreadsheet application. This allowed efficient collection the data prior to inserting the data into a statistical software application. The combination of these three factors made the use of SRS a powerful research tool that streamlined the data collection and analysis in this study.

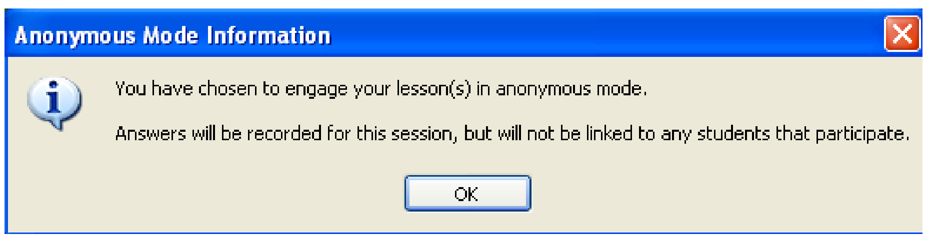

Figure 2. CPS Software Alert before Entering Anonymous Mode.

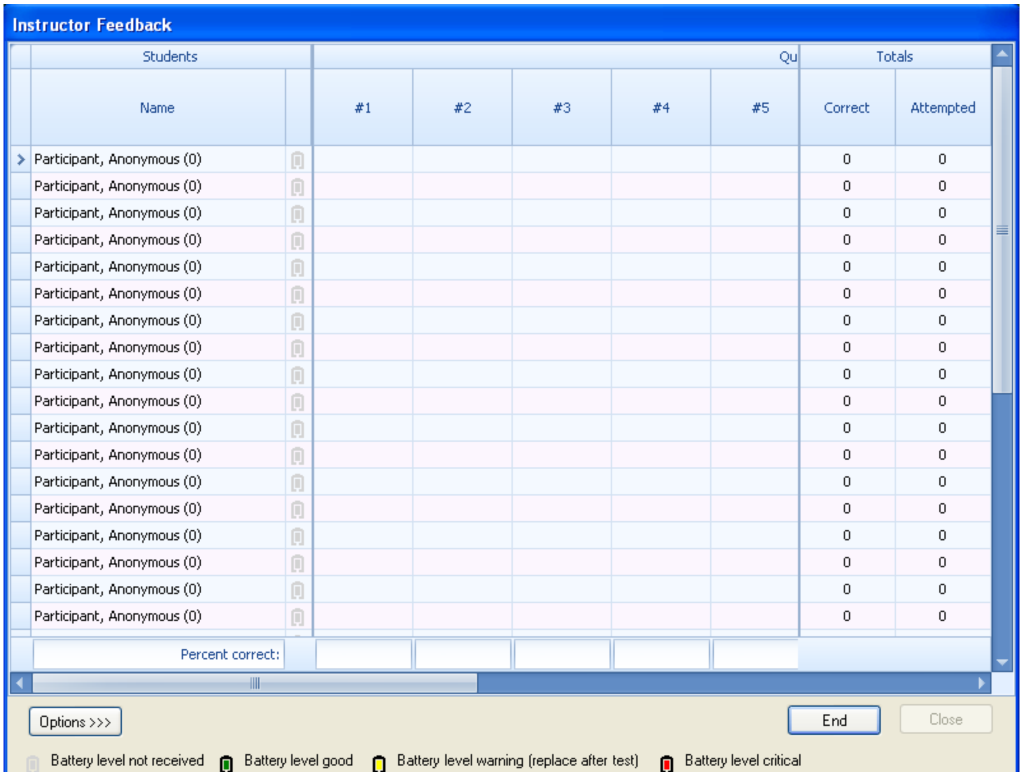

Figure 3. CPS Software While in Anonymous, Student Paces Assessment Mode Setting.

The course used in this study occurred in a 100-seat lecture hall with stadium-type seating. The seats were arranged in three sections, with the instructor area at the bottom of the room's incline. The room was equipped with a computer, projector, document camera, and adjustable lights. The instructor brought the SRS receiver with her to the classroom and students brought their own SRS pad with them to each class session. The control section of the course occurred from 10:30 A.M. to 11:50 A.M. on Tuesday and Thursday of each week, and the treatment section of the course occurred from 12:30 P.M. to 1:50 P.M. on Tuesday and Thursday of each week.

Procedures

Data collection took place during the Fall 2008 semester. This study occurred during Unit One of the course, which focused primarily on insect classification. Subjects in this study were assigned to the PI section or IR section by a convenience intact group sample based on which section they were enrolled in. The decision of which strategy to use in each section was decided by a coin toss.

At the third class session, the solicitation script approved by the Institutional Review Board (Appendix F) was read to all students at the beginning of the class session in which data was collected. Next, a paper copy of the research questionnaire was distributed to all students, with the informed consent form attached to the front of the questionnaire. The students who chose to participate in the study removed the informed consent form from the questionnaire. This served as their consent to participate in the study under the terms outlined in the consent form. Students did not receive any inducements or rewards for participating in the study.

The first administration of the questionnaire included the basic demographic questions, the Course Interest Survey, and the Metacognitive Awareness Survey. To collect the responses from students on the questionnaire by using SRS, the CPS™ software contained a module with the questions included in the questionnaire. The CPS session was initiated in Anonymous Student Managed Assessment mode. This process was displayed to students to make it evident that the responses were received anonymously. Once the session was initiated, the student response pads downloaded the question set, and then participants began to enter their responses to the questionnaire with their response pad. The first question asked the participant to enter the last 5 digits of his or her Social Security number. This number allowed the participants' responses on the subsequent questionnaire to be linked to their initial questionnaire responses, while maintaining the participants' anonymity.

For the next four weeks, the students in the course received instruction on identical concepts covered in Unit One of the course. The IR section received instruction during Unit One that utilized SRS to increase feedback in an individualized fashion. The PI section received instruction during Unit One that utilized SRS to increase both feedback and collaboration.

At the end of the Unit One instruction, but before the Unit One exam, the research questionnaire was administered to the control and treatment groups, following the same procedures as the first questionnaire administration. The second version of the research questionnaire did not include the demographic questions, but added the ECTA. The participants did not receive the results of their own assessment, however the questions were discussed as part of the review for the Unit One exam. At this time, participants were able to determine for themselves the results of their own performance.

The procedures for this study are summarized in Table 4. CS refers to the groups assigned by convenience sample of intact course sections. X_{IR} represents the independent responding SRS group. X_{PI} represents the Peer Instruction SRS group. O_1 refers to the demographics questionnaire. O_2 refers to the pre and post administrations of the CIS and the MAI. O_3 refers to the post-test-only administration of the ECTA.

Table 4

Procedures

CS	$O_{1, 2}$	X_{IR}	$O_{2, 3}$
CS	$O_{1, 2}$	X_{PI}	$O_{2, 3}$

This study involved the use of student response system technology. Therefore it seemed logical to also use the technology for collecting student responses to the research instruments as well. The strategy was effective for the most part, however some issues did arise. For example, some students at the beginning of the course experienced difficulty with their pad not being recognized when a question session was engaged. Most often this was due to students mis-entering their pad serial numbers while registering their pad to the course through the CPS Online™ website. This caused a decrease in the number of responders to the initial questionnaire, and therefore excluded them from the pre/post analysis.

Another issue that occurred was several instances where a subject's questionnaire contained one or more missing responses. In situations where a subject stopped responding to the majority of the questions, those cases were omitted from the analysis. However, there were several cases of subjects that did not respond to four or fewer questionnaire statements. There was no clear pattern to the non-responses, so it was assumed that these small numbers of missing responses were due to the subject inadvertently hitting the send key before entering a choice, thereby leaving that question blank. In order to reclaim these cases, a strategy was used whereby subjects who had four or fewer blank questions in either the CIS or MAI, an average of the rest of the respective group's response to that question was used to replace those missing responses. Use of this strategy increased the usable number of responses from 96 to 116 on the CIS, and from 67 to 108 on the MAI. It was felt that this increase in sample size warranted using the transformation procedure to reclaim these missing cases.

Analysis

The data collected during this study was analyzed using Statistical Package for Social Sciences™, version 16. Hypothesis One asked if there would be a difference in motivation overall, or between the IR and PI sections. This hypothesis was tested using a split-plot factorial MANOVA (Kirk, 1995). The within variable was time, as the CIS was administered pre- and post-treatment. The between variables were the treatment and gender. The CIS provided scores for each of the components of ARCS: attention, relevance, confidence, and satisfaction. Therefore, each of these dependent variables was part of the analysis.

Hypothesis Two asked if there was a difference in metacognitive awareness overall, or between the IR and PI sections. This hypothesis was also tested using a split-plot factorial MANOVA. The within variable was time, as the MAI was administered pre- and post-treatment. The between variables were treatment and gender. The MAI provided scores for both knowledge of cognition and regulation of cognition. Therefore, each of these dependent variables was part of the analysis.

Hypothesis Three asked if there was a difference in the ability to perform conceptual transfer between the IR and PI sections. This hypothesis was tested with a MANOVA of the results of the ECTA, factoring for both the treatment and for gender.

Validity of the Study

As is common with all quasi-experimental research, there were several nuisance factors that posed challenges for this study. The most difficult challenge was isolating factors that could influence the dependent variables to only that occurring by the presence and use of the treatment method of instruction. While theoretically desirable, this was practically impossible. However, the design of this study was intended to best accommodate the limitations, based on the parameters within which the study had to occur.

Violating the assumption of independence of observations is serious threat to a research design (Stevens, 1996). Since this study involved group interaction, the independence of observations may be questioned. However, when the fact that each student responded with SRS individually was considered, the treatment became individualized, and the concern for independence was accommodated.

Other threats to internal validity include selection and mortality. Selection was accounted for by the measures that ensured homogeneity of the groups. Mortality was accounted for by the use of intact classrooms within a semester period. While participation was voluntary, most students were willing to participate.

To reduce the influence of the focus of the study on students' responses, students were informed that the study is investigating learner characteristics in general, and not motivation, metacognition, and transfer based on SRS instructional methods. If students felt particularly positive or negative towards the use of SRS, this could have influenced their responses on the motivation instrument in particular. For example, if a student was disgruntled at having to purchase a SRS pad for the course, knowing the goal of the study might have encouraged the student to respond negatively with the intention of voicing opposition for having to purchase a SRS pad. Purchasing an SRS pad was a course requirement for all students, apart from of this study.

Chapter IV

RESULTS

The purpose of this study was to investigate the impact of two strategies for using student response systems in a large undergraduate science course for non-majors on course motivation, metacognitive awareness, and learner transfer. This chapter summarizes the results of the data collected and the statistical analyses conducted in regards to each of the research questions.

Learner Motivation

The first research question in this study asked if there would be a significant impact on learner motivation for students in a large undergraduate course that used Student Response System (SRS)-based instruction, as well as if there would be a difference in the impact on learner motivation depending on what type of SRS strategy was used. Table 5 presents a summary of the means and standard deviations for the four ARCS components of the Course Interest Survey (CIS) measure of learner motivation for each section as well as the sections combined.

Table 5

Descriptive Statistics for Course Interest Survey Responses

	Section					
	IR (n=61)		PI (n=55)		Combined (N=116)	
	M	SD	*M*	SD	*M*	SD
Attention						
Pre	3.27	0.7	3.19	0.68	3.23	0.69
Post	3.23	0.75	3.28	0.78	3.26	0.76
Relevance						
Pre	3.46	0.68	3.46	0.67	3.46	0.67
Post	3.48	0.63	3.48	0.75	3.48	0.69
Confidence						
Pre	4.03	0.49	4.03	0.53	4.03	0.51
Post	3.85	0.54	3.90	0.61	3.87	0.57
Satisfaction						
Pre	3.39	0.74	3.43	0.64	3.41	0.69
Post	3.43	0.7	3.48	0.69	3.45	0.69

Note. IR – Individually Responding Group; PI – Peer Instruction Group.

A split-plot factorial MANOVA was conducted for attention, relevance, confidence, and satisfaction with section (IR, PI) and gender as the between subjects factors and time (pre and post) as the within subjects factor. There were no significant results among three or two-way interactions, however, the results did reveal a significant main effect for time, $F(4, 109) = 6.23$, $p < .01$, partial $\eta^2 = .19$. At the univariate level, the multivariate significance was shown to be solely due to a significant drop in confidence $F(1, 112) = 16.03$, $p < .01$, partial $\eta^2 = .13$. Accounting for 13% of the variance, this is considered a meaningful effect size (Stevens, 1996). For both sections combined, confidence dropped from $M = 4.03$ to $M = 3.87$, with a larger decrease in the IR section as illustrated in Figure 4.

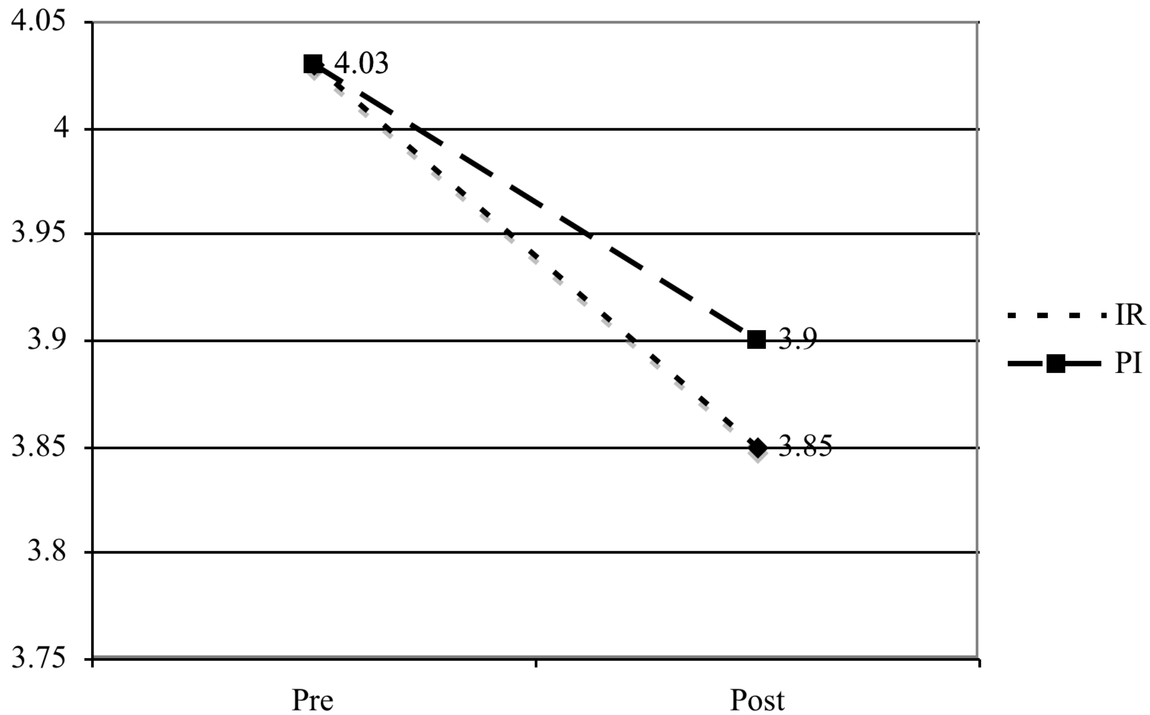

Figure 4. Change in Confidence by Section.

Metacognitive Awareness

The second research question in this study asked if there would be a significant impact on metacognitive awareness for students in a large undergraduate course that used SRS-based instruction, as well as if there would be a difference in the impact on metacognitive awareness depending on what type of SRS strategy was used. Table 6 presents a summary of the means and standard deviations for knowledge and regulation of cognition from the Metacognitive Awareness Inventory (MAI) measure of metacognitive awareness for each section as well as the sections combined.

Table 6

Descriptive Statistics for Metacognitive Awareness Inventory Responses

	Section					
	IR (n = 54)		PI (n = 54)		Combined (N = 108)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Knowledge of Cognition						
Pre	14.16	2.48	13.62	2.95	13.89	2.72
Post	14.70	2.55	14.03	3.19	14.36	2.89
Regulation of Cognition						
Pre	24.97	5.76	25.43	5.61	25.20	5.67
Post	25.75	6.79	26.78	6.46	26.26	6.62

Note. IR – Individually Responding Group; PI – Peer Instruction Group.

A split-plot factorial MANOVA was conducted for knowledge of cognition and regulation of cognition with section (IR, PI) and gender as the between subjects factors and time (pre and post) as the within subjects factor. The results revealed a significant main effect for time, $F(2, 103) = 3.47$, $p < .05$, partial $\eta^2 = .06$. At the univariate level, knowledge of cognition, $F(1, 104) = 5.69$, $p < .05$, partial $\eta^2 = .05$, was significantly different over time. For both sections combined, knowledge of cognition increased from

M = 13.89 to M = 14.36. Figure 5 illustrates the increase in knowledge of cognition for each section.

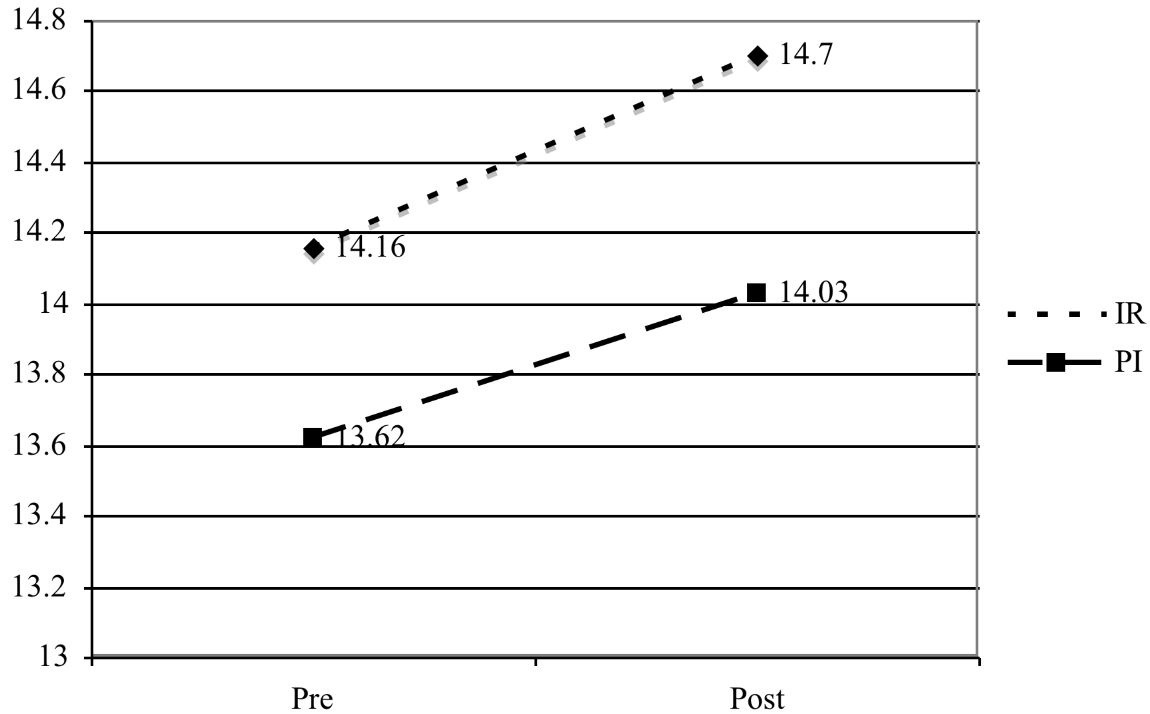

Figure 5. Change in Knowledge of Cognition by Section.

The MANOVA also revealed a multivariate significant interaction effect for Time X Section X Gender, $F(2, 103) = 3.32$, $p < .05$, partial $\eta^2 = .06$. A univariate test showed that this was due to a significant difference for regulation of cognition, $F(1, 104) = 4.95$, $p < .05$, partial $\eta^2 = .05$, between males and females in each section. Figure 6 summarizes the interaction effect in that males in the IR section improved significantly in regulation of cognition, $t(28) = 2.12$, $p < .05$, $d = .39$, from pre-test ($M = 25.21$, SD = 6.38) to post-test ($M = 27.02$, $SD = 7.27$), while females in the PI section significantly improved in regulation of cognition, $t(34) = 2.91$, $p < .01$, $d = .49$, from pre-test (M = 25.41, SD = 4.88) to post-test (M = 27.42, SD = 5.72). The means and standard deviations for responses on regulation of cognition by section and gender are presented in Table 7. Although there was a decrease in regulation of cognition for females in the IR section, the drop was not statistically significant.

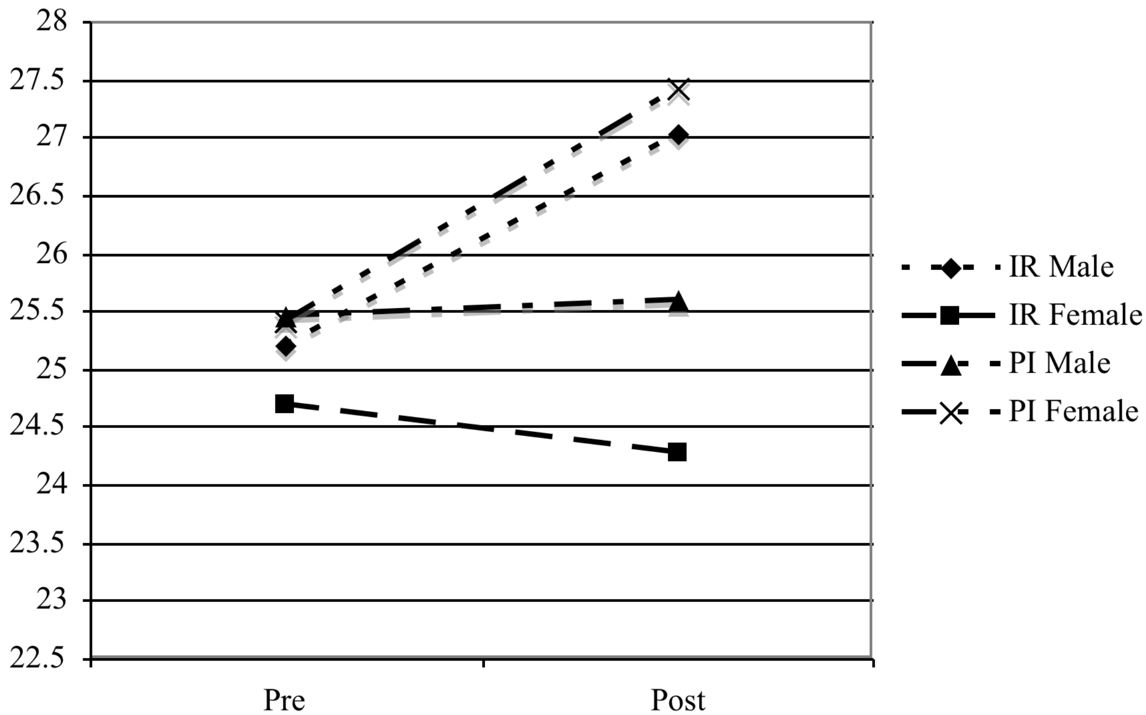

Figure 6. Change in Regulation of Cognition by Section and Gender.

Table 7

Regulation of Cognition by Section and Gender

	Section							
	IR				PI			
	Male (n = 29)		Female (n = 25)		Male (n = 19)		Female (n = 35)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Regulation of Cognition								
Pre	25.21	6.38	24.69	5.07	25.45	6.90	25.41	4.88
Post	27.02*	7.27	24.29	5.99	25.60	7.67	27.42**	5.72

*Significant at $p < .05$. **Significant at $p < .01$.

Transfer

The third research question in this study asked if there would be a significant difference in the ability to perform near and far transfer of course concepts for students in a large undergraduate course that used SRS-based instruction, depending on what type of SRS strategy was used. Table 8 presents a summary of the means and standard deviations for each section of the Entomology Concepts Transfer Assessment (ECTA) scores.

Table 8

Descriptive Statistics for Near and Far Transfer

	Section	*M*	*SD*	N
Near Transfer	IR	4.61	1.76	46
	PI	5.53	1.61	36
Far Transfer	IR	4.17	1.89	46
	PI	4.08	1.95	36

Note. IR – Individually Responding Group; PI – Peer Instruction Group.

A factorial MANOVA was conducted for near and far transfer with section (IR, PI) and gender as the between subjects factors. The results revealed a multivariate significant difference between the two sections, $F(2, 77) = 3.56$, $p < .05$, partial $\eta^2 = .09$. At the univariate level there was a significant difference between the two sections for near transfer, $F(1, 78) = 4.56$, $p < .05$, partial $\eta^2 = .06$. The PI section scored significantly higher on near transfer ($M = 5.53$, $SD = 1.61$) than the IR section ($M = 4.61$, $SD = 1.76$). Figure 7 summarizes these differences.

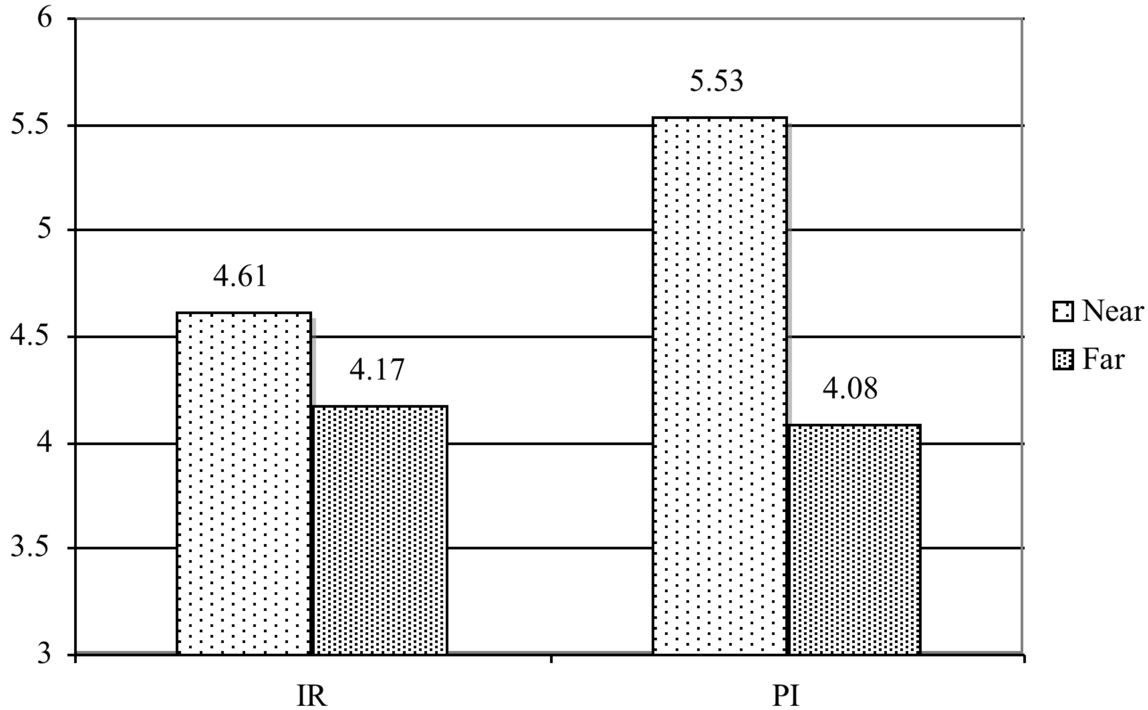

Figure 7. Near and Far Transfer by Section.

Chapter V

DISCUSSION

The results of this study are discussed relative to the research questions in the following sections: (a) Student Response System (SRS) instruction and learner motivation, (b) SRS instruction and metacognitive awareness, and (c) SRS instruction and learner transfer. Limitations of the study are discussed, followed by implications for practice and suggestions for further SRS research.

SRS Instruction and Learner Motivation

This study sought to examine the impact of SRS-based instruction on learner motivation, which previously has only been measured through anecdotal evidence (eg., Poirier & Feldman, 2007). The Course Interest Survey (CIS) was used to more robustly measure learner motivation in regards to attention, relevance, confidence, and satisfaction. The only significant change in motivation was a drop in learner confidence, regardless of Peer Instruction (PI) or Individualized Responding (IR) section. Several areas of motivation theory are drawn from to explain the CIS results, including question difficulty, attribution theory, and goal orientation theory. Also, an alternative view is offered to suggest the drop in confidence many not have been a negative outcome, but instead may have been a recalibration to a more appropriate level, when considered in concert with the increased metacognitive awareness.

Due to the nature of increased engagement through use of SRS, there was an expectation to see an increase in all aspects of ARCS motivation. The continual opportunities for students to try out their understanding and receive instant feedback, in comparison with the responses of their peers, was expected to particularly increase learner confidence. However, this was not the case. The analysis of pre and post responses on the CIS revealed a significant drop in confidence for students in both sections of the course, regardless of gender.

The construct of learner confidence represents learners' feelings of personal control and expectancy of success (Keller, 2008). If the learners in this course experienced a decrease in confidence, then the first consideration is whether this was a result of the SRS questions used. The instructor is an important variable in the equation of learner motivation, particularly for learner confidence and satisfaction (Small & Gluck, 1994). This is mostly through deciding at what level of difficulty or complexity is most appropriate to instruct learners (Margolis & McCabe, 2004). Therefore, if the SRS questions were too difficult at the onset, then learners who did not answer initial questions correctly may have experienced a feeling of perpetual falling behind as they continued to struggle with the questions.

Another explanation of the decrease in confidence may have to do with the displaying of a histogram of the students' responses to each question. Seeing a chart of their wrong choice in comparison to a majority of students selecting a correct choice may have contributed to some learners experiencing doubt about their success in the course. This could suggest that learner attribution could be a factor in how learners respond to SRS-based feedback. According to Attribution Theory, learners differ on what they attribute to success or failure in learning (Weiner, 2008). While some students attribute success to internal control such as ability and effort, others attribute success to external control, such as chance or luck (Weiner, 2008). This is akin to an athlete who attributes success or failure as being a result of wearing a particular article of clothing. It may be that use of SRS questioning and feedback may serve to inadvertently encourage external attributions in learners.

Another consideration in the loss of confidence may be explained through Goal Orientation Theory (Elliott & Dweck, 1988). According to goal theory, learners ascribe to either learning goals or performance goals. Learning goals students seek challenges and pursue mastery while performance goals students seek to gain praise or avoid negative judgment (Elliott & Dweck, 1988). Use of SRS questioning in different ways may encourage either learning or performance goals in students. For example, in the course used in this study, students are not completely anonymous, as they are registered to their SRS pad and are therefore tied to their responses. This may encourage a performance goal approach in the students. As Elliott and Dweck (1988) found, learners that are both performance oriented and low in confidence exhibit the same characteristics as learned helplessness. Considering the drop in confidence resulting in this study, if the students were also adopting a performance orientation, this would be a great concern.

Alternatively, the drop in learner confidence may not necessarily be a negative outcome. As Figure 8 demonstrates, both extremely high and extremely low confidence can hinder learner performance (Keller, 1987c).

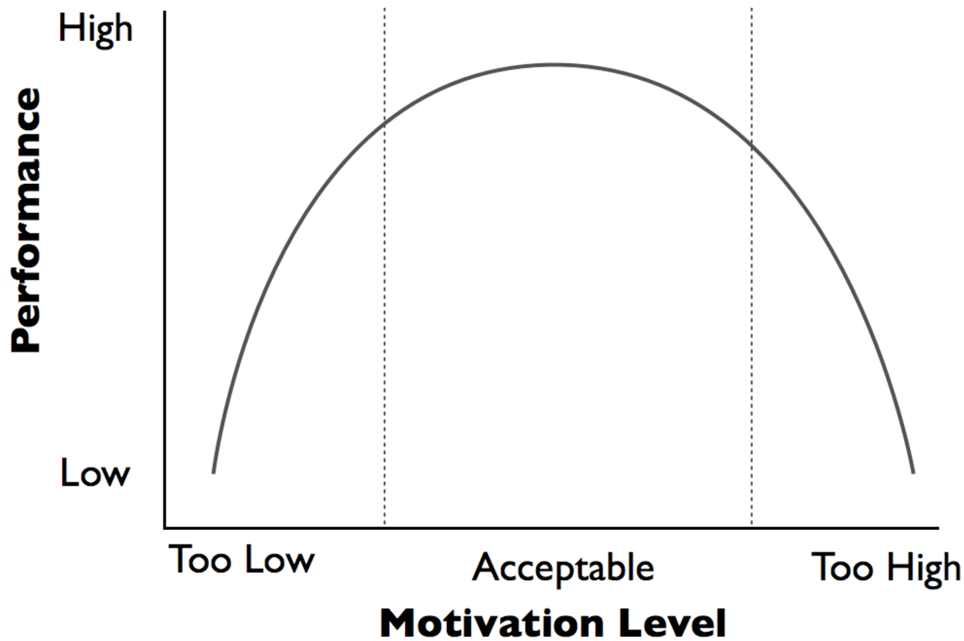

Figure 8. Relationship of Performance to Motivation Level. From "The systematic process of motivational design," by J. M. Keller, 1987, *Performance and Instruction*, 26(9-10), 1-8. Copyright 1987 by Wiley Periodicals, Inc. Adapted with permission.

A recent study has pointed out that generationally, today's learners have higher levels of self-confidence than learners 30 years ago, however this is not accompanied by higher levels of competence (Twenge & Campbell, 2008). Therefore, overconfidence may be a detrimental attribute of this generation of learners. It is possible that students in this study began the course at an overconfident level, and as a result of improvements to knowledge and regulation of cognition, the students more accurately calibrated their expectancy for success, and therefore rated their confidence levels at a lower, but more realistic level. Therefore, the drop in confidence may in fact indicate better self-regulatory practices by the learners. This is supported by the significant improvement in metacognitive awareness.

SRS Instruction and Metacognitive Awareness

This study is one of the first attempts to examine the impact of SRS-based instruction on metacognition of learners. Research has suggested that learners must experience within-instruction opportunities for developing metacognitive skills (Pintrich, 2002). The nature of SRS-based instruction was thought to provide these opportunities during instruction for learners to reflect on their own understanding of the concepts being taught in the course, as well as provide opportunities for learners to better regulate their cognition in response to their performance on SRS questions. The results of the Metacognitive Awareness Inventory (MAI) showed that this was indeed what occurred in this SRS-augmented course. The increase in knowledge of cognition will be explained by feedback theory. Also, an interesting gender-based interaction was observed for increased regulation of cognition. Gender-based learning research and theory will be used to explain this finding.

The analysis of pre and post responses on the MAI revealed a significant increase in both knowledge and regulation of cognition in both IR and PI sections. The combination of dependent variables in this study told a greater story than each variable alone. If only motivation were measured, the significant drop in confidence may have appeared to be a warning against using SRS-augmented instruction. However, when taken into context with the significant change in metacognitive awareness, the re-calibration of confidence level seems understandable.

One important characteristic of the SRS strategies used in both sections of this study was an increase in feedback over non-SRS instruction. In both the IR and PI sections, all students had multiple opportunities to try out their understanding and receive feedback as to their accuracy in learning the course content. This increased feedback could serve as a catalyst for the increase in metacognitive awareness, which could be a mediating agent in the learners' level of confidence. According to the Feedback Cycle (Dempsey, Driscoll, & Swindell, 1993), each cycle ends in an adjustment, not only in learners' knowledge, but also in goals, interests, and self-efficacy. Therefore, use of SRS to increase the frequency of these feedback cycles during each class session could serve to increase metacognitive knowledge and regulation in the learners.

While there was a significant increase in knowledge of cognition for both sections, interestingly, there was an interaction effect for regulation of cognition between gender and SRS strategy. Males in the IR section significantly improved in regulation of cognition, while it was females in the PI section that significantly improved in regulation of cognition. This seems to suggest that the differences in SRS strategies benefitted students differently in this regard depending on their gender.

Gender-based learning research has supported the notion that males and females generally approach learning differently (Brotman & Moore, 2008). Psychologically, women are more driven by connections between individuals, while men are more driven by separation between individuals (Kaenzig, Anderson, Hyatt, & Griffin, 2006). Applying this to instruction, females prefer learning that is more relational and cooperative, while males prefer learning that is more competitive (Brotman & Moore, 2008). Also, females have shown to be more active and persistent in collaborative learning environments (Goldstein & Puntambekar, 2004), particularly in technology-enhanced learning (Hakkarainen & Palonen, 2003). This may help to explain the gender-based differences in change to cognitive regulation between the two SRS strategies. As the PI strategy is more relational and cooperative in nature, females benefitted more. However, as the IR strategy lent more to individualized performance, males benefitted more. These findings support previous research that suggests using gender-specific strategies to accommodate both males and females, in lieu of evidence that there are gender-based differences in learning approaches and study motivation (De Lange & Mavondo, 2004).

SRS Instruction and Learner Transfer

While the PI and IR strategies appear to influence learners' regulation of cognition differently based on gender, an overall difference between the PI and IR strategies on learner transfer was also observed. This difference will be discussed according to cognitive flexibility theory, and explained through increases to collaboration, articulation, and reflection, as well as a delayed feedback effect that occurs in the PI strategy.

Due to the very course-specific nature of questions necessary to measure transfer of the course concepts, only a post-test was used to compare the groups' performance. The analysis of the transfer assessment revealed that the PI section significantly outperformed the IR group in near transfer. This was an encouraging finding, as transfer has been noted as a very challenging skill to affect through instruction (Haskell, 2001).

The result indicates that students in the PI section may have exhibited greater levels of cognitive flexibility, which is the driving force in transfer of knowledge (Spiro, et al., 2003). According to cognitive flexibility theory, to perform transfer of knowledge learners must be able to adaptively restructure knowledge to apply it to a new situation (Spiro, et al., 2003). Increasing cognitive flexibility requires multiple representations of contextualized concepts in a manner that deepens connections among the complexity of the domain, as opposed to oversimplified transmission of disconnected facts (Spiro, et al., 2003). With the effort to maintain control over as many extraneous influences as possible, the increased cognitive flexibility as inferred by the increased ability to perform near transfer in the PI section may be attributed to the differences between the PI strategy and the IR strategy.

If this is the case, then the primary differences for consideration are that the PI strategy incorporates increased learner collaboration as well as a second chance to respond to each question. During collaboration, learners have the opportunity to articulate their understanding to their peers. To perform this, the learner must draw on their own depth of understanding of the concepts relevant to the question and how it relates to the learner's prior understanding. As a result, deeper connections occur for the learner between the new concepts and their previously held knowledge (Berland & Reiser, 2008; Chin & Brown, 2000). Therefore, this may explain the increased ability of the PI section to perform transfer of the course concepts to new situations.

The repeated responding to each question may also be beneficial to transfer as explained by research in instructional feedback. Some evidence supports the notion that delaying feedback may be more beneficial to learners than providing immediate feedback (Butler & Winne, 1995). This is explained by allowing learners more time to process a question, the answer choices, and their answer choice selection. Haskell's principles for increasing transfer also recognizes this through the principle of "Allow time for the learning to incubate" (Haskell, 2001, p. xv). It is possible that the PI cycle allows a brief, but sufficient period of processing for learners to better reflect on their question choice in comparison with the other choices, before the correct response is disclosed. During this period, deeper connections between the new content and their pre-existing knowledge could be forming, which enhances the ability to perform transfer (Bransford, et al., 2000).

Limitations

There are several limitations to this study that must be taken into consideration. The most apparent limitation is that, like most educational research, this was a quasi-experimental study. Without random sampling and assignment to groups, the results of this study should not be assumed as being causative in nature (Kirk, 1995). Relationships between independent and dependent variables should be interpreted as correlational at best. However, it has been suggested that evaluating the impact of technology in non-authentic learning settings may not reflect the impact of the technology in a real setting that includes the full spectrum on the classroom milieu (Champion & Novicki, 2006). Therefore, use of quasi-experimental methods is important to gauge the pedagogical impact of SRS in real classroom settings.

In addition, the lack of a control group that did not use SRS limits the ability to consider if the changes in dependent variables would have also occurred in a non-SRS using group. The decision to not use a non-SRS using group was to intentionally avoid the focus of the study being on the tool itself, and instead ensuring the focus was on SRS pedagogy, which has not been the case in most SRS research to date. Due to the quasi-experimental nature and lack of a control group, in addition to the sample size, the results of this study may not generalize to other settings.

This study used a self-reporting method that did not provide external rewards for participation. Therefore, the data collected is only as reliable as the participants' willingness and ability to provide accurate information. Students in this study had to purchase the SRS pad and a license fee for use in the course. This, along with previous experiences with using the tool in courses, whether positive or negative, may have influenced their responses on the motivation instrument. In addition, the reliability of the transfer instrument make those results questionable, and should be confirmed with replications of the study with more precise measures of learner transfer.

Finally, limitations of sample size and length of treatment should be taken into account. If all students participated fully on all instruments, the overall sample would have been nearly 200 subjects. However, due to mortality and missing data, the overall N was greatly reduced. The length of the treatments is also an issue. It is possible that extending the time before re-administering the questionnaire or adding additional administrations of the questionnaire would reveal different results. These approaches were not used in this study for specific reasons. First, the length of treatment was limited due to the desire to measure motivation before the first unit exam, as that would undoubtedly influence motivation responses regardless of the impact of the SRS strategy. Second, the questionnaire was not administered additional times due to the likelihood of participant frustration over the intrusion causing an influence on the responses.

Implications for Practice

The findings of this study add to the quickly growing evidence that SRS-based instruction has great potential for eliciting meaningful learning. The results suggest that not only the presence of SRS, but also how SRS is used can result in different outcomes. This study provides several considerations for implementing SRS technology in large undergraduate classrooms.

While this study used the ARCS model for defining and measuring learner motivation, it did not fully implement the ARCS model for specifically integrating motivational design into the instruction (Keller & Kopp, 1987). ARCS research has shown that it is possible to influence each component of ARCS independently through specific strategies (Means, Jonassen, & Dwyer, 1997; Small & Gluck, 1994). For targeting learner confidence, the ARCS model recommends providing clear learning requirements, providing opportunities for success, and fostering a feeling of learners' personal control of success (Keller, 1987c).

To accommodate a possible threat to learner confidence, such as that observed in this study, SRS could be used to implement these confidence-building strategies in large courses. SRS questions could be designed to begin easier to provide opportunities for success, and gradually increase in difficulty as the learners collectively are prepared to move to that level.

It may be helpful or even necessary for instructors to use SRS questions in a more adaptive manner by dynamically adjusting in difficulty based on the responses of students on each question. For example, if a determined threshold percentage of students miss a question, another easier question presented directly after the missed question may be able to re-garner learner confidence. As a result, students can be scaffolded towards being able to succeed on the more difficult question (Bransford, et al., 2000). This SRS strategy would require much of the instructor. First, the instructor must have a large bank of SRS questions that are ranked in difficulty. Second, the instructor must be able to flexibly adjust the questions asked, as well as the ensuing instruction, based on the responses of the students. This strategy could be considered dynamic data-driven instruction. While it appears to be a powerful strategy, it would most likely be very challenging to perform, especially for instructors new to using SRS during instruction. It may also require enhanced functionality in the SRS software. Nonetheless, this is a strategy which further research should explore.

Additionally, how instructors use the SRS feedback is very important to the impact on learners. SRS and instructor feedback should encourage internal attributions so that learners equate success to persistent effort, and not to luck or chance. SRS and instructor feedback should also foster a learning goal orientation.

In regards to using SRS to impact metacognition, while it appears that both PI and IR strategies work equally well for enhancing knowledge of cognition, a blend of both PI and IR strategies may be necessary to impact both males and females in regulation of cognition. In addition, PI appears to also enhance the ability to perform near transfer. Thus, a balance of PI and IR strategies may provide the greatest impact of SRS-augmented instruction on meaningful learning.

The significant improvement in near transfer for the PI section suggests that the PI method is an effective strategy for deepening learner understanding as well as how concepts are applicable to new situations. As these are key goals of instruction, instructors using SRS should consider using the PI strategy, at least in conjunction with other SRS strategies. How much of the SRS questioning should be done in the PI method is a necessity of further study.

Recommendations for Future Study

One recommendation for future SRS research is to design SRS-based instruction according to the ARCS motivational design model (Keller, 1987c). Studies have shown that each element of ARCS can be independently targeted (Keller, 2008). Therefore, studies should focus on targeting learner confidence. For example, the use of the dynamic data-driven approach to SRS instruction discussed previously should be explored.

Also, further research on this topic should include a measure of learner attribution as well as learner goal orientation. This would allow the analysis of motivation, metacognitive awareness, and transfer to be factored based on these learner characteristics.

SRS, like any instructional strategy, is best used for learning when it engages students' prior understandings, helps students develop both factual and conceptual knowledge in a meaningful context, and increases students' use of metacognitive strategies (Champion & Novicki, 2006). A study has shown that technology-enhanced science instruction caused teachers to value metacognitive skill development as equally important to science concept learning (Mayer-Smith, Pedretti, & Woodrow, 2000). This was most likely true in the present study as well, because if the instructor did not value learner motivation, metacognition, and transfer as important outcomes, there would not have been a willingness to adapt instruction accordingly. It would be helpful for future studies to investigate instructor characteristics and how they utilize SRS technology. For example, an instructor's epistemological beliefs may be linked to use of SRS along a continuum of viewing SRS as an assessment tool or as an engagement tool.

Finally, better-designed measures of learner transfer are needed in order to validly and reliably measure this important aspect of learning. Others have noted this difficulty and attribute it mostly due to the very content specific nature of learner transfer in any particular course as well as the difficulty in clearly delineating between levels of transfer (Haskell, 2001). Standardized measures of learner transfer would be necessary to replicate the measurement of transfer in this study in other settings.

Conclusion

Introductory undergraduate courses have been recognized as being gateways to future studies (Tai, Sadler, & Loehr, 2006). If these courses indeed lay the foundation from which further understanding is built, then it is paramount that these courses be of the highest quality. However, it is of great concern that students in these courses often see the poorest quality instruction taught by ill-prepared instructors in settings that handicap the implementation of effective pedagogies, such as Active Learning (Margolis & McCabe, 2004; Ramsden, 2003).

Research on the impact of technology in learning has been inconclusive to date. This is most probably due to the struggle to measure important aspects of learning in an appropriate way (Champion & Novicki, 2006). SRS technology has shown great promise for facilitating Active Learning, even in the difficult circumstances presented in large undergraduate courses (Allen & Tanner, 2005; Bonwell & Eison, 1991; Manivannan, 2004; Poirier & Feldman, 2007). However, there is yet a great need for more research into SRS pedagogies. This study attempted to advance our understanding of how SRS technology can be used to target meaningful learning in large undergraduate classrooms, as opposed to only measuring learner performance. The results of this study underscore the complexity of meaningful learning, as well as the complexity of attempts to measure it (Bransford, et al., 2000). The results drawn from each dependent variable proved much more meaningful when considered in concert with the other dependent variables. As suggested by Gestalt theory (Wertheimer, 1959), the whole of this study was truly greater than the sum of its parts. It is hoped that future studies will continue to explore how SRS-augmented pedagogy may be able to enhance learning in a variety of meaningful ways.

The results of this study showed that SRS appears to have a positive impact when used to facilitate active learning strategies in large classrooms, especially when used to implement the PI strategy. These results lend credence to idea that active learning is plausible in large undergraduate classrooms through the use of SRS-augmented instruction. However, the tool itself does nothing but offer an opportunity for the instructor to capitalize on the pedagogical possibilities that are catalyzed by the tool. The instructor must choose to make the most of what SRS-augmented instruction can do to improve learning.

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Appendix A: Demographics Questionnaire

Demographics Questionnaire

1. Enter the last 5 numbers of your Social Security number
2. Gender
    - a. Male   b. Female
3. College
    - a. Agricultural Sciences
    - b. Arts and Sciences
    - c. Education
    - d. Engineering
    - e. HES
    - f. Business
4. Year
    - a. Freshman   b. Sophomore   c. Junior or Senior
5. High School Size
    - a. 1A or smaller
    - b. 2A
    - c. 3A
    - d. 4A
    - e. 5A or larger
6. Overall ACT Score
    - a. > 30
    - b. 25 – 30
    - c. 20-24
    - d. < 20
7. Science ACT Score
    - a. > 30
    - b. 25 – 30
    - c. 20-24
    - d. < 20
8. High School GPA
    - a. above 3.5
    - b. 3.0 - 3.5
    - c. 2.5 - 2.9
    - d. below 2.5
9. How would you generalize your grades in high school science courses?
    - a. Mostly A’s
    - b. A’s and B’s
    - c. B’s and C’s
    - d. C’s and D’s
    - e. D’s and F’s

Appendix B: Course Interest Survey

Course Interest Survey

- There are 34 statements in this questionnaire. Please think about each statement in relation to the instructional content you have just studied, and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.
- Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

A	B	C	D	E
Very True	Mostly True	Moderately True	Slightly True	Not True

1. The instructor knows how to make us feel enthusiastic about the subject matter of this course.
2. The things I am learning in this course will be useful to me.
3. I feel confident that I will do well in this course.
4. This class has very little in it that captures my attention.
5. The instructor makes the subject matter of this course seem important.
6. You have to be lucky to get good grades in this course.
7. I have to work too hard to succeed in this course.
8. I do NOT see how the content of this course relates to anything I already know.
9. Whether or not I succeed in this course is up to me.
10. The instructor creates suspense when building up to a point.
11. The subject matter of this course is just too difficult for me.
12. I feel that this course gives me a lot of satisfaction.
13. In this class, I try to set and achieve high standards of excellence.
14. I feel that the grades or other recognition I receive are fair compared to other students.
15. The students in this class seem curious about the subject matter.
16. I enjoy working for this course.
17. It is difficult to predict what grade the instructor will give my assignments.
18. I am pleased with the instructor’s evaluations of my work compared to how well I think I have done.
19. I feel satisfied with what I am getting from this course.
20. The content of this course relates to my expectations and goals.

21. The instructor does unusual or surprising things that are interesting.
22. The students actively participate in this class.
23. To accomplish my goals, it is important that I do well in this course.
24. The instructor uses an interesting variety of teaching techniques.
25. I do NOT think I will benefit much from this course.
26. I often daydream while in this class.
27. As I am taking this class, I believe that I can succeed if I try hard enough.
28. The personal benefits of this course are clear to me.
29. My curiosity is often stimulated by the questions asked or the problems given on the subject matter in this class.
30. I find the challenge level in this course to be about right: neither too easy nor too hard.
31. I feel rather disappointed with this course.
32. I feel that I get enough recognition of my work in this course by means of grades, comments, or other feedback.
33. The amount of work I have to do is appropriate for this type of course.
34. I get enough feedback to know how well I am doing.

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Appendix C: Metacognitive Awareness Inventory

Metacognitive Awareness Inventory

- The following questions ask about you as a learner in general, not just with this course.
- Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.
- Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

Respond to the following statements with A = True and B = False.

1. I ask myself periodically if I am meeting my goals.
2. I consider several alternatives to a problem before I answer.
3. I try to use strategies that have worked in the past.
4. I pace myself while learning in order to have enough time.
5. I understand my intellectual strengths and weaknesses.
6. I think about what I really need to learn before I begin a task
7. I know how well I did once I finish a test.
8. I set specific goals before I begin a task.
9. I slow down when I encounter important information.
10. I know what kind of information is most important to learn.
11. I ask myself if I have considered all options when solving a problem.
12. I am good at organizing information.
13. I consciously focus my attention on important information.
14. I have a specific purpose for each strategy I use.
15. I learn best when I know something about the topic.
16. I know what the teacher expects me to learn.
17. I am good at remembering information.
18. I use different learning strategies depending on the situation.
19. I ask myself if there was an easier way to do things after I finish a task.
20. I have control over how well I learn.
21. I periodically review to help me understand important relationships.
22. I ask myself questions about the material before I begin.
23. I think of several ways to solve a problem and choose the best one.
24. I summarize what I’ve learned after I finish.

25. I ask others for help when I don’t understand something.
26. I can motivate myself to learn when I need to
27. I am aware of what strategies I use when I study.
28. I find myself analyzing the usefulness of strategies while I study.
29. I use my intellectual strengths to compensate for my weaknesses.
30. I focus on the meaning and significance of new information.
31. I create my own examples to make information more meaningful.
32. I am a good judge of how well I understand something.
33. I find myself using helpful learning strategies automatically.
34. I find myself pausing regularly to check my comprehension.
35. I know when each strategy I use will be most effective.
36. I ask myself how well I accomplish my goals once I’m finished.
37. I draw pictures or diagrams to help me understand while learning.
38. I ask myself if I have considered all options after I solve a problem.
39. I try to translate new information into my own words.
40. I change strategies when I fail to understand.
41. I use the organizational structure of the text to help me learn.
42. I read instructions carefully before I begin a task.
43. I ask myself if what I’m reading is related to what I already know.
44. I reevaluate my assumptions when I get confused.
45. I organize my time to best accomplish my goals.
46. I learn more when I am interested in the topic.
47. I try to break studying down into smaller steps.
48. I focus on overall meaning rather than specifics.
49. I ask myself questions about how well I am doing while I am learning something new.
50. I ask myself if I learned as much as I could have once I finish a task.
51. I stop and go back over new information that is not clear.
52. I stop and reread when I get confused.

Schraw, G. & Dennison, R.S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology, 19,* 460-475.

Appendix D: Entomology Concepts Transfer Assessment

This organism belongs to which class?

A. Arthropoda
B. Arachnida
C. Insecta
D. Animalia
E. Crustacea

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The 4 largest insect orders have what in common?

A. Chewing mouthparts
B. 2 pairs of wings
C. Complete metamorphosis
D. Gradual metamorphosis

Which of the following animals is NOT an arachnid?

A. Fig. A
B. Fig. B
C. Fig. C
D. Fig. D
E. Fig. E

A

Copyrighted Image

B

Copyrighted Image

C

Copyrighted Image

D

Copyrighted Image

E

Copyrighted Image

Which of the following animals is capable of stinging?

A. Fig. A
B. Fig. B
C. Fig. C
D. Fig. D

A. mosquito

Copyrighted Image

B. horsefly

Copyrighted Image

C. tick

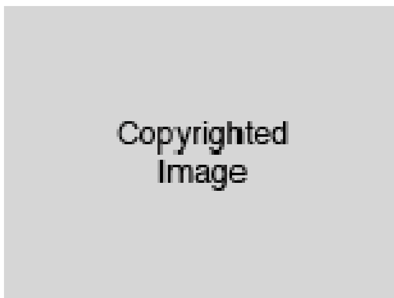
Copyrighted Image

D. Fire ant

Copyrighted Image

This animal would be classified in which phylum?

A. Coleoptera
B. Lepidoptera
C. Arthropoda
D. Arachnida
E. Insecta



Which of the following animals is NOT an arthropod?

A. Fig. A
B. Fig. B
C. Fig. C
D. Fig. D
E. Fig. E

A

C

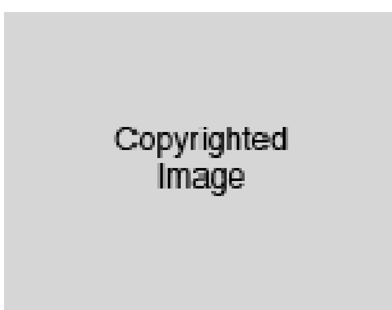
B

D

E

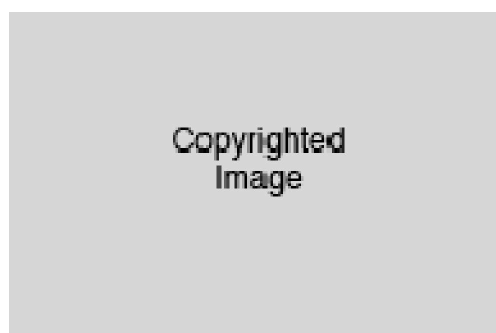
This animal would be classified in which order?

A. Coleoptera
B. Lepidoptera
C. Arthropoda
D. Diptera
E. Insecta



If the structure indicated by the arrow was broken, which function would be impaired?

A. Sensing the environment
B. Absorbing water
C. Frightening predators
D. Egg-laying



A person visits the doctor complaining of parasite infestation on his skin. The doctor deduces that it is an allergic reaction to his laundry detergent and the patient is relieved and agrees to switch detergents. This person has which condition?

A. Delusory parasitosis
B. Illusory parasitosis
C. Morgellon's disease
D. Ekbom's syndrome

Which of the following would most likely react to the injection of spider venom?

A. hummingbird
B. human
C. Yellow jacket
D. Both A and C

What do lobsters, cockroaches and centipedes have in common?

A. Open circulatory system
B. Endoskeleton
C. 1 pair of antennae
D. Complete metamorphosis

What do butterflies, dragonflies and fireflies have in common?

A. Complete metamorphosis
B. Chewing mouthparts
C. hemelytra
D. None of them are actually flies

What do grasshoppers and cockroaches have in common?

A. Complete metamorphosis
B. Piercing-sucking mouthparts
C. hemelytra
D. tegmina

In which life stage would a Japanese beetle be most resistant to chemical insecticides?

A. larva
B. pupa
C. adult

Which of the following would probably be most susceptible to a lethal genetic mutation?

A. Fruit fly
B. Honeybee drone (male)
C. Queen fire ant
D. Monarch butterfly

Under which of the following circumstances would you be most likely to see parthenogenesis in insects?

A. During a drought
B. When an epidemic is spreading through the population
C. When food supply is unlimited

Which of the following is not a pollinator?

A. Bumble bee
B. mosquito
C. Spider wasp
D. Luna moth

Insects exhibit parental care to ensure the survival of their young

A. true
B. false

One of the advantages of metamorphosis is to allow insects to exploit different ecological niches. Which form of metamorphosis best facilitates this?

A. No metamorphosis
B. Gradual metamorphosis
C. Incomplete metamorphosis
D. Complete metamorphosis

What could be one potential consequence of all millipedes disappearing?

A. Less incidence of vector-borne disease
B. Certain insects might flourish from lack of predation
C. Large build-up of decaying plant matter
D. Many plants would go unpollinated

Appendix E: Course SRS Questions

Course CRS Questions

Class 1

•Which of the following insect-related topics sounds most interesting to you?

A. Environmental issues related to insects (climate change, invasive species, conservation…)
B. Biotechnology; transgenics; genetic engineering
C. Medical entomology (insect issues & human disease)
D. Veterinary entomology (insect issues of domestic animals)
E. Insects in the arts (music, movies, literature)
F. Agricutural and forest entomology
G. Forensic entomology

•What is your reaction to seeing an insect?

A. Mostly positive or curious
B. Depends on what kind of insect it is
C. Mostly negative

•Does knowing something about the insect (eg. Whether or not it bites or stings) make a difference in how you feel about it?

A. Yes
B. No

•Is it wrong to dislike an animal (human or not) simply because of appearance

A. Yes
B. No

•What would happen to you if you could kill off all of the mites, worms, microbes and other tiny foreign organisms living in and on your body?

A. I would be cleaner and happier
B. I'd gain weight because they wouldn't be there to share the calories
C. I would probably die

• Which of the following would be most similar to Morgellon's disease?

A. Ekbom's syndrome
B. Bell's syndrome
C. Illusory parasitosis
D. parasitosis

•Is a rigid exoskeleton really a good adaptation?

A. Insects would be better off if they had a more flexible outer layer that could expand and bend easier
B. The external skeleton has more advantages than disadvantages

•Which of the insects pictured here is/are considered “aquatic”

A. A
B. B
C. C
D. All of the above

•I am comfortable handling this insect (picture of hissing cockroach)

A. Strongly Agree
B. Agree
C. Neutral
D. Disagree
E. Strongly Disagree

•I can explain why insects do not grow as large as elephants

A. Strongly Agree
B. Agree
C. Neutral
D. Disagree
E. Strongly Disagree

•Oxygen is carried in the blood of insects, just like it is in us

A. True
B. False

Class 2

•What is the impact of insects on society?

A. Mostly positive
B. Equally positive and negative
C. Mostly negative

•Are ticks capable of blood-feeding on cold-blooded animals, like lizards, snakes and turtles?

A. Yes
B. No

•What might help to explain the higher incidence of Lyme disease in the northern states vs. the southern states

A. There are more ticks in the north than in the south
B. There are more small reptiles in the southern states
C. Northern people are less resistant to Lyme disease
D. There is just as much Lyme disease in the south but people do not report it

•Daddy-long-legs, or harvestmen, are the most poisonous spiders out there. Their mouthparts are just too small to do any harm

A. True
B. False

•Arachnids would fit into which functional feeding group?

A. predators
B. herbivores
C. scavengers
D. All of the above

•Diplopods are fierce predators that prey on insects

A. True
B. False

Class 3

•Which group of insects share the same type of life cycle (development)?

A. Grasshoppers, roaches, ants
B. Ants, beetles, flies
C. Butterflies, grasshoppers, beetles

•Arachnids have which feeding strategy?

A. predation
B. herbivory
C. parasitic
D. Omnivory
E. All of the above

• Daddy-long-legs, or harvestmen, are the most poisonous spiders out there. Their mouthparts are just too small to do any harm

A. True
B. False

• A "roly-poly," pillbug, sowbug….belongs to which class?

A. insecta
B. arachnida
C. crustacea
D. diplopoda

•Which is stronger – a strand of steel or a strand of spider silk (equal in diameter)

A. steel
B. Spider silk

•Which type of spider do you think would be subject to predation and parasitism?

A. Orb web weavers
B. Wandering spiders that do not spin a web
C. both

•It is important to be aware of the diversity of spiders that exist and to make conservation efforts to protect them

A.Strongly Agree
B.Agree
C.Neutral
D.Disagree
E.Strongly Disagree

Class 4

•Which of the following are “order level” characteristics?

A. Type of wings, type of metamorphosis
B. Number of legs, number of antennae
C. Presence or absence of chlorphyll, having a mobile life stage

• Is a Louse fly really in the order Diptera?

A. Yes
B. No

•If you saw a true bug how would you know whether or not it is an adult?

A. Size- if it is mature it will be larger
B. It will have full wings rather than wing buds
C. It will have very long antennae

•How many bug parts are allowed to be in your food according to the FDA?
Wheat flour limits…

A. Average of 75 insect fragments per 50 grams
B. none
C. Average of 5 or more insect fragments per 50 grams

•Which of the following, regarding the order hymenoptera is NOT true?

A. Of the thousands of species of wasps found in this order, only several are capable of stinging a human
B. Of those that sting, only the female has a stinger
C. Social hymenoptera are made up almost entirely of females
D. All hymenoptera are social

•If you had to be an insect, which type of insect would you prefer to be?

A. Hemiptera
B. Hymenoptera
C. Diptera
D. Lepidoptera
E. Orthoptera
F. Coleoptera

Class 5

•The main difference between viviparity and ovoviviparity is the food source of the developing larvae

A. True
B. False

•The type of childbirth we see in humans is most similar to:

A. oviparity
B. ovoviviparity
C. viviparity

•Which of the following would be an example of arthropods exhibiting "parental care?"

A. Wolf spider carries her spiderlings on her back until their first molt
B. Mother head louse lays her eggs in the hair of a 6 year old human
C. Gypsy moth lays her eggs on a nice Oak tree
D. All of the above

•Which of the following insect control mechanisms would be LEAST safe for humans?

A. Insecticide developed from spider venom that does not affect vertebrates
B. Insecticide developed from juvenile hormone (an endocrine disruptor) that disrupts the molting process
C. Broad spectrum chemical insecticide
D. Parasitoid wasps

•One of the advantages of metamorphosis was that it allowed exploitation of different ecological niches. Which type of metamorphosis best facilitates that?

A. No metamorphosis
B. Gradual metamorphosis
C. Incomplete metamorphosis
D. Complete metamorphosis

Appendix F: Institutional Review Board Approved Documents

Oklahoma State University Institutional Review Board

Date	Wednesday, July 16, 2008	**Protocol Expires:**	**3/30/2009**
IRB Application	ED0859		
Proposal Title:	A Comparision of Student Response System Strategies in a Large Undergraduate Science Course for Nonmajors: The Impact on Motivation, Metacognition and Transfer		
Reviewed and Processed as:	Exempt **Modification**		

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s) :

Mark Jones 102 Telecommunications Stillwater, OK 74078	Pasha Antonenko 210 Willard Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB

☒ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

Signature :

Sheila Kennison, Chair, OSU Institutional Review Board

Wednesday, July 16, 2008
Date

Okla. State Univ.
IRB
Approved 7/16/08
Expires 3/30/09
IRB# ED0859(M)

Learning in Large University-Level Science Courses
Subject Solicitation Script

"My name is Mark Jones and I am a Ph.D. candidate in educational technology. I am conducting a dissertation study on learning in large university-level science courses.

I am inviting you to participate in this study, if you are willing. Your participation is completely voluntary and anonymous. My advisor and I are the only people who will access the questionnaire data, and you are not identifiable by the questionnaire responses. You are completely free to decline if you are unwilling to participate. Before you agree to complete the questionnaire, please read the attached Consent Form that gives details of the project and your participation. Removal of the consent form from the questionnaire serves as you giving consent to participate in this study.

To participate in the study, you will complete a short questionnaire at two times during the semester. Each session will take 20 to 30 minutes of class time.

You are asked to enter the last 5 digits of your social security number on the questionnaire. This will allow your responses to be linked between the two questionnaires, while also maintaining your anonymity. Please carefully enter this information to ensure that it is correct.

You will use your clicker to respond to the items in the questionnaire. These responses will be delivered in anonymous, student-managed mode, so there is no way that you will be identified through use of your clicker. You will be shown on the screen that the software is in anonymous mode. You can take as little or as much time as you wish to complete the questionnaire, but most people finish in about 20-30 minutes.

We will now pass out the questionnaires. Remember to keep the consent form for yourself. Please do not write on these questionnaires. When everyone has finished responding, the PI and TA's will collect the questionnaires.

Thank you very much for your participation."

Okla. State Univ.
IRB
Approved 7/16/08
Expires 3/30/09
IRB# ED0859-M

Learning in Large University-Level Science Courses
Participant Consent Information

This is a research study to investigate student learning in large university classrooms. Specifically, motivation, metacognitive awareness, and learner transfer will be assessed at two times: a) the beginning of the semester and b) at the end of Unit 1.

Your participation in this research is completely voluntary and anonymous. There are no special incentives for participation, there are no negative consequences for declining participation, and you are free to decline to participate for any reason without explanation. There are no known risks in participating in this research beyond those encountered in daily life.

If you choose to participate in this study, you will be asked to respond to a questionnaire at two times during the semester. The PI and TA's will distribute the questionnaire to everyone. If you wish to participate, simply remove the consent form and respond when directed to do so.

The questionnaire will ask for the last 5 digits of your Social Security Number. This will connect your responses over time, while maintaining your anonymity and confidentiality. Therefore, it is VERY IMPORTANT that you correctly enter this information each time you complete the questionnaire.

You will enter all responses with your clicker in anonymous student managed mode, so there is no need to write on the questionnaire. When everyone has finished responding, the PI and TA's will collect the paper copy of the research questionnaires. Remember to keep the Consent Form for your own records.

If you agree to participate, you agree to the following conditions regarding your voluntary and anonymous participation in this research:

- Your participation will involve completing a questionnaire at two times during the semester.
- You will be asked to enter the last 5 digits of your Social Security Number as an anonymous identifier.
- The questionnaires will be completed during class time, and will take approximately 20-30 minutes.
- Information you provide will be anonymous and treated with complete confidentiality. The data will only be accessed by the PI and the PI's advisor.
- Information you provide will be secured at all times by the PI.
- The data yielded from this study will be used solely for educational research purposes.
- Any data from this research used in preparation and publication of professional literature and reports will be anonymous and reported only in aggregate. No specific reference to your name or personal identity will be made at any time.
- Research data will be kept in a secured location by the Principal Investigator for up to one year for analysis and preparation of professional literature. After one year, all data will be destroyed.

If you have questions or concerns, you may contact the Principal Investigator, Mark Jones, by phone at Oklahoma State University at (405) 744-6614 or by email at mark.jones12@okstate.edu.

If you have questions about your rights as a research volunteer, you many contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North,Stillwater, OK 74078, (405) 744-1676 or irb@okstate.edu.

To give your consent to participate in this research and submit your data for inclusion in analysis and use in professional education literature, please remove this Consent Form and complete the questionnaire.

VITA

Mark E. Jones

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE IMPACT OF COLLABORATIVE AND INDIVIDUALIZED STUDENT RESPONSE SYSTEM PEDAGOGY ON LEARNER MOTIVATION, METACOGNITION, AND TRANSFER

Major Field: Education

Biographical:

Education: Graduated from Catoosa High School in 1994; Earned a Bachelor's of Science in Secondary Science Education from Oklahoma State University in May, 1999; Earned a Master's of Education in Educational Technology from Northern Arizona University in May, 2004. Completed the requirements for the Doctor of Philosophy in Education with an emphasis in Professional Education Studies at Oklahoma State University, Stillwater, Oklahoma in May, 2009.

Experience: Science Teacher, Locust Grove Public Schools, Locust Grove, OK, 1999-2000; Science Teacher, Wister Public Schools, Wister, OK, 2000-2002; Technology Director/Distance Learning Coordinator, Heavener Public Schools, Heavener, OK, 2002-2005; Instructional Designer, Oklahoma State University Institute for Teaching and Learning Excellence, Stillwater, OK, 2007-2008; Assessment Specialist, Oklahoma State University College of Education, Stillwater, OK, 2005-2007, 2008-Present

Professional Memberships: AECT, OTA

Name: Mark E. Jones Date of Degree: May, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: THE IMPACT OF COLLABORATIVE AND INDIVIDUALIZED STUDENT RESPONSE SYSTEM PEDAGOGY ON LEARNER MOTIVATION, METACOGNITION, AND TRANSFER

Pages in Study: 128 Candidate for the Degree of Doctor of Philosophy

Major Field: Education

Scope and Method of Study:

The purpose of this study was to explore how student response system technology (SRS) can facilitate active learning in a large undergraduate science course for non-science majors. Two forms of SRS pedagogy were compared in how they facilitate meaningful learning as represented by learner motivation, metacognition, and transfer. One SRS strategy involved only individualized responses to SRS questions, while the other SRS strategy followed the Peer Instruction method, which incorporates student collaboration in conjunction with responding to SRS questions. Split-plot factorial MANOVAs were used to identify any change in learner motivation or metacognitive awareness, factoring for SRS strategy used and gender, on responses to surveys administered at the beginning and end of a unit of instruction. In addition, differences in the ability to perform transfer of course concepts was measured by factorial MANOVA, factoring by scores on a transfer assessment and gender.

Findings and Conclusions:

Analysis revealed a decrease in confidence in both SRS strategies, however, knowledge of cognition increased for both SRS strategies. An interaction effect by gender and SRS strategy occurred for regulation of cognition. Males increased in the individualized strategy, while females increased in the Peer Instruction strategy. Also, the Peer Instruction group performed near transfer of course concepts better that the individualized responding group.

The results suggest that the drop in confidence may have been mediated by the increase to metacognitive awareness. Also, both SRS strategies appear to have benefits in different ways, therefore instructors should give attention to *how* SRS is used in instruction, not simply *if* it is used. Implications for practice and suggestions for further study are discussed.

ADVISER'S APPROVAL: Dr. Pavlo Antonenko