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Effects Of Rural High School Size And Socioeconomic Status On Achievement Of Tenth Graders

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EFFECTS OF STUDENT RESPONSE SYSTEM USE ON STUDENT LEARNING AND VERBAL PARTICIPATION FOR A SIXTH-GRADE MATHEMATICS UNIT

A Dissertation

Presented to

The School of Graduate Studies

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In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

By

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ABSTRACT

The purpose of this quasi-experimental quantitative study was to examine the effects of Student Response System (SRS) use on student learning and verbal participation in an authentic K-12 classroom environment for a sixth-grade mathematics unit on probability. A self-report survey was administered to report student attitudes regarding SRS use for the unit. A sample of 84 sixth-grade students from a rural Midwestern elementary school was used for the study by established grouping. Two sections of the sixth-grade class were used as the treatment condition of SRS use and two sections of the sixth-grade class were used as the control group of SRS non-use for a week long mathematics unit on probability. The study used a comparative posttest only design to compare mean posttest scores, the mean total number of student-to-teacher responses, and the mean total number of student-to-student responses between treatment and control groups for the unit.

Results of the study found no significant difference in student learning as measured by a teacher created posttest for the probability unit. No significant difference was found to exist in student verbal participation for the mean total number of student-to-teacher responses between the treatment group of SRS use compared to the control group of SRS non-use. A significant difference was found in student verbal participation between the treatment and control groups for the mean total number of student-to-student responses. Results of a survey of student attitudes regarding SRS use are also presented.

DEDICATION

This dissertation is dedicated to my grandfather, Elwood Grissom, a World War II veteran with an eighth-grade education who fought for and won America's freedom over fifty years ago. My grandfather served as a rifleman in the Infantry during World War II under General Patton and worked to provide security at the Nuremberg trials. Without his sacrifices I would not have had the opportunity to pursue my dream of achieving a Ph.D. degree. Grandpa worked as an electrician for most of his career and although he did not have much formal education he always did his best at whatever he set his mind to do. I am the first in our family to reach this level of education and I hope my grandfather is proud of my efforts.

I would also like to dedicate this dissertation to my wife's late sister, Debra McMurray, who suddenly passed away at the age of 45 this year. Life is short and although she never lived to see me complete my goal of obtaining my doctorate I know she would be proud. Debbie leaves behind two children, Katie and Adam, and husband Scott.

ACKNOWLEDGMENTS

Pursuing this doctoral degree has been one of my life goals and has often felt like a long journey that would never end. This journey could not have been completed without the help and assistance of many people. I thank my dissertation committee for their assistance and encouragement to keep going and with helping me complete this journey.

I would like to thank the principal, teacher, and students at the participating school for their willingness to work with me on the study. The study would not have been possible without their cooperation and efforts. The teacher and students were wonderful to work with and many hours have been spent together to make this a successful study.

My family members have stood by me in good times and bad and have sacrificed along with me on this journey. It has been a long road and we have suffered setbacks and lost loved ones along the way. To my wife Gail, son T.C., and daughter Niki I hope I have encouraged you to pursue your dreams no matter how difficult. I thank my parents for their love and support and for providing me the opportunities to be successful in life. The thousands of hours of work toward the goal of obtaining my doctorate has taken me away from family activities and obligations. I thank my family for staying with me on this journey and I look forward to spending more quality time with them as I move on to the next phase of my life and apply the lessons learned from this journey to benefit others.

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INTRODUCTION

Background

Student Response Systems (SRS) are promoted as a facilitative tool for the creation of active learning environments that lead to increased student participation and improved student learning in K-12 and higher education classrooms. Use of SRS in traditional classrooms is increasing as the technology becomes more affordable with purchases of systems accelerating in both K-12 and higher education markets (Duncan, 2005; Penuel, Roschelle, Crawford, Shechtman, & Abrahamson, 2004).

SRS utilize a combination of hardware and software to collect and publicly display aggregate student responses to questions posed by the teacher (Beatty, 2004). Students utilize individual handheld keypads, similar to a TV remote control, to respond to multiple-choice questions posed by the teacher in real-time. The public display of aggregate student responses allows for instantaneous feedback to the teacher and students offering a snapshot of student understanding. Multiple-choice questions are prepared ahead of class time and typically consist of four to five answer choices per question. Every student selects the appropriate letter or number choice on the keypad associated with their response to answer the multiple-choice question. Providing rapid as well as charted formative assessment information for every student is an important component for raising student achievement (Black & Wiliam, 1998; Stiggins, 2002). When used with interactive pedagogies that allow for increased student participation and questioning in the classroom SRS have the potential to create dynamic interactive learning environments that lead to higher student achievement (Duncan, 2005; Mazur, 1997; National Research Council, 1999).

SRS are being utilized by teachers at all grade levels in K-12 settings. In a survey of 585 K-12 teachers using systems manufactured by eInstruction Inc., 35.7% of respondents were identified as elementary school teachers, 29.7% as middle school teachers, and 34.4 % as high school teachers (Penuel, Crawford, DeBarger, Boscardin, Masyn, & Urdan, 2005). In the same survey, SRS were identified as being used in a variety of K-12 subject areas including; English/language arts, mathematics, social studies, science, and in the foreign languages.

Assessing what students are thinking is a challenge that is faced everyday by classroom teachers (Kauchak & Eggen, 1998; Terreri, 2005). How do teachers know if students are paying attention and understanding the content being taught? Lecturing students for long periods without opportunities for feedback is often ineffective (Bligh, 2000). Teachers have long utilized homework, quizzes, and tests as methods of gauging student achievement but too often there are long time lags between student submissions of assignments and the return of graded assignments (Chickering & Ehrmann, 1996).

Questioning is one of the most effective tools that teachers use to engage students in the classroom (Kauchak & Eggen, 1998). Equitably distributing questions to all students in a class can be very demanding of teachers but worth the effort. In traditional classrooms the teacher asks a question and typically calls on a volunteer or targets the question to a specific student. Classrooms that use SRS collect answers for all students simultaneously allowing every student to participate by having their answers recorded and displayed. Questions are routinely used in the classroom to probe student understanding but research suggests that teachers often do not allow adequate wait-time for students to respond. Teachers typically wait less than one second for students to respond to questions before asking another student, prompting, or giving the answer themselves (Kauchak & Eggen; Rowe, 1986).

An alternative to traditional questioning is the use of SRS. SRS allow for the simultaneous questioning of all students in a non-threatening and efficient manner by allowing every student to respond to questions anonymously with the added benefit of immediately seeing the aggregate results of all student responses in the classroom (Duncan, 2005). The aggregate public display of answers focuses student attention to the front of the room and provides an agenda and a transition for class-wide discussion to SRS questions (Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996). Students report that knowing the distribution of class responses is important and the public display provides information to students about where they stand in relation to fellow students (Davis, 2003; Dufresne et al.).

Statement of the Problem

Research regarding SRS is currently lagging behind implementation across the nation as little scientifically-based research evidence exists regarding the effects of SRS in K-12 classroom environments (Penuel et al., 2004). Historically much of the research regarding SRS has been at the college level when used with large lecture classes (Judson

& Sawada, 2002). Additional research is needed in a variety of subjects, grade levels, and class sizes to identify effects of SRS use in K-12 classrooms (Penuel et al., 2005).

Advocates of SRS claim increased participation and improved learning environments that lead to increased student understanding and achievement (Duncan, 2005; Mazur, 1997; Ward, 2003). Over the past decade SRS have become more reliable, affordable, and easier to use. Consequently, they are increasingly being used in traditional classrooms in both K-12 and higher education environments but little is known regarding effectiveness on student learning (Penuel et al., 2005). Additional research is needed to affirm or refute the claimed effects of SRS in classrooms at the K-12 level.

Purpose of the Study

The purpose of this comparison study is to investigate the effects of SRS use and non-use on student learning and student verbal participation for a sixth-grade mathematics unit on probability in a rural public school setting. The goal of this study is to determine if there are differences in student learning and verbal participation for classes using a SRS compared to classes that do not use a SRS. Attitudes of students regarding the use of the SRS will also be investigated by the use of a self-report questionnaire administered to the treatment group only.

Research Questions

1. Is there a significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?
2. Is there a significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on

probability, between the treatment group of SRS use and the control group of SRS non-use?

3. Is there a significant difference in student verbal participation, as measured by mean total number of student-to-student responses for a sixth-grade unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?

4. What are student attitudes regarding SRS use for a sixth-grade mathematics unit on probability?

Significance of the Study

The results of this study contributes to the understanding of the effects of SRS on student learning, student verbal participation, and student attitudes of SRS use in an authentic K-12 public school classroom setting. To date most research studies on SRS have been at the college level and research is needed at the K-12 level to affirm or refute previous findings. Much of the higher education research has been conducted for large lecture classes and little is known regarding SRS effects in traditional classrooms of 10 to 30 students.

The National Center for Education Statistics (NCES) reports that mathematics scores for U.S. fourth and eighth grade students participating in the Trends in International Mathematics and Science Study (TIMSS) scored above the International average in 2003 with consistent gains in scores since 1990 (NCES, 2005). A recent reassessment of the TIMSS data of 2003 used in the NCES report has called into question the ranking of U.S. fourth- and eighth-grader student achievement in comparison with other industrialized countries (Ginsberg, Cook, Leinwand, Noell, & Pollock, 2005). In prior studies it has been the common perception that it is at the secondary level that United States students lag behind other countries in mathematical achievement. The recent reassessment of the 2003 TIMSS data suggest that U.S. students may be falling behind other countries in mathematics achievement as early as fourth grade (Ginsberg et al.).

Schools spend on average $103 per pupil for educational technologies yearly (Technology Counts, 2005). Of that total 69% of the dollars go to hardware, 16% to software, 9% to outside services, and 6% to professional development. Technology spending is being influenced nationwide by the No Child Left Behind Act that puts a premium on technologies used for data-collection and assessment purposes. Educational purchases for SRS are accelerating but little is known regarding the conditions necessary for successful implementation in the K-12 environment. There is a paucity of research regarding the use of SRS in the K-12 setting and this study investigated SRS effects in a traditional sixth-grade mathematics classroom.

Definition of Terms

The following terms are defined for use in this study:

Student Response Systems (SRS). A generic term for a combination of hardware and software that allows the teacher to easily poll student responses to questions and instantly display the aggregated results to the class. There are several vendors of SRS and features vary from vendor to vendor (Lowery, 2005). In general all SRS typically consist of the following three elements:

- A method of presenting questions or problems to students, usually in a multiple–choice type format.

- Individual remote control-like keypads (clickers) that are used by each student to transmit student responses to a central receiving unit.
- A method of receiving and storing student responses for shared aggregate public display typically in the form of a histogram.

Clickers. A generic term for student response pads. Clickers are small wireless handheld devices, similar to a TV remote control, that transmit student responses to a central receiving unit where responses are collected and processed for public aggregate display to the class.

Interactive slide. A slide that is incorporated within a PowerPoint presentation that is capable of polling student responses to a question posed by the teacher using a SRS, after all students have selected an answer a slide is generated that publicly displays the aggregate student responses to the question usually in the form of a histogram.

TurningPoint. A SRS created by Turning Technologies, LLC. TurningPoint software is 100% integrated within Microsoft PowerPoint and provides a method for easily creating interactive PowerPoint slides that are capable of displaying shared public displays of aggregate student responses usually in the form of histograms. TurningPoint 2006 is the SRS used in this study.

PowerPoint. A presentation software program created by Microsoft, Inc. that has become the industry standard.

Student verbal participation. Oral communication used by students to answer questions, make comments, or provide explanations that are on-task for the given classroom activity. Student verbal participation was measured by observation of total counts of student-to-teacher and student-to-student responses for the unit.

Student learning. For the purposes of this study student learning was measured by a teacher created test instrument for a sixth-grade mathematics unit on probability.

Assumptions

The following assumptions are made for the study:

1. The teacher created test instrument used in this study and reviewed by two sixth-grade teachers and a professor of mathematics is an appropriate measure of student learning for the sixth-grade probability unit.
2. Students were assigned to sections by the school by mixing ability levels of the students. The school does not use tracking.
3. Students in the treatment group followed the teacher instructions when using the SRS.
4. The measure of student verbal participation using total counts for student-to-teacher and student-to-student verbal responses for each student is an appropriate measure of student verbal classroom participation for the unit.
5. It is assumed that all sixth-grade students participating in the study in both treatment and control groups honestly answered all posttest questions and completed practice sets to the best of their ability.
6. Students in the treatment group honestly answered the student questionnaire.

Limitations

The following are limitations for this study:

1. The study is of a quasi-experimental design that is limited to one school and teacher at the sixth-grade level in the specific content area of mathematics for a unit on probability and may affect the generalizability of results.

2. The time period for the study is chosen to be for one mathematics unit on probability over a five day period with the SRS being introduced one week prior for the treatment group to limit possible novelty effects.
3. The teacher is familiar with PowerPoint having used PowerPoint in all four mathematics classes for whole class instruction for the previous six months. Teachers not familiar with PowerPoint may require additional training in using the SRS.
4. The SRS used in this study was the TurningPoint 2006 system by Turning Technologies, LLC.
5. All sixth-grade mathematics sections met during the first half of the school day. Each class period meets for 40 minutes every weekday.

Delimitations

The study was limited to four sections of approximately 20 students per section at the selected school for a sixth-grade mathematics unit on probability. The treatment group consisted of two sections and the control group consisted of two sections. The study began after the state achievement test so as to not interfere with state testing preparation or results. Agreement of participation by the school, teacher, parents, and students in the study was completely voluntary.

Organization of the Study

This study follows the framework for research established by the School of Graduate Studies and the Department of Curriculum, Instruction, and Media Technology at Indiana State University. Chapter 1 includes background information, statement of the problem, purpose of the study, research questions and hypotheses, significance of the study, definition of terms, assumptions, limitations, delimitations, and organization of the study. Chapter 2 provides a review of the literature of SRS used in educational settings. Chapter 3 describes the methodology used for this study including information regarding participants, instruments used, data collection procedures, and statistical methods used. Chapter 4 presents the results of the study. Chapter 5 provides the discussion of the results and recommendations as a result of the findings of this study.

Chapter 2

REVIEW OF THE LITERATURE

SRS have been identified by a variety of names over the years. Various names found in the literature include: student response systems (Frey & Wilson, 2002; Horowitz, 1988; Littauer, 1972; Shapiro, 1997), group response systems (Cutts, Kennedy, Mitchell, & Draper, 2004), audience response systems (Miller, Bimal, & Getz, 2003), computerized response systems (Garg, 1975), electronic response systems (Bessler & Nisbet, 1971), personal response systems (Cue, 1998; d'Inverno, Davis, & White, 2003; Elliott, 2003) electronic voting systems (Draper & Brown, 2004; Kennedy & Cutts, 2005; Stuart, Brown, & Draper, 2004), classroom communication systems (Abrahamson, 1999; Beatty, 2004; Boyle & Nicole, 2003; Dufresne, et al., 1996), classroom response systems (Roschelle & Pea, 2002), and classroom performance systems (Ward, 2003). SRS have also been referred to generically as response pads, keypads, or more commonly as "clickers" (Duncan, 2005).

Early Uses of Student Response Systems

The first SRS developed were typically used at the college level in large lecture halls where the costs could be justified to assist faculty with assessing student understanding of content delivered to large lecture classes (Bessler & Nisbet, 1971; Garg, 1975; Littauer 1972). Features of early SRS vary but the common element is the ability to electronically receive student responses and publicly display aggregate results of questions posed by the teacher (Beatty, 2004).

The earliest SRS were hard-wired devices attached to student seats in large college lecture halls with wires running to a central location where the lecturer could view responses at a main console. Draper (2005) describes a one-button response system used in the late 1940s for large university lecture classes in Holland and Belgium as being one of the first known electronic response systems.

Commercial companies began marketing SRS in the 1960s and 1970s but costs of early systems were expensive, approximately $40,000 at the time to equip a 200 seat lecture hall (Littauer, 1972). Because of high-cost Littauer designed and built a system used at Cornell University by using off the shelf parts for a fraction of the costs of commercial systems available at the time. Before building the system Littauer's first challenge was to decide if he wanted a tagged mode or an anonymous mode system. In a tagged mode system all student responses can be identified for each student and recorded. A tagged mode system receives and tallies responses separately for each student and is therefore useful for taking attendance and administering quizzes where student identities for responses are required. In anonymous mode only the totals for all responses are recorded. Because of the complexities involved in building a tagged mode system Littauer opted to build the simpler anonymous mode system.

Littauer's teaching experiences with the homemade SRS in anonymous mode were positive with 92% of the students reporting that the system increased their value of attending lectures (Littauer, 1972). Littauer was one of the first to describe increased student interactions as a consequence of using SRS to pose questions. Littauer states, "The quiz material becomes public property and stimulates interaction between students" (p. 70).

Many of the early SRS studies reported favorable reviews by students but did not report significant findings on student achievement (Bessler & Nisbet, 1971; Littauer, 1972). Garg (1975) reports on a computerized response system built at Duke University described as a feedback device used to obtain student feedback and acquaint students with computer-based developments in technology. In early experiments with the system 63% of the class felt that the feedback process seemed useful. Student responses could be categorized and publicly displayed and students could then discuss options to arrive at the correct result. Garg characterized the systems use as a favorable experience.

Bessler and Nisbet (1971) describe a SRS at Ball State University used in large-enrollment college level biology classes. The Bessler and Nisbet study found no significant difference in student achievement on biology test scores but did report that instructors of less experience using electronic response systems performed as well as more experienced instructors and noted that this finding should be explored in future research. Cuban (2001), a critic of educational technology, made reference to a SRS used at Stanford in the late 1960s and described the system as falling into a state of disrepair by 1972. A system used at New Mexico State University consisted of one button that students could depress when they did not understand the lecture material. All the student buttons were wired to a meter at the lecture podium and gave the instructor a relative view of how many students were depressing the button indicating the overall level of understanding for the class at a particular time (Draper, 2005; Hunt, 1982).

Student Response System Use in Physics Courses

Much of the research work completed on SRS effectiveness has been led by physics departments at the college level for use in large lecture introductory physics courses. Physics instructors were concerned by findings indicating it was possible for students to go through an entire physics course without having a grasp of basic physics concepts (Halloun & Hestenes, 1985a, 1985b). Courses often emphasize "plug and chug" problems and cookbook labs that do not develop student understanding of basic physics concepts and principles even though students could successfully solve problems using memorized formulas (Mazur, 1997). Physics instructors were searching for more effective methods for students to become actively engaged with physics content by assessing student understanding in the formative stage where student misconceptions could be corrected early in the teaching process (Hake, 1998; Mazur).

Shapiro (1997) describes a low cost homemade system used at Rutgers University in the mid-1990s used in physics courses by five instructors. Shapiro built the system after learning of Littauer's work from a colleague. The Rutgers system served a 330 seat lecture hall and could be used in both tagged and anonymous modes. Instructors varied the use of the system from simple attendance taking to gauging student understanding by administering multiple-choice questions. Technical problems occurred early in the semester and limited the system's use. Shapiro referred to the high-costs of commercial systems of the day quoting pricing of $150,000 to equip a 330 seat lecture hall. As was the case with Littauer, high-cost was the primary impetus for Shapiro to build a proprietary homemade system used at Rutgers. SRS costs have significantly decreased in price over the years with a clicker unit today costing approximately $30 per student and costs are decreasing rapidly (Duncan, 2005).

Interactive Pedagogies

Physics instructors were also at work during the 1990s developing interactive pedagogies to be used with SRS to improve student learning. Mazur (1997) used the Classtalk system at Harvard for physics lectures that proved to be one of the early successes in proving increases in student achievement in college physics courses (Abrahamson, 1999; Hake, 1998; Mazur). SRS and interactive feedback have consistently demonstrated improvement in student achievement in physics courses for students of all ability levels (Crouch & Mazur, 2001; Mazur; Poulis, Massen, Robens, & Gilbert, 1998). Mazur used the SRS to create a more interactive student-centered classroom environment based upon constructivists learning principles (Mazur). Classtalk was commercially available from 1992 through 1999 before being replaced in the marketplace by simpler and more affordable SRS that have become increasingly popular today (Beatty, 2004). Classtalk when combined with interactive pedagogy was successfully used to create student-centered learning environments by fostering an interactive classroom environment to help keep students interested and attentive (Dufresne et al., 1996).

Mazur (1997) developed the "Peer Instruction" method of teaching physics and used the method in combination with a SRS to promote increased student engagement and achievement of physics content at the university level. Peer Instruction involves the use of carefully crafted questions that Mazur calls ConcepTests that are presented to students after a mini-lecture to promote student understanding. In Mazur's Peer

Instruction method students are presented with a question and asked to individually enter their answers using the SRS. Next the students are encouraged to discuss their answers with each other and convince one another as to why their chosen answer is correct. If convinced by other students the student may change their answer after the Peer Instruction and are asked to re-enter their responses to the question using the SRS a second time. The final step is to provide an explanation of the correct answer by the teacher so that the teacher can address any discrepancies in student understanding. The Peer Instruction method not only gives every student immediate feedback about their understanding but also gives every student the opportunity to verbalize their thinking with other students and learn from each other. The teacher displays the data in the form of the aggregate SRS histogram display to determine overall class understanding and address any areas that may require additional attention.

Using the Peer Instruction method with SRS Mazur utilizes approximately one-third of class time for interactive questions. Research results of Peer Instruction with SRS have consistently identified gains in student understanding of physics content over a ten-year period (Crouch & Mazur, 2001). The verbal explanation of answers by the individual student appears to be a vital factor for increased student understanding (Dufresne et al., 1996; Mazur, 1997; Nicole & Boyle, 2003).

Ward (2003) developed the Methodology for Academic Progress (MAP) approach using formative assessment for raising standards of achievement. Ward is the founder of eInstruction, Inc. that is one of the major manufacturers of SRS. In the MAP approach Ward recommends four pre-questions, five inserted questions and finishing with three post questions to gauge student understanding for each hour of daily instructional activity. Ward also recommends bi-weekly, weekly, and bi-monthly activities to provide students with additional formative assessment opportunities.

Conceptual Understanding

In the late 1980s and early 1990s physics instructors developed instruments to measure student conceptual understanding of Newtonian Mechanics. The Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992) and Mechanics Baseline Test (Hestenes & Wells, 1992) were created to gauge student knowledge and understanding of physics principles. Studies on the use of SRS with formative assessment techniques including peer instruction in physics have proven beneficial for improving student conceptual knowledge, understanding, and problem solving for students of all abilities (Crouch & Mazur, 2001; Hake, 1998; Mazur 1997).

Hake (1998) coined the term "Interactive Engagement" (IE) to describe teaching methods designed to promote student conceptual understanding of students in a "heads-on" (always) and "hands-on" (usually) activity approach that yields immediate feedback through discussion with peers and/or instructors. Hake completed a research study using data from over 6000 students on the effects of IE on student conceptual understanding of physics related content over a diverse setting of high school, community college, and university physics courses. SRS were utilized in a small number of the classes in Hake's study to promote IE. Hake's findings include a significant difference in student conceptual understanding measured by mean normalized gain scores in courses that used IE versus traditional lecture methods of instruction as measured by the Halloun-Hestenes Mechanics Diagnostic test (Hake), the Force Concept Inventory test (Hestenes et al., 1992), and the problem-solving Mechanics Baseline test (Hestenes & Wells, 1992).

Hake (1998) used mean normalized gain scores based upon pretest and posttest scores of the Force Concept Inventory (FCI) to determine if significant differences existed in student learning between traditional lecture courses and Interactive Engagement courses. By utilizing normalized gain scores and plotting the results of posttest versus pretest FCI scores Hake was able to identify scores that achieved large normalized gains based upon the two types of courses for the FCI. Hake found that mean normalized gain scores of the Force Concept Inventory were approximately 0.25 in physics courses taught in the traditional format of using lectures and recipe labs. The mean normalized gain scores for the FCI for IE courses were approximately 0.45 demonstrating a significant difference in pretest versus posttest scores of IE courses compared to traditional lecture courses.

Current Generation of Student Response Systems

The latest generation of SRS utilizes wireless technologies that have broken free of the tethered hard-wired systems of the past. Today, most SRS load software on a personal computer and use a standard Universal Serial Bus (USB) connector for receivers to collect student responses from wireless response pad transmitters (clickers). SRS vendors state there have been millions of units sold to over 600 universities and hundreds of K-12 schools (eInstruction, Inc., 2005; Fleetwood Group, Inc., 2005). Some of the larger vendors include: eInstruction, Inc., Turning Technologies, LLC, Interwrite, Quizdom, and Hyper Interactive Teaching Technology (Lowery, 2005).

There are three major types of wireless response pad technologies currently being used with SRS, Infrared (IR), Radio Frequency (RF), and WiFi. Infrared is the least expensive of the three technologies but requires a line of sight from the transmitter of the response pad to the receiver. Infrared response pads are effective in an area up to 90 feet away from the receiver. RF systems are more expensive but offer the advantage of not requiring a line of sight to the receiver and having ranges in excess of 200 feet. In addition, these devices are also faster at polling students and can serve greater numbers of students. A third type of wireless SRS uses the computing industry wireless networking standards to transmit and receive student responses and offers the benefit of using existing wireless infrastructure where it exists (Lowery, 2005).

Each SRS vendor has unique software and methods of transmitting and receiving student responses and there are no standards that currently exist that allow for interoperability between SRS. Having multiple vendors can add to support costs and can also result in multiple types of response pads being required of students causing implementation problems (Stone, 2004). The market is currently expanding as competition between vendors is resulting in more affordable SRS. It is estimated that 1.7 million Infra Red response pad units were sold in 2004 (Fleetwood Group Inc., 2005).

Textbook Publishers and Student Response Systems

The latest development that education institutions implementing SRS face is from traditional textbook publishers bundling response pads with student textbooks (Stone, 2004). Publishers such as Pearson, Addison Wesley, Thomson, Prentice Hall, Longman, and McGraw-Hill are teaming up with SRS vendors to bundle response pads with textbook purchases to make their product more attractive to classroom instructors. By working with textbook publishers SRS companies have made faculty more aware of their products and are selling response pads directly to higher education students to be used in conjunction with class textbooks. Instructors can benefit from pre-made questions by using a publisher that bundles SRS with textbooks and thus save the time of developing question sets.

Changing Views of Teaching, Learning, and Student Response Systems

SRS have been used in classrooms for more than four decades and over this time a shift has occurred from behaviorist to constructivist pedagogies (Judson & Sawada, 2002). Constructivists view learners as developing their own understanding based upon the learners making sense of new information based on prior knowledge. New understanding depends upon the current understanding of the learner and is facilitated by social interaction in meaningful and authentic learning tasks (Good & Brophy, 1997). Driscoll (2002) states that learning must occur in a specific context that makes sense to the learner by requiring individual learner participation along with social and reflective components to be effective.

It is not unusual for technologies such as SRS to take time before innovative uses of the technology are discovered. Brown (2000) describes how it often takes time before technological innovations improve existing practices. Brown gives examples of how adopting new technologies are often first used for purposes that are similar to the previous technology being replaced. The early days of photography went through a period that imitated paintings, when movies were invented they mimicked theatre. SRS have followed a similar trend and have been used for checking attendance, giving quizzes, and as a method for pacing lectures (Shapiro, 1997).

Student attitudes toward SRS use has been generally favorable with evidence that students enjoy using SRS and that students value the systems as being useful for their understanding of content (Abrahamson, 1999; Bessler & Nisbet, 1971; Boyle & Nicole, 2003; Draper & Brown, 2004; Dufresne et al., 1996; Duncan, 2005; Frey & Wilson, 2004; Garg, 1975; Jackson & Trees, 2003; Littauer, 1972; Mazur, 1997; Ober, 1997; Shapiro, 1997).

While student attitudes of using SRS have been positive, the results on student achievement have been mixed. Judson and Sawada (2002) note that the only studies that show evidence of increased student achievement with the use of SRS occurred when students communicated with each other to help one another understand. Judson and Sawada describe a shift away from teaching methods using behaviorist principles to constructivist principles beginning in the 1990s with SRS being used in combination with interactive pedagogies most notably in the sciences. Recent findings suggest that the implementation of SRS require an interactive pedagogy as a necessary component for increased student understanding and achievement and students need the opportunity to verbalize thoughts (Crouch & Mazur, 2001; Dufresne et al., 1996; Duncan; 2005; Mazur, 1997; Roschelle, Pea, Hoadley, Gordin, & Means, 2000). Judson and Sawada (2002) offer the following advice in terms of a buyer beware statement to users of SRS, "An electronic response system does not come prepackaged with interactive engagement" (p. 179).

Many SRS studies utilize self-reported data in the form of student questionnaires inquiring about student attitudes and perceived engagement level while using the SRS with all studies showing favorable results for the use of SRS (Draper & Brown, 2004; Duncan, 2005; Guthrie & Carlin, 2004; Paschal, 2002). Results of a study by Jackson and Trees (2003) at the University of Colorado at Boulder on university student perceptions of SRS use in large lecture classes indicated student support for opportunities for immediate feedback. Students indicated that they perceived clickers as improving their learning and that they paid more attention to clicker questions.

Introduction of SRS require changes in the structure of classroom activities to promote interactive pedagogies (Dufresne et al., 1996; Mazur, 1997). One barrier to SRS use is the belief that the teacher cannot cover the same amount of content with the system because its use takes up class time. Mazur (1997) counters this argument with a restructuring of lecture time by requiring readings outside of class and regularly quizzing students on the readings. This requires the student to come to class prepared for class discussions. Mazur uses approximately one-third of the class by asking conceptual questions and having students use peer instruction methods to convince each other of the correct answer. Dufresne et al. utilizes a question cycle similar to the peer instruction method but uses cooperative groups prior to students individually answering questions followed by class-discussion to more actively involve students with content.

Anonymous Shared Displays

Students report being more willing participants when using anonymous displays because of the safety of not being publicly identified as is the case with hand raising (Davis, 2003). In a study of prototype handheld devices used in high school mathematics classrooms Davis reports that public anonymity allows students to explore answers in a non-threatening environment. Students are able to identify their answers using the shared aggregate display and discuss reasons that someone may have selected a particular answer. This freedom allows students to explore content without identifying publicly who has the right and wrong answers. Students are able to identify their answers in the shared displayed space and compare their response with the rest of the class and know that they are not alone in selecting certain answers. Davis reports that class discussions often increase with more students participating when classroom communication technologies are used.

Classroom Networks and Mathematics

Roschelle, Penuel, and Abrahamson (2004) describe classroom networks consisting of handheld devices that connect to a laptop that can display a shared screen between devices. Classroom networks offer additional capability beyond simple SRS in that students have the ability to share individual handheld screen displays with the teacher and other students. Handheld devices such as graphing calculators, Palm Pilots, and Pocket PC's are used to connect to each other with the capability of sharing device displays. The SimCalc project (Kaput, 2002) uses graphing calculators that allow students to interact with shared displays used in middle and high school mathematics courses. Hegedus and Kaput (2003) report improvements in seventh, eighth, and ninth grade student achievement for items on standardized tests using classroom network technologies.

The area of mathematics has a history of incorporating technologies into the curriculum as many researchers see the potential of portable low cost devices that offer communications features for classroom use (Roschelle & Pea, 2002). Every new generation of technology takes some time to untangle and unlock the learning value of the raw technological potential. Roschelle and Pea describe three classroom uses for mobile technologies and provide descriptions for response systems, participatory simulations, and collaborative data gathering.

Researchers working on classroom networks and SRS are investigating socio-cultural effects on learning as new pedagogies are explored that take advantage of technological advances in the classroom (Hegedus & Kaput, 2004; Penuel, Roschelle, Crawford, Shechtman, & Abrahamson, 2004; Stroup, Kaput, Ares, Wilensky, Hegedus, Roschelle, et al. 2002). As the technologies mature new pedagogies are needed to integrate technology with effective classroom practices (Roschelle, Abrahamson, & Penuel, 2003).

Student Engagement

The term student engagement is often found in the literature of teaching and learning. Jones, Valdez, Nowakowski, and Rasmussen (1994) describe eight indicators for engaged learning and note the shift from teacher-centered to learner-centered classrooms. Increasing student engagement by fostering active learning environments leads to better student learning (Chickering & Gamson, 1991; Driscoll, 1994, 2002; Gagné, 1985). Elementary students that actively participate in class activities are more likely to achieve than students that passively participate (Finn & Cox, 1992).

In defining student engagement in the classroom McLaughlin et al. (2005) provide a framework identified as Student Content Engagement (SCE) and describe four components necessary for the learner to become cognitively engaged with the subject matter. The four components McGaughlin et al. identify are; Subject Matter Content level, Occasions for Processing, Physiological Readiness, and Motivation.

In order for learning to occur the student must be cognitively engaged with the appropriate subject matter knowledge. Subject Matter Content level refers to the requirement that subject matter be at the appropriate level for students to be cognitively engaged. If subject matter is too difficult the learner will not have the necessary prior knowledge to make cognitive links, if content is too easy students may become bored. Students require opportunities to participate in activities that support Occasions for Processing of new material. Offering multiple occasions for processing provides students with multi-pass learning opportunities to become cognitively engaged with content (Beatty, 2004). Physiological Readiness concerns itself with physiological needs, disabilities, or psychological states that may need to be addressed so as to not deter learning. The last component of the Student Content Engagement model is the willingness of the student to become involved with learning activities and McGaughlin et al. (2005) call this Motivation.

SRS facilitate student engagement by offering Occasions for Processing opportunities for every student simultaneously and seem to have some motivating effect on participation (Davis, 2003). Abrahamson (1999) describe SRS classrooms as being more lively, active, and happy. SRS technologies can assist teachers by automating the collection of student responses and unlike traditional classrooms students do not have to raise their hand and be publicly identified. Some students may choose not to raise their hand for fear of embarrassment of their answers or being singled out as having the wrong answer. Students using SRS have answers displayed anonymously in aggregate form and are more likely to participate (Davis).

Summary

This chapter has reviewed the literature related to SRS. SRS are promoted as a technology that can create interactive learning environments that engage students with content and each other. The systems are being used by K-12 and higher education students in a variety of subject areas. Most of the research studies regarding SRS use have been at the higher education level with a paucity of research in K-12 settings (Judson & Sawada, 2002; Penuel et al., 2004). This study contributes to the research base by investigating SRS effects in a sixth-grade mathematics classroom. Chapter 3 presents the methodology used in this study.

Chapter 3

METHODOLOGY

This chapter provides the methodology used for the study. The first section develops the information related to the research design. The second section provides information regarding the participants. The third section describes the research instruments, materials, and variables used in the study, the fourth section presents the research questions and hypotheses, and the fifth section describes the research and statistical procedures used.

Research Design

The study used a quasi-experimental comparative design. The study utilized a posttest only design with treatment and control groups to compare mean posttest scores between treatment and control groups for a sixth-grade mathematics unit on probability. Classroom observations were used to determine student verbal participation with comparisons being made between treatment and control groups for the mean total number of student-to-teacher responses and the mean total number of student-to-student responses for the unit. A student questionnaire was used to determine student attitudes regarding the use of the SRS in the classroom for the treatment group only.

Participants

Participants of the study were selected as an established group in a K-12 classroom setting. Previous SRS studies have been conducted at the college level but no known studies have used treatment and control conditions at the K-12 level. The school principal and teacher were contacted to determine interest in the study and agreed to participate. The participating school is located in a rural Midwestern community with the student body being predominantly white.

The participants of the study were 84 public school students from four different sections of a sixth-grade class and the students participated in a five-day mathematics unit on probability. Students selected for the study represent the norm of the student body at the participating school. The four sections are of mixed gender (48 male, 36 female) with students randomly assigned to the sections by the school with class sizes ranging from 19 to 22 students per section. All participant data has been kept confidential with alphanumeric numbers used to identify students.

Materials

The study used the TurningPoint 2006 SRS (Turning Technologies, LLC, 2005) to investigate the effects of a SRS introduced in two of the four sections of a rural sixth-grade mathematics curriculum. The teacher utilized TurningPoint 2006 software integrated with Microsoft PowerPoint installed on a laptop computer. TurningPoint 2006 software was used with the treatment group to create interactive slides capable of polling student responses via use of small wireless response pads (clickers).

The entire SRS consists of a laptop computer with Microsoft Office 2003, TurningPoint 2006 software (Turning Technologies, LLC, 2005), receiver, student response pads for each student, and a projection unit for publicly displaying PowerPoint slides to the class. Students used the same practice sets for homework assignments assigned by the teacher and graded by a teacher aide for both treatment and control groups. The practice sets are located in Appendix H. The teacher used math manipulatives in the form of spinners, coins, dice, decks of cards, and a bulletin board display for demonstrating probability concepts for both treatment and control groups. The SRS was made available to the teacher for use with students in the control group for the week following the end of the probability unit.

Instruments

The instrument used for the posttest for the sixth-grade probability unit was a 20 question teacher created test that underwent expert review by two sixth-grade teachers and a professor of mathematics at the university level to assure age appropriateness and verify accuracy. A pilot test was conducted with a group of 30 sixth-graders (14 male, 16 female) from a neighboring school to determine reliability of the test instrument using the split-half reliability procedure. The test instrument is located in Appendix A. Using the Spearman-Brown odd-even split-half reliability calculation the reliability coefficient was calculated to be .76 with a mean for the pilot test of 53.00% and Standard Deviation of 17.69 ($N = 30$). The correct answers to test instrument questions were randomly assigned to the letters A, B, C, or D by the use of a table of random numbers to avoid any correct answer pattern. The test instrument was also utilized to verify that no significant difference existed between proposed treatment and control groups the week prior to the beginning of the probability unit.

The second research instrument used was a seating chart of the classroom (Appendix B) with numbers used to identify classroom seats to record observations of student verbal participation. Observations using a seating chart (Acheson & Gall, 1987) were used to capture student verbal participation by utilizing arrows as tally marks to indicate student-to-teacher and student-to-student verbal responses. An upward arrow was used to indicate a student-to-teacher response and a sideways arrow was used to indicate a student-to-student response. For observations of student responses during group work the researcher scanned the room at 20 second intervals using a stop watch and recorded student verbal responses on the seating chart. At the end of the instructional unit totals for student-to-teacher responses and totals for student-to-student responses were calculated for each student for the unit.

The third research instrument (Appendix C) was a student questionnaire that was administered to the treatment group only. The clicker survey was reviewed by two university professors and two elementary teachers for content and age appropriate language. Prior research studies have collected data on student attitudes regarding SRS use at the college level (Draper & Brown, 2004; Dufresne et al., 1996; Duncan, 2005).

Variables

The primary independent variable in the study was the use or non-use of a SRS for the teaching of a sixth-grade mathematics unit on probability. There were three dependent variables used in the study. To measure student learning mean posttest scores of the treatment and control groups were used to measure end of unit learning. To determine student verbal participation the mean total number of student-to-teacher responses and the mean total number of student-to-student responses of the treatment and control groups were used.

Research Questions

The four research questions this study investigated are:

1. Is there a significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?
2. Is there a significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on probability, between the treatment group of SRS use and the control group of SRS non-use?
3. Is there a significant difference in student verbal participation, as measured by mean total number of student-to-student responses for a sixth-grade unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?
4. What are student attitudes regarding SRS use for a sixth-grade mathematics unit on probability?

Hypotheses

The following hypotheses were tested for the research questions:

Hypothesis 1. There will be no significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between students in the treatment group of SRS use compared to students in the control group of SRS non-use.

Hypothesis 2. There will be no significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on probability, between students in the treatment group of SRS use compared to students in the control group of SRS non-use.

Hypothesis 3. There will be no significant difference in student verbal participation, as measured by mean total number of student-to-student responses for a sixth-grade unit on probability, between students in the treatment group of SRS use compared to students in the control group of SRS non-use.

There will not be a hypothesis tested for research question four but will instead use descriptive statistics for informational purposes regarding student attitudes toward SRS use. Prior studies have utilized descriptive statistics to measure self-reported student attitude regarding SRS use in higher education classrooms. Results from the questionnaire were reported for the treatment group using descriptive statistics.

Four controls were used in the study. First, the exact same posttest was used for treatment and control groups. Second, identical mathematical content was selected and presented for treatment and control groups. Third, the exact same practice sets were used for treatment and control groups. Fourth, the same teacher taught all treatment and control groups for the unit.

Research Procedures

Two class sections were used for the treatment group and two class sections were used for the control group with the results pooled to increase the statistical power of the study. The teacher was provided with professional development in the use of the SRS approximately three weeks before the study began. To avoid any novelty effect, the SRS was introduced the week prior to the mathematics unit being studied for the treatment sections to familiarize students with the use of the SRS (Draper & Brown, 2004). The clickers used in the study were of a very simple design similar to a TV remote control and students had no difficulty in using the clickers. The test instrument was administered by the researcher to determine if there was a significant difference in student ability level between proposed treatment and control groups the prior week to the beginning of the probability unit. To avoid any back-to-back teaching of treatment or control group conditions the treatment and control sections proposed were assigned to every other class period. An independent-samples two-tailed t-test was used to determine if there was a significant difference between the mean test scores of the proposed treatment and control groups.

The treatment and control groups experienced the exact same content, a mathematical unit on probability. The teacher utilized PowerPoint slides to present material for whole class teaching of the content to the treatment and control groups for approximately half the period. The treatment condition was the use of the SRS to answer selected interactive slides. The treatment group utilized the exact same PowerPoint slides and practice sets as the control group with the addition of interactive slides added throughout each lesson to replace questions that were verbally asked by the teacher for the control group. The treatment group also used the SRS to answer the first five practice set questions during student work-time using peer instruction. The student response pads were referred to as clickers by the teacher and students were instructed to "vote" for the response of their choice using the interactive slides at the appropriate time in the lesson by the teacher. A student was assigned to distribute the clickers at the beginning of class and collect the clickers at the end of the class period to help the teacher manage the equipment.

Time was given to work on practice sets in class for both treatment and control groups however the treatment group answered the first five practice set questions using the SRS with peer instruction and any remaining work-time time was used by students to individually answer the remaining five practice set questions. The control group answered all practice set questions during work-time and asked for teacher assistance when needed. The teacher utilized a "cup system" for individual students to signal when assistance was required during the work-time given for practice sets. Students kept two plastic cups on their desk, a blue cup and a red cup. If students wanted to request assistance during work-time on practice sets the student placed the red cup on top, otherwise the blue cup was on top. This prevented the student holding a raised hand in the air until the teacher could assist. The students were instructed to go on to the next problem during work-time until the teacher could assist the student.

Two to four interactive slides were used for the treatment group during the main instructional time for each lesson with the anonymous aggregate results of each interactive slide immediately shown to the whole class in the form of a histogram. The treatment group used the first five questions of each practice set as clicker questions and the teacher utilized the peer instruction method with the SRS modeled and adapted after Mazur (1997) using the following procedure:

1. Question posed in PowerPoint using an interactive slide to the whole class
2. Students given time to think (no talking allowed)
3. Students record individual answer using their clickers
4. Teacher views anonymous aggregate results of students first responses (results of first aggregate display not immediately shown to class)

5. Students convince their neighbor of the correct answer (peer instruction)
6. Teacher displays results of first polling and students continue peer instruction
7. Teacher resets the slide for a second polling students record answers again after peer instruction (student may change answer if warranted)
8. Teacher displays the anonymous aggregate responses of the second polling to whole class
9. Teacher gives explanation of the correct answer with discussion if necessary

The remaining five practice set questions for the treatment group not answered by use of the SRS and peer instruction were worked on individually just as in the control group and students could individually ask the teacher for assistance if needed using the cup system to signal for assistance. All practice set questions were completed in class for both treatment and control groups.

Statistical Procedures

Computer statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) program. An alpha level of .05 was used as the level of confidence for all statistical tests. For Hypothesis 1 an independent-samples two-tailed *t*-test was used to determine if there was a significant difference between the mean posttest scores of the treatment and control groups.

For Hypothesis 2 an independent-samples two-tailed *t*-test was used to determine if there was a significant difference between the mean total number of student-to-teacher responses for the unit between the treatment and control groups. For Hypothesis 3 an independent-samples two-tailed *t*-test was used to determine if there was a significant difference of the mean total number of student-to-student responses for the unit between the treatment and control groups. If a significant difference was found for Hypothesis 1, Hypothesis 2, or Hypothesis 3 a Cohen's d was calculated to report effect size related to any significant findings.

Research question four did not have a hypothesis to test but instead used descriptive statistics to report on the self-reported results of the student questionnaire of the treatment group regarding student attitudes of SRS use.

The unit on probability was scheduled for four days of instruction followed by the administration of a teacher created posttest on the fifth day. The first day provided an introduction and overview to probability terms and concepts. Practice sets were assigned to the treatment and control groups after the instruction for days two, three, and four of the unit. Students had the option to take any practice set problems home for homework if problems were not completed in class. The teacher lesson plans are located in Appendix G and the practice sets are located in Appendix H. The first two practice set assignments were graded by a teacher's aide and returned to the students in class the following day that the assignment was due. Answers to the third practice set were given at the end of the class period on the fourth day and the graded practice set was returned the same day so that all students had the correct answers to study for the end of unit posttest scheduled for the fifth day. The students participating in the study that were assigned to the control group for the probability unit used the clickers in class the following week.

Human Subjects Considerations

Approval from the Review Committee for the Protection of Human Subjects at Indiana State University was obtained prior to data collection. Informed consent and assent letters were created to inform parents/guardians and children of their rights and obtain permission to participate in the study. The Institutional Review Board approval letter is located in Appendix D. The informed consent letter used for the study is located in Appendix E and the assent form used for the study is located in Appendix F. Participation in the research study was entirely voluntary.

Summary

This chapter has outlined the methodology used for the study. The study utilized a quasi-experimental posttest only design using a comparison of treatment to control groups of sixth-grade students from a rural Midwestern community. The treatment condition was the use of a SRS and the control condition was the non-use of a SRS for a sixth-grade mathematics unit on probability. The study investigated the effects of SRS use on student learning and verbal participation along with student attitudes of SRS use. Chapter 4 presents the results of the study and Chapter 5 provides the discussion and recommendations of the study.

Chapter 4

RESULTS

The purpose of this chapter is to report on the results of the study. The study considered three research questions related to SRS use on student learning and verbal participation between the treatment group of SRS use and the control group of SRS non-use for a sixth-grade mathematics unit on probability. The study also considered a fourth question relating to student attitudes of SRS use for the treatment group only.

The four research questions this study investigated are:

1. Is there a significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?
2. Is there a significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on probability, between the treatment group of SRS use and the control group of SRS non-use?
3. Is there a significant difference in student verbal participation, as measured by mean total number of student-to-student responses for a sixth-grade unit on

probability, between the treatment group of SRS use compared to the control group of SRS non-use?

4. What are student attitudes regarding SRS use for a sixth-grade mathematics unit on probability?

Participants

Informed consent and assent forms were obtained prior to data collection from 84 out of a total of 85 sixth-grade students eligible to participate in the study (48 male, 36 female) from the math sections of the selected teacher at the school, one student declined to participate in the study. Participation in the study was entirely voluntary. The test instrument was used to test the assumption that the proposed treatment and control groups were of mixed ability levels the week prior to the beginning of the probability unit. An independent-samples two-tailed *t*-test was conducted to determine if there was a significant difference between the mean test scores of the proposed treatment and control groups. No significant difference was found to exist between the proposed treatment group mean test score ($M = 54.89$, $SD = 15.04$, $n = 44$) and the proposed control group mean test score ($M = 56.88$, $SD = 18.83$, $n = 40$), $t\,(82) = -.537$, $p = .593$.

The assigned treatment group of SRS use consisted of the first and third sections of the sixth-grade mathematics class and the assigned control group of SRS non-use consisted of the second and fourth sections of the sixth-grade mathematics class using established grouping at the selected elementary school to avoid back-to-back teaching of the treatment and control groups. Results from a total of 76 participants, with 38 in the treatment group and 38 in the control group, are considered for analysis of the first three research questions for the study. Eight students were removed from the sample due to absences during the instructional unit on probability. An independent-samples two-tailed *t*-test was conducted to confirm that no significant difference existed between the 38 students remaining in the treatment group and the 38 students remaining in the control group. An independent-samples two-tailed *t*-test using test data from the week prior to the probability unit found no significant difference between the mean test score of the 38 students in the treatment group ($M = 54.07$, $SD = 15.42$, $n = 38$) and the mean test score of the 38 students in the control group ($M = 57.24$, $SD = 19.13$, $n = 38$), $t\,(74) = -.792$, $p = .431$. The assigned treatment and control groups are considered of equal ability with no significant difference of mean test scores between the groups.

Research Question 1

The first research question explored by this investigation was:

Is there a significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?

An independent-samples two-tailed *t*-test was used to determine if there was a significant difference between the mean posttest scores of the treatment and control groups. An alpha level of .05 was used to determine the level of significance. For the posttest the Spearman-Brown odd-even split-half reliability coefficient was .80. Table 4.1 displays the results of the mean Posttest scores for the treatment group of SRS use and the control group of SRS non-use.

Table 4.1

Results of Mean Posttest Scores for Treatment and Control Groups

Group	*n*	*M*	*SD*	Std. Error Mean
Treatment	38	73.55	15.46	2.51
Control	38	78.03	16.99	2.76

Figure 4.1 displays the histogram of the treatment group posttest scores for the probability unit ($n = 38$). The distribution of scores is negatively skewed with a skewness value of -.535 and standard error of skewness of .383. The kurtosis value is -.200 with the standard error of kurtosis of .750.

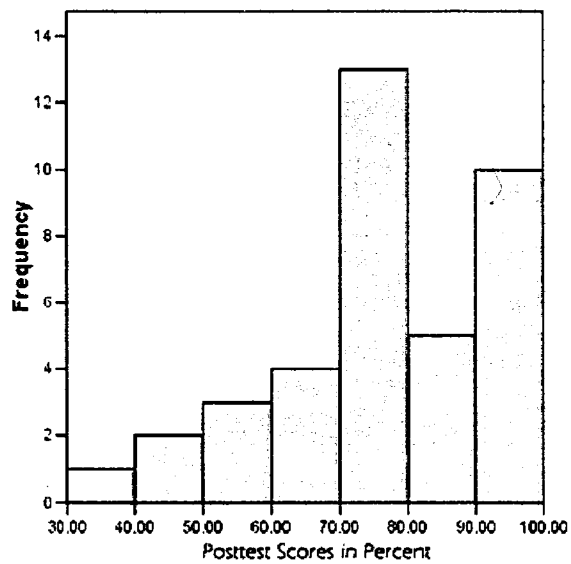

Figure 4.1: Histogram of Treatment Group Posttest Scores ($n = 38$).

Figure 4.2 displays the histogram of the control group posttest scores for the probability unit ($n = 38$). The distribution of scores is negatively skewed with a skewness value of -1.021 and standard error of skewness of .383. The kurtosis value is .852 and the standard error of kurtosis of .750. For *t*-tests normal distributions are assumed, skewed data distributions may be used with *t*-tests if the skewness is in the same direction and the equality of variance assumption is met (Myers & Well, 1995).

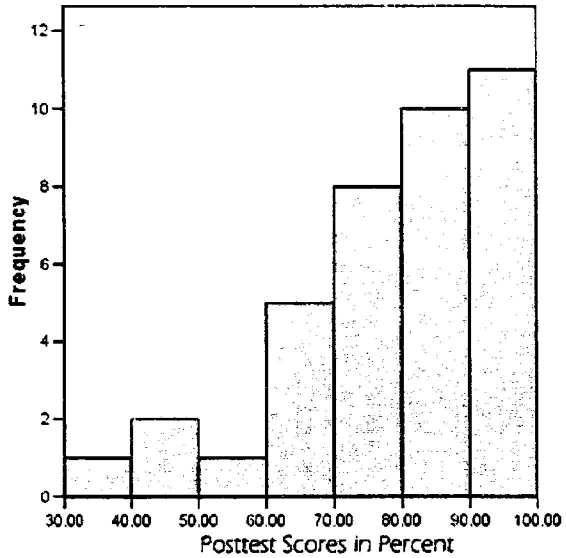

Figure 4.2: Histogram of Control Group Posttest Scores (n = 38).

The null hypothesis for research question 1 was: There will be no significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between students in the treatment group of SRS use compared to students in the control group of SRS non-use.

The result of an independent-samples two-tailed *t*-test for the null hypothesis for research question 1 is not significant. Levene's Test for Equality of Variance for the posttest scores reports a significance value of .716. This number is greater than the alpha level of .05 indicating no significance. The assumption of homogeneity of variance has been met. The result of an independent-samples two-tailed *t*-test for the mean posttest scores of the treatment group of SRS use (M = 73.55, SD = 15.46, n =38) compared to the control group of SRS non-use (M = 78.03, SD = 16.99, n = 38) is not significant, t (74) = -1.201, p = .234.

Research Question 2

The second research question explored by this study was:

Is there a significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on probability, between the treatment group of SRS use and the control group of SRS non-use?

An independent-samples two-tailed t-test was conducted to determine if there was a significant difference between the mean total number of student-to-teacher responses of the treatment and control groups. An alpha level of .05 was used to determine the level of significance. Table 4.2 displays the results of the mean total number of student-to-teacher responses for the sixth-grade probability unit for the treatment group of SRS use and control group of SRS non-use.

Table 4.2

Results of Mean Total Number of Student-to-teacher Responses for Treatment and Control Groups

Group	*N*	*M*	*SD*	Std. Error Mean
Treatment	38	10.47	4.67	.76
Control	38	11.34	3.83	.62

Figure 4.3 displays the histogram of the total number of student-to-teacher responses for the sixth-grade probability unit for the treatment group of SRS use. The

distribution of the total number of student-to-teacher responses for the unit is approximately normal for the treatment group with a skewness value of .153 and standard error of skewness of .383. The kurtosis value was -.279 with a standard error of kurtosis of .750.

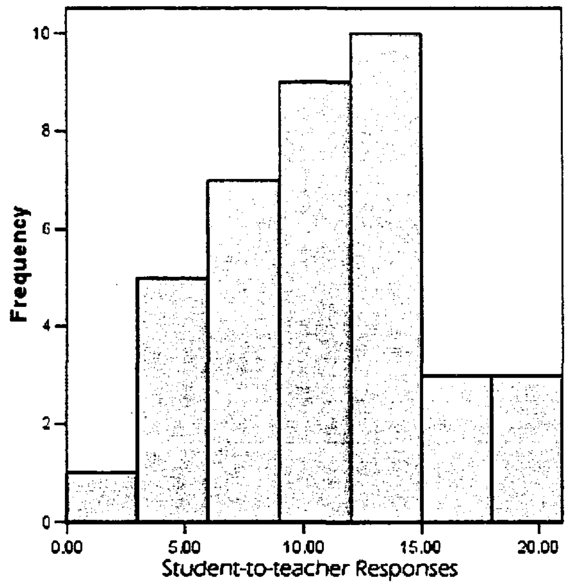

Figure 4.3: Histogram of Treatment Group Total Number of Student-to-teacher Responses for the Unit (n = 38).

Figure 4.4 displays the histogram of total number of student-to-teacher responses for the sixth-grade probability unit for the control group of SRS non-use. The distribution of the total number of student-to-teacher responses for the unit is approximately normal for the control group with a skewness value of .064 and standard error of skewness of .383. The kurtosis value was -.663 with a standard error of kurtosis of .750. The distribution of the total number of student-to-teacher responses of the control group for the unit is approximately normal.

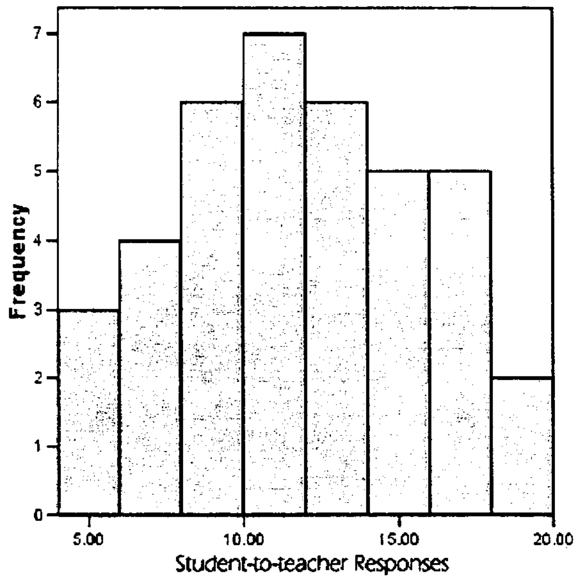

Figure 4.4: Histogram of Control Group Total Number of Student-to-teacher Responses for the Unit (n= 38).

The null hypothesis for research question 2 is: There will be no significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on probability, between students in the treatment group of SRS use compared to students in the control group of SRS non-use.

The result of an independent-samples two-tailed t-test for research question 2 is not significant. Levene's Test for Equality of Variance for the mean total number of student-to-teacher responses reports a significant value of .309. This number is greater than the alpha level of .05 indicating no significance. The assumption of homogeneity of variance has been met. The result of an independent-samples two-tailed t-test for the mean total number of student-to-teacher responses of the treatment group of SRS use (M = 10.47, SD =4.67, n = 38) compared to the control group of SRS non-use (M =11.34, SD =3.83, n = 38) is not significant, t (74) = -.887, p = .378.

Research Question 3

The third research question explored by this study was:

Is there a significant difference in student verbal participation, as measured by mean total number of student-to-student responses for a sixth-grade unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?

An independent-samples two-tailed *t*-test was used to determine if there was a significant difference between the mean total number of student-to-student responses between the treatment and control groups. An alpha level of .05 was used to determine the significance level. Table 4.3 displays the results of the mean total number of student-to-student responses for the sixth-grade probability unit for the treatment group of SRS use and control group of SRS non-use.

Table 4.3

Results of Mean Total Number of Student-to-student Responses for Treatment and Control Groups

Group	*n*	*M*	*SD*	Std. Error Mean
Treatment	38	12.82	1.67	.27
Control	38	5.63	1.89	.31

Figure 4.5 displays the histogram of the total number of student-to-student responses for the treatment group of SRS use for the unit ($n = 38$). The distribution of the total number of student-to-student responses for the treatment group is approximately

normal with a skewness value of .198 and standard error of skewness of .383. The kurtosis value a kurtosis value of -.638 with a standard error of kurtosis of .750.

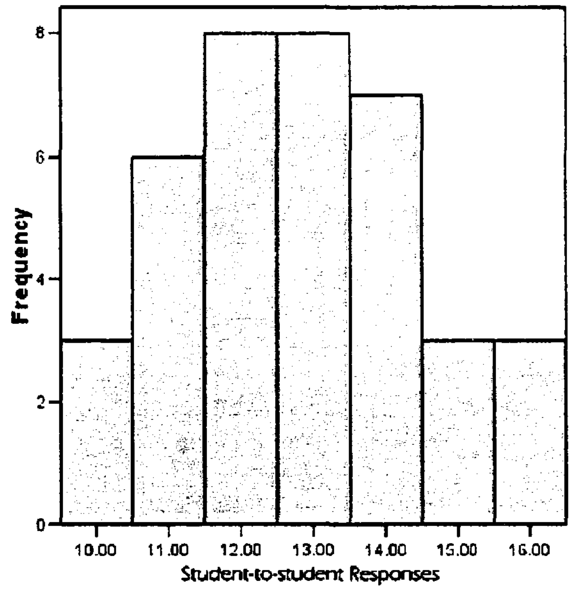

Figure 4.5: Histogram of Treatment Group Total Number of Student-to-student Responses for the Unit (n = 38).

Figure 4.6 displays the histogram of the total number of student-to-student responses for the control group of SRS non-use (n = 38). The distribution of the total number of student-to-student responses for the control group is approximately normal with a skewness value of .011 and standard error of skewness of .383. The kurtosis value was -.988 with a standard error of kurtosis of .750.

The null hypothesis for research question 3 was: There will be no significant difference in student verbal participation, as measured by mean total number student-to-student responses for a sixth-grade unit on probability, between students in the treatment group of SRS use compared to students in the control group of SRS non-use.

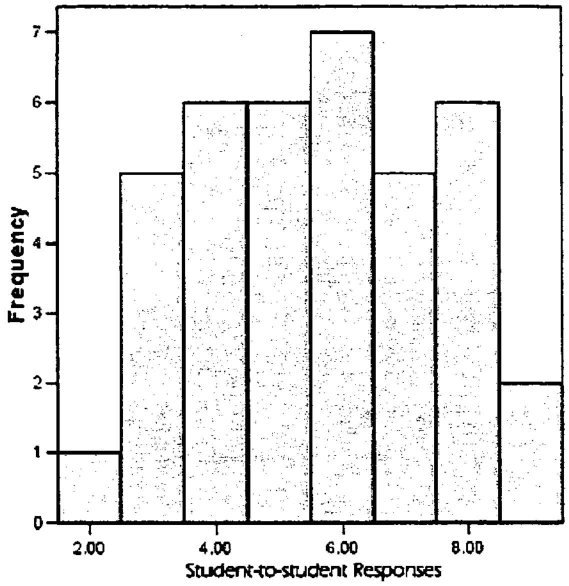

Figure 4.6: Histogram of Control Group Total Number of Student-to-student Responses for the Unit (n = 38).

Levene's Test for Equality of Variance for student-to-student responses reports a significant value of .289. This number is greater than the alpha level of .05 indicating no significance. The assumption of homogeneity of variance has been met.

The result of an independent-samples two-tailed t-test for the mean total number of student-to-student responses of the treatment group of SRS use (M = 12.82, SD =1.67, n = 38) compared to the mean total number of student-to-student responses of the control group of SRS non-use (M = 5.63, SD = 1.89, n = 38) is significant, t (74) = 17.52, p < .001. A Cohen's d value of 4.07 was calculated for the effect size.

Research Question 4

A survey was administered at the end of the probability unit to the treatment group of sixth-grade students that used the SRS for the mathematics unit on probability (n = 44). The clicker survey is located in Appendix C. Items were coded using a 4 point scale with 4 representing a high score and 1 representing a low score. High scores are viewed as a favorable response to the item regarding SRS use. Item number 4 was reverse coded to reflect a favorable result that students would not think that the clickers took up too much time in the classroom. The Coefficient alpha value is .78 for the clicker survey (n = 44). Results of the Clicker Survey are found in Table 4.4 and include the mean response and standard deviation for the item along with the item question with assigned item score values.

Table 4.4

Results of Student Response System Clicker Survey (n = 44)

Mean Response	Standard Deviation	Item
3.84	.36999	1) How did you like using clickers in the classroom? 4=Really liked, 3=Kind of liked, 2= Did not like, 1=Really did not like
3.07	.87332	2) Using clickers in class makes me try harder to learn more. 4=Really Agree, 3=Kind of Agree, 2= Kind of Disagree, 1=Really Disagree
3.45	.62708	3) I paid more attention in class when the clickers were used. 4=Really Agree, 3=Kind of Agree, 2= Kind of Disagree, 1=Really Disagree
3.77	.47562	4) Using clickers in class took up too much time. 1=Really liked, 2=Kind of Agree, 3= Kind of Disagree, 4=Really Disagree
3.41	.72555	5) I learn better with clickers. 4=Really Agree, 3=Kind of Agree, 2= Kind of Disagree, 1=Really Disagree

Table 4.4 (continued)

Mean Response	Standard Deviation	Item
3.50	.62877	6) Seeing the clicker results in graphs for everybody in the class helped me learn better. 4=Really Agree, 3=Kind of Agree, 2= Kind of Disagree, 1=Really Disagree
3.39	.68932	7) Talking about the answers to clicker questions with others helped me understand better. 4=Really helped, 3=Kind of helped, 2= Did not help, 1=Really did not help
3.73	.58523	8) Would you recommend using clickers in other classes? 4=Really recommend, 3=Kind of recommend, 2=Do not recommend, 1= Really do not recommend

Summary

This chapter has reported on the results of the study. Three research questions were investigated using independent-samples two-tailed *t*-tests for student learning and verbal participation. No significant difference is found between the treatment group of SRS use and the control group of SRS non-use for student learning. For student verbal participation no significant difference is found for student verbal participation between the treatment and control groups for the mean total number of student-to-teacher responses for the sixth-grade probability unit. A significant difference is found for student verbal participation of the mean total number of student-to-student responses between the treatment and control groups for the sixth-grade probability unit. A clicker survey was administered to students in the treatment group of SRS use at the end of the probability unit with descriptive statistics reported for the survey. Chapter 5 provides the discussion and recommendations based upon the results of the study.

CHAPTER 5

DISCUSSION AND RECOMMENDATIONS

This chapter provides the discussion of the results for the study and provides recommendations and implications for practice based upon the data and information from previous chapters. Chapter 1 provided an overview and statement of the problem. Chapter 2 provided a review of the literature, Chapter 3 provided the methodology used for the study, and Chapter 4 provided the results of the study.

The purpose of this comparison study was to investigate the effects of SRS use and non-use on student learning and student verbal participation for a sixth-grade mathematics unit on probability in an authentic K-12 classroom setting. The study also investigated student attitudes regarding the use of a SRS for a sixth-grade mathematics unit on probability. The probability unit began one week after state achievement testing so as to not to interfere with state achievement testing preparation or results. The discussion is organized by research question.

Research Question 1

Is there a significant difference in student learning, as measured by mean posttest scores of students for a sixth-grade mathematics unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?

No significant difference is found between mean posttest scores for the treatment group of SRS use (*M* = 73.55, *SD* = 15.46, *n* = 38) compared to the control group of SRS non-use (*M* = 78.03, *SD* = 16.99, *n* =38), *t* (74) = -1.201, *p* = .234.

The only studies that previously demonstrated significant differences in student learning with SRS use have been Interactive Engagement classes compared to lecture only classes at the high school and college level (Hake, 1998; Mazur, 1997). Both treatment and control groups in this study were considered to be Interactive Engagement classes as described by Hake with the students engaged in the content with "hands-on" and "minds-on" activities. The effective use of questioning by the teacher and the use of mathematic manipulatives in the form of coins, dice, decks of cards, and bulletin board displays used for instruction provided an interactive learning environment for both treatment and control groups. The added use of the SRS with peer instruction for the treatment group did not produce a significant difference in student learning.

Using data available from the test given the prior week to the beginning of the unit to determine if the treatment and control groups were significantly different in ability levels it was found that the assigned treatment group began the unit with a lower mean test score (*M* = 54.07, *SD* = 15.42, *n* = 38) compared to the control group (*M* = 57.24, *SD* =19.13, *n* = 38) but the difference was not significant. The assigned treatment and control groups are considered of equal ability with no significant difference of mean test scores between the groups before instruction. The treatment group mean posttest score remained lower than the control group mean posttest score after the instruction for the unit. The difference in mean posttest scores between the treatment and control groups is found to be not significant after the instruction. The use of the SRS for the treatment group did not result in a significant difference in student learning as measured by the mean posttest scores between the treatment and control groups.

Four controls were used in this study. First, the exact same posttest was used for treatment and control groups. Second, identical mathematical content was selected and presented for treatment and control groups. Third, the exact same practice sets were used for treatment and control groups. Fourth, the same teacher taught all treatment and control groups for the unit. The combination of the four controls along with the Interactive Engagement (Hake, 1998) of both treatment and control groups may have set a hurdle too high for the treatment group to demonstrate a significant difference in student learning. The timeframe of the study was also limited to a one week unit on probability and longer timeframes may be necessary to demonstrate significant differences in student learning.

Results from the teacher created test instrument used for the study were negatively skewed for the mean posttest scores for both treatment and control groups. This suggests that the test instrument item difficulty may need to be increased for future studies. This was the first time the test instrument was used following instruction of the probability unit. Increasing the item difficulty and possibly increasing the test length could lessen the likelihood of negatively skewed results if this study were repeated in the future. All students completed the posttest within 25 minutes so there was ample time allowed for the students to complete the test without feeling rushed. Consideration for increasing the length of test and item difficulty must be balanced with a sixth-graders attention span and ability level.

Research Question 2

Is there a significant difference in student verbal participation, as measured by mean total number of student-to-teacher responses for a sixth-grade unit on probability, between the treatment group of SRS use and the control group of SRS non-use?

No significant difference is found to exist between the mean total number of student-to-teacher responses for the treatment group of SRS use (M = 10.47, SD = 4.67, n = 38) compared to the control group of SRS non-use (M = 11.34, SD = 3.83, n = 38), t (74) = -.887, p = .378. The instruction for the unit was provided by a veteran teacher with seventeen years of teaching experience and the teacher was effective in involving students in both the treatment and control groups with the content. The sixth-grade mathematics classroom environment in this study differed from lecture only classes described at the college level in large lecture halls where little interaction occurs (Mazur, 1997). The teacher used questioning effectively to involve students with the content and no significant difference in the mean total number of student-to-teacher responses was found to exist between the treatment and control groups.

The teacher was able to effectively distribute questions to all students for the probability unit. The small class size allowed the teacher to call upon students and keep the students engaged with the content. Most students were ready to participate when the teacher called upon a student to answer specific questions. The mean for the treatment group of 10.47 total student-to-teacher responses for the unit and the mean for the control group of 11.34 total student-to-teacher responses for the unit were approximately equal for the two groups. Students in both treatment and control groups were actively engaged with the teacher during the instruction of the unit.

Students in the treatment group of SRS use were not required to verbalize their responses to the teacher when using the clickers to vote on the correct answer for interactive slides. The SRS provided an alternative way for students to communicate their answer to the teacher that allowed 100 % student participation for every clicker question. The use of the clickers as an alternative method to communicate the student answers to the teacher may account for the slightly lower mean number of student-to-teacher responses for the treatment group.

Research Question 3

Is there a significant difference in student verbal participation, as measured by mean total number of student-to-student responses for a sixth-grade unit on probability, between the treatment group of SRS use compared to the control group of SRS non-use?

A significant difference was found to exist for the mean total number of student-to-student responses for the sixth-grade mathematics unit on probability between the treatment group of SRS use (M =12.82, SD = 1.67, n = 38) compared to the control group of SRS non-use (M = 5.63, SD = 1.89, n = 38), t (74) = 17.52, p < .001.

Students in the treatment group had more opportunity to participate in structured group discussion through peer instruction when using the SRS by utilizing the first five questions of Practice Sets A, B, and C as clicker questions. The increase in student-to-student responses was not unexpected since peer instruction when used in combination with SRS encourages student-to-student interaction and was part of the treatment condition (Ward, 2003). The effect size was large with a Cohen's d of 4.07. Students were willing to discuss their answers with each other providing an explanation as to how they arrived at a particular answer. The teacher instructed the students in the treatment group to talk with their neighbor to explain why their answer was correct during the peer instruction. The addition of the shared anonymous display allowed the student to compare their answer to that of the entire class and the student could use this information to change their answer during the peer instruction if warranted. The shared anonymous display became part of the content of the discussion as described by Beatty (2004).

Even though a significant difference was found for the mean total number of student-to-student responses between treatment and control groups the effect did not translate into a significant difference in student learning between the treatment and control groups. Previous studies describing significant differences in student learning involved peer instruction when used in combination with SRS between lecture only classes and Interactive Engagement classes (Crouch & Mazur, 2001; Hake, 1998; Mazur, 1997). Results of the study indicate that for interactive classrooms the use of the SRS did not produce a significant difference in student learning for the probability unit as measured by the teacher created test. The effects of the interaction of student-to-teacher responses of the control group may have offset any benefits from the use of the SRS and peer instruction. The timeframe of the study of one-week may not have been long enough to determine significant differences in learning and longer term studies are needed.

The sixth-grade classroom in the study is a different environment than large lecture halls described in previous research on SRS at the college level (Shapiro, 1997). Sixth-grade students in both treatment and control groups had ample opportunity to interact with the teacher as is evidenced by the nearly equal mean total number of student-to-teacher responses. The treatment group of SRS use did experience a significant difference in student-to-student responses but did not translate into a significant difference in student learning.

Research Question 4

Research question four did not have a hypothesis to test but instead used descriptive statistics to report on the self-reported results of the student questionnaire of the treatment group regarding student attitudes of SRS use. Most studies on SRS use have been at the college level with studies reporting favorable experiences by the students (Beatty, 2004). Results of the survey findings are presented in Table 4.4 and are similar to previous studies conducted at the college level on student satisfaction with SRS with most students having favorable views of SRS use (Duncan, 2005).

When asked if the sixth-grade students liked using the clickers in the classroom for item 1 of the survey the mean response was 3.84 on a 4 point scale indicating a positive overall experience with clicker use for the unit. No technical difficulties were experienced with the SRS for the probability unit and thus did not factor in to the students opinion of SRS use. Previous studies have mentioned technical difficulties with equipment (Shapiro, 1997). The lowest mean response of the survey questions was 3.07 on a 4 point scale for item 2 regarding use of clickers and students trying harder to learn. For item 3 of the survey students reported agreement with paying more attention in class when the clickers were used ($M = 3.45$). Students did not report that the clicker use took up too much time in class ($M = 3.77$). Students reported learning better with the clickers with a mean response of 3.41 for survey item number 5. Results for item 6 ($M = 3.50$) about students seeing the clicker results in the form of graphs and for item 7 ($M = 3.39$) regarding students talking about answers with others provides evidence that students believe they benefit from seeing others answers and talking about their answers with each other, this is similar to the findings of Davis (2003). The final question of the clicker survey asked if the sixth-grade students would recommend the use of clickers in other classes, the mean response was 3.73 on a 4 point scale for item 8 indicating a positive experience with clicker use. Overall results of the self-reported clicker survey indicate positive satisfaction with using clickers in the classroom and an overall recommendation by the sixth-grade students for clicker use in other classes.

Implications for Practice in Schools

The use of the SRS in combination with peer instruction provided an unanticipated benefit to the teacher. Observations of group work that occurred during peer instruction using the SRS provided an orderly and structured group discussion environment for the sixth-grade students. The teacher was able to effectively use the SRS to keep students focused on the clicker questions and was able to control the group discussions by using the peer instruction method with the SRS. When the teacher wanted to regain control of the discussion and make transitions between questions the teacher would ask the class to get quiet before re-polling the question. Once the class was quiet the teacher would reset the SRS so the students could vote again or move on to the next question. Teachers interested in having group discussions in a structured format may be interested in utilizing peer instruction with a SRS.

All of the students in the treatment group voted on all of the clicker questions achieving a one-hundred percent participation rate when using the clickers. The teacher was able to immediately see the group results and thus gauge the level of understanding of the class for each clicker question in real-time. The use of the SRS made student answers immediately visible to the teacher. When the level of agreement was high little group discussion was needed by the students during peer instruction. When the clicker questions were more difficult the students required more time to think of the answer before students could begin the peer instruction. This is similar to the findings of Mazur (1997) and demonstrates the need for carefully crafting clicker questions that are to be used with peer instruction.

Sixth-grade students in the treatment group had an overall favorable view of using the SRS for the probability unit. Classrooms that use SRS collect answers for all students simultaneously allowing every student to participate by having their answers recorded and anonymously displayed. Results of the self-reported clicker survey indicate the students perceived benefits from using the SRS system even though no significant difference was found for student learning. Students were motivated and engaged in the content and were prepared to vote on each clicker question. Teachers interested in methods of increasing class participation for all students may benefit from SRS use.

The study found no significant difference in student verbal participation as measured by the mean total number of student-to-teacher responses between the treatment group of SRS use and the control group of SRS non-use. The teacher was able to effectively distribute questions to students of both treatment and control groups. The smaller class sizes investigated in this study are a different learning environment than large lecture classes at the university level where much of the previous SRS research has occurred. The use of SRS for smaller class sizes may not offer the same benefits as described in previous research for large lecture courses at the university level.

SRS require an additional cost to educational institutions interested in using the technology for classroom use. Educators interested in the use of SRS should weigh cost factors versus potential benefits of SRS use by identifying instructional goals and matching SRS use with appropriate pedagogies. If instructional goals can be met efficiently without the use of a SRS the additional costs may not be justified. The use of SRS provides information to the students and teachers in real-time that have previously been unavailable in the classroom environment. Educators should identify how this information can be effectively used to improve instruction otherwise the potential benefits of SRS use may not be realized.

The use of the SRS did require extra preparation time for the teacher. The teacher had to develop clicker questions and input them into the system. Having pre-made questions in a format that can easily be imported into the system would save teachers question entry time and benefit teachers.

Recommendations for Further Study

Additional scientifically-based research studies are needed in authentic classroom environments using SRS at the K-12 level in a variety of subject areas. There is a paucity of research regarding the use of SRS in the K-12 setting. Longer term and larger scale studies are needed to determine if SRS effect student learning and retention over the course of an academic year. SRS offer the ability to easily collect real-time assessment data but little is known regarding how the teacher can utilize the real-time assessment data to significantly improve student learning.

The study determined a significant difference in mean total number of student-to-student responses between treatment and control groups for the unit. Follow-up studies are needed that compare peer instruction with SRS use to classrooms that use peer instruction without SRS to determine if the same level of interaction can be achieved without SRS use and if a significant difference in learning occurs for other grade levels and subject areas.

ConceptTests similar to those developed by Mazur (1997) need to be developed for K-12 subject matter and tested over longer time periods with larger sample sizes. Clicker questions focusing on conceptual knowledge should be developed and tested by researchers for a variety of subject areas and grade levels and shared with educators. Textbook publishers, SRS manufacturers, educators, and researchers should consider collaborating on the creation of public domain test bank items of clicker questions that are freely available for classroom use.

Less experienced teachers may not be as skilled in distributing questions to all students in class as suggested by Bessler and Nisbet (1971). Future studies should consider experience level of the teacher to determine if experience level makes a difference in the ability of the teacher to distribute questions to all students. The use of SRS can achieve 100% class participation but more studies are needed to determine if and how SRS use can be translated into improved student learning at the K-12 level.

The current study did not explore the teacher attitudes of SRS use. Studies are needed that investigate teacher attitudes regarding SRS use and investigate what works in authentic K-12 classrooms and to identify barriers of SRS adoption. SRS have the capability of making student thinking visible in real-time by the display of histograms of student responses. Teachers previously have not had the ability to see in real-time the question results for every student in the class. More research is needed to determine effective methods for utilizing real-time data and to investigate how teachers use the data to adapt their teaching methods.

Summary

The study expands upon previous research on SRS use at the K-12 level. Most of the previous studies of SRS use have been at the college level (Judson & Sawada, 2002). The study collected and analyzed data on SRS use and non-use on student learning and verbal participation for a sixth-grade mathematics unit on probability. The goal of the study was to determine if there are differences in student learning and verbal participation for classes using a SRS compared to classes that do not use a SRS and to determine sixth-grade student attitudes regarding SRS use.

The study found no significant difference in student learning as measured by a teacher created test between the treatment group of SRS use and the control group of SRS non-use for the probability unit. The study found no significant difference in the mean total number of student-to-teacher responses for the unit, however, the study did find a significant difference in mean total number of student-to-student responses for the unit between treatment and control groups. Results of a self-report survey regarding student attitudes of SRS use were favorable with sixth-grade students in the treatment group reporting overall satisfaction with the use of the SRS for the probability unit.

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APPENDIX A

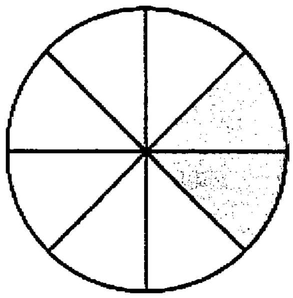
TEST INSTRUMENT

Section: ____ Desk Number: _____

Sixth-Grade Probability Unit

Please circle the letter of the correct answer. Reduce all fractions to simplest form.

1. A dart is randomly thrown at the board below.



What is the probability that the dart will hit the shaded region?

[A] $\frac{1}{3}$ [B] $\frac{1}{4}$ [C] $\frac{1}{8}$ [D] $\frac{1}{6}$

2. A six-sided die is rolled once. How many possible outcome(s) are there?

[A] 12 [B] 1 [C] 6 [D] $\frac{1}{6}$

3. The probability of an event happening is **.8**
What is the probability of the event **not** happening?

[A] .2 [B] 0 [C] .8 [D] 1

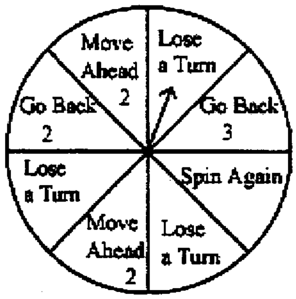
4. A six-sided die is rolled once. What is the probability of rolling a 9?

[A] $\frac{1}{9}$ [B] $\frac{1}{6}$ [C] 0 [D] 6

5. You toss a coin five times in a row and get Heads on all five tosses. What is the probability that if you toss the coin a sixth time that the coin will land on Heads?

[A] not very likely [B] $\frac{1}{2}$ [C] very likely [D] $\frac{1}{64}$

6. For a game it is Patty's turn to spin the spinner. What is the probability that Patty will Lose a Turn?



[A] $\frac{1}{8}$ [B] $\frac{3}{8}$ [C] 3   [D] $\frac{1}{5}$

7. A six-sided die is rolled once. What is the probability of obtaining a number greater than 4?

[A] .375   [B] $\frac{2}{3}$ [C] $\frac{1}{3}$ [D] $\frac{1}{6}$

8. What is the probability of drawing a King from a standard deck of 52 playing cards?

[A] $\frac{1}{13}$ [B] $\frac{1}{4}$ [C] $\frac{4}{100}$ [D] none of these

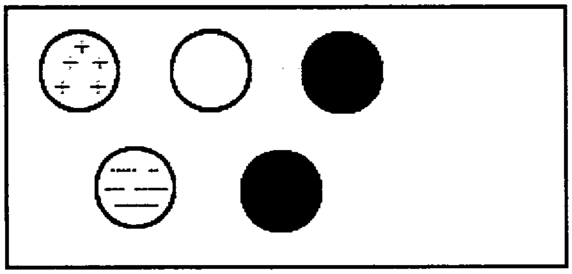
9. You are playing a game that has the goal of drawing the number 5 from a stack of cards. The dealer gives you a choice of card stacks to choose from. Stack A contains 8 cards numbered 1 through 8. Stack B contains 16 cards numbered 1 through 16. What stack of cards would you choose to get the best chance of winning?

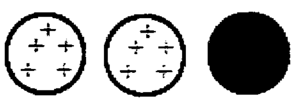
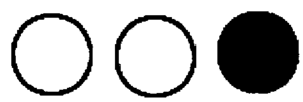
[A] Stack A
[B] Stack B
[C] It does not matter which deck
[D] Not enough information to tell

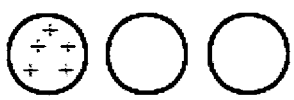
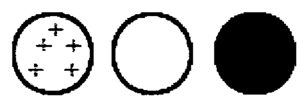
10. A coin is tossed three times in a row. How many different possible outcomes are there?

[A] 6   [B] 8   [C] 2   [D] 16

11. A box contains five marbles. All marbles in the box are the same shape and size but have different patterns. If three marbles are selected from the box one at time without returning any, what is a possible outcome?



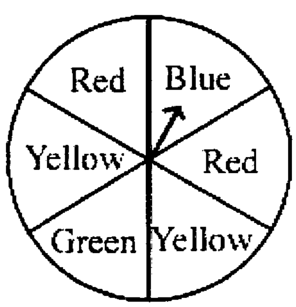
[A] 
[B] 

[C] 
[D] 

12. A six-sided die is rolled once. What is the probability of obtaining an even number?

[A] $\frac{2}{3}$ [B] $\frac{1}{2}$ [C] $\frac{1}{6}$ [D] 2

13. For a game John needs to spin the spinner once.



How many possible outcomes are there?
[A] 5 [B] 4 [C] 1 [D] 6

14. A glass jar contains 4 red, 4 black, 7 blue and 5 yellow marbles. If a single marble is chosen at random from the jar, what is the probability of choosing a black marble?

[A] $\frac{1}{5}$ [B] $\frac{1}{4}$ [C] **.375** [D] **5**

15. The probability of winning a game is $\frac{1}{4}$

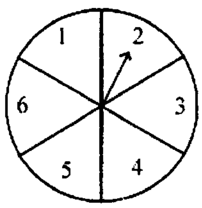
How many times would you expect to win the game if you played it 20 times?

[A] 4 [B] 5 [C] 8 [D] 10

16. What is the probability of drawing a Diamond from a standard deck of 52 playing cards?

[A] $\frac{1}{13}$ [B] $\frac{1}{4}$ [C] $\frac{1}{2}$ [D] $\frac{13}{100}$

17. For a game Monica needs to spin the spinner once.



How many possible outcomes are there?

[A] 6 [B] 3 [C] 2 [D] 1

18. What is the probability of drawing a 4 of Hearts from a standard deck of 52 playing cards?

[A] $\frac{13}{100}$ [B] $\frac{1}{13}$ [C] $\frac{1}{4}$ [D] $\frac{1}{52}$

19. A 12-sided colored die is rolled once. It has five green sides, three red sides, two yellow sides, and two purple sides. Identify the number of outcomes possible and the most likely outcome.

[A] 12; a purple side [B] 4; a red side
[C] 12; a green side [D] 4; a green side

20. A jar contains 15 black marbles and 5 white marbles. A marble is drawn at random. What is the probability of drawing a black marble?

[A] **.875** [B] $\frac{2}{3}$ [C] **.75** [D] **.25**

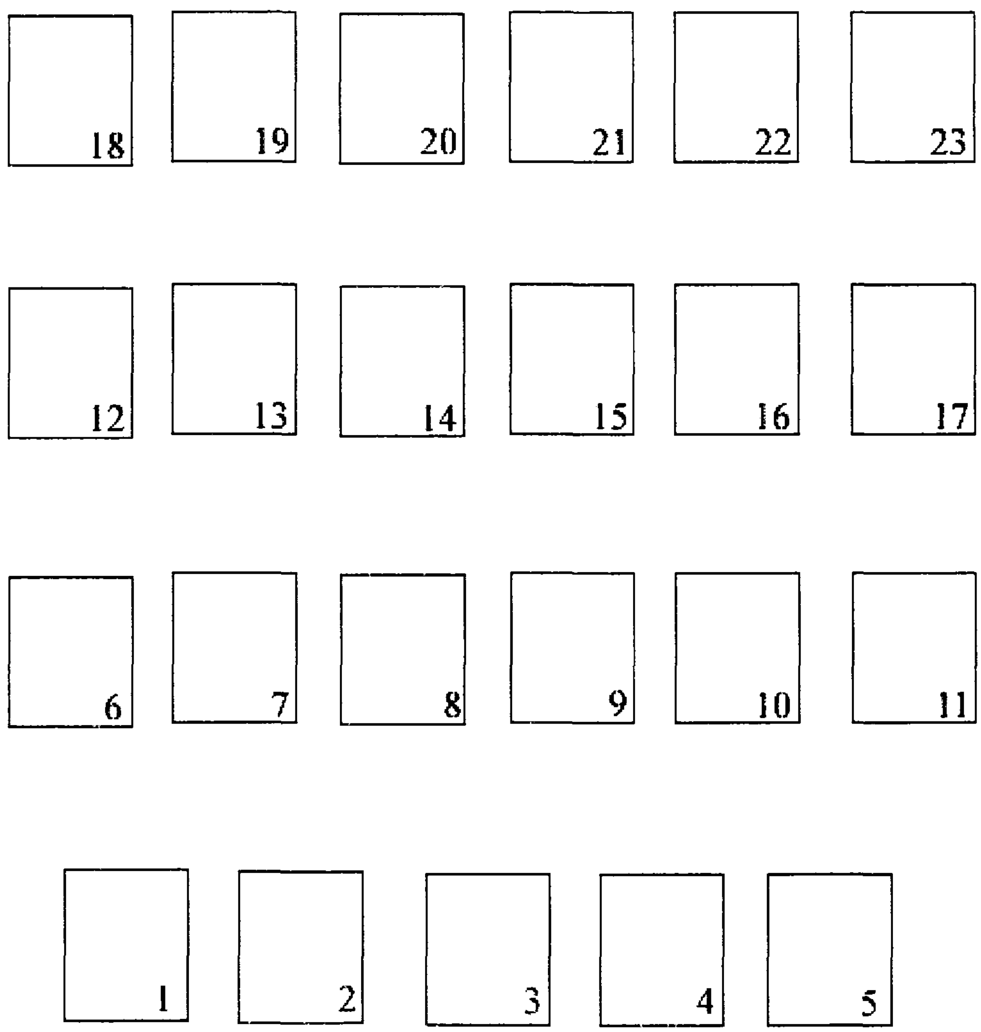
APPENDIX B

SEATING CHART

Seating Chart

Section: _____ Date: __________

Begin Time: __________ End Time: __________



↑ student-to-teacher response

→ student-to-student response

APPENDIX C

CLICKER SURVEY

Section: ____ Desk Number: _____

Clicker Survey

Please circle the letter of the response that best describes your answer.

1) How did you like using clickers in the classroom?

[A] Really liked [B] Kind of liked [C] Did not like [D] Really did not like

2) Using clickers in class makes me try harder to learn more.

[A] Really Agree [B] Kind of Agree [C] Kind of Disagree [D] Really Disagree

3) I paid more attention in class when the clickers were used.

[A] Really Agree [B] Kind of Agree [C] Kind of Disagree [D] Really Disagree

4) Using clickers in class took up too much time.

[A] Really Agree [B] Kind of Agree [C] Kind of Disagree [D] Really Disagree

5) I learn better with clickers.

[A] Really Agree [B] Kind of Agree [C] Kind of Disagree [D] Really Disagree

6) Seeing the clicker results in graphs for everybody in the class helped me learn better.

[A] Really Agree [B] Kind of Agree [C] Kind of Disagree [D] Really Disagree

7) Talking about the answers to clicker questions with others helped me understand better.

[A] Really helped [B] Kind of helped [C] Did not help [D] Really did not help

8) Would you recommend using clickers in other classes?

[A] Really recommend [B] Kind of recommend

[C] Do not recommend [D] Really do not recommend

APPENDIX D

INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

Indiana State University
More. *From day one.* *Institutional Review Board*

Terre Haute, Indiana 47809
812-237-3088
Fax 812-237-3092
Federal Wide Assurance Number: FWA00001884

9 February 2006

Gary Grissom
David Hofmeister
Department of Curriculum, Instruction, and Media Technology
College of Education
Indiana State University

RE: EFFECTS OF STUDENT RESPONSE SYSTEM USE ON STUDENT LEARNING AND VERBAL PARTICIPATION FOR A SIXTH GRADE MATHEMATICS UNIT (IRB# 6107)

Dear Mr. Grissom

I have reviewed your proposed study listed above, pursuant to Indiana State University's *Policies and Procedures for the Review of Research Involving Human Subjects* and 45 CFR 46. This proposed study falls within an exempt category and is therefore considered exempt from Institutional Review Board Review. You do not need to submit continuation requests or a completion report. Should you need to make modifications to your protocol or informed consent forms that do not fall within the exemption categories, the IRB must approve the modifications prior to implementation.

Informed Consent: A stamped approved copy of your informed consent form and assent form is enclosed. Please either copy that document for use or type the IRB number, approval date, and expiration information at the bottom of the informed consent form. As a reminder, the signed informed consent forms must be kept for at least three years after your study is completed.

Reporting of Problems: Any problems involving risk to subjects or others, injury or other adverse effects experienced by subjects, and incidents of noncompliance must be reported to the IRB Chairperson or Vice Chairperson via phone or e-mail immediately. Additionally, you must submit Form F to the Office of Sponsored Programs within five working days after the first awareness of the problem.

If you have any questions, please contact the Office of Sponsored Programs at 812-237-3088, or irb@indstate.edu, and your question will be directed to the appropriate person. I wish you well in completing your study.

Sincerely,

Thomas L. Steiger
Vice Chair, Institutional Review Board

cc: Dawn Underwood, IRB Administrator

APPENDIX E

INFORMED CONSENT LETTER

Indiana State University
More. From day one.

Department of Curriculum, Instruction and Media Technology

Terre Haute, Indiana 47809
812-237-2960
Fax 812-237-4556

February 27, 2006

Dear Parent or Guardian:

My name is Gary Thomas Grissom II, and I am a doctoral student in the Department of Curriculum, Instruction, and Media Technology at Indiana State University. I am conducting a research project entitled: Effects of Student Response System Use on Student Learning and Verbal Participation For a Sixth-Grade Mathematics Unit to be used for my doctoral dissertation. This research will help teachers and researchers learn more about Student Response System use in the classroom. I request permission for your child to participate.

The study consists of the use of a Student Response System that utilizes clickers in the classroom. A clicker is a small device that is similar to a TV remote control unit and is used by students to record answers to selected multiple-choice questions asked by the teacher in class. Once the student records their answer using the clicker a computer is used to display the total class results in the form of a graph. The study will compare student learning and verbal participation between students that use and students that do not. Students in class sections selected to use the clickers for the five day long mathematics unit will use a clicker to record answers to selected questions. Students in sections that do not use the clickers in class for the selected unit will be given the opportunity to use the clickers in class the following week. All students participating in the research will have the opportunity to use the clickers in class. Your child will be asked to use the clicker to answer multiple-choice questions in class and then discuss answers with the teacher and other students. All students regardless of section will cover the same mathematics content for the unit. There are no known risks to using clickers. Your child will be asked to complete a multiple-choice test at the beginning and end of the unit and work on practice problems. Sometimes the researcher will observe your child as he or she takes part in classroom activities. Students using clickers for the unit will also be given a survey about clicker use. The project will be explained in terms that your child can understand, and your child will participate only if he or she is willing to do so. Only I and my dissertation chair will have access to information from your child. At the conclusion of the study, children's responses will be reported as group results only.

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect the services normally provided to your child by the school. Your child's participation in this study will not lead to the loss of any benefits to which he or she is otherwise entitled. Even if you give your permission for your child to participate, your child is free to refuse to participate. If your child agrees to participate, he or she is free to end participation at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

Should you have any questions or desire further information please contact

Mr. Gary Thomas Grissom II
Principal Investigator
Department of Curriculum, Instruction, and Media Technology
200 North 7th Street
Terre Haute, IN 47809
(217) 276-3278
ggrissom@indstate.edu

Dr. David Hofmeister
Professor, Dissertation Chair
Department of Curriculum, Instruction, and Media Technology
200 North 7th Street
Terre Haute, IN 47809
(812) 237-2960
eshofmei@isugw.indstate.edu

If you have any questions about your rights as a research subject, you may contact the Indiana State University Institutional Review Board (IRB) by mail at 114 Erickson Hall, Terre Haute, IN 47809, by phone at (812) 237-8217, or e-mail the IRB at irb@indstate.edu. You will be given the opportunity to discuss any questions about your rights as a research subject with a member of the IRB. The IRB is an independent committee composed of members of the University community, as well as lay members of the community not connected with ISU. The IRB has reviewed and approved this study.

Complete the bottom portion of this letter including your signature and return it to [redacted]; sign the other copy and keep it for your records.

Sincerely,

Gary Thomas Grissom II
Indiana State University

Please indicate whether or not you wish to allow your child to participate in this project by checking one of the statements below, sign your name and return one copy to [redacted] Sign the other copy and keep it for your records.

_____ I grant permission for my child to participate in Mr. Grissom's study on Student Response System use for a Sixth Grade Mathematics Unit.

_____ I do not grant permission for my child to participate in Mr. Grissom's study on Student Response System use for a Sixth Grade Mathematics Unit.

______________________ Signature of Parent/Guardian

______________________ Printed Parent/Guardian Name

______________________ Printed Name of Child

______________________ Date

Date of IRB Approval: *this information will be provided*
IRB Number: *upon IRB approval*
Project Expiration Date:

Indiana State University
Institutional Review Board
APPROVED
IRB Number: 6107
Approval: 2/10/06
Expiration Date: EXEMPT

Page 2 of 2

APPENDIX F

ASSENT TO PARTICIPATE IN RESEARCH FORM

ASSENT TO PARTICIPATE IN RESEARCH

Using Clickers for a Sixth-Grade Math Unit

1. My name is, Mr. Grissom. I am from Indiana State University.

2. [redacted] and I are asking you to take part in a research study because we are trying to learn more about using clickers in the classroom and how clickers are used by sixth-grade math students. Clickers are like a TV remote control and allow you to record answers to multiple-choice questions asked by the teacher by pressing a button on the clicker to record your answer.

3. If you agree to be in this study you will be asked to take two tests, work on practice sets, and complete a survey. I will make notes about what is going on in classrooms that use and do not use clickers for a math unit.

4. There are no known risks to using clickers.

5. By answering questions using clickers in the classroom you will be able to see how everyone else in class answers questions and discuss your answers with the teacher and other students.

6. Please talk this over with your parents before you decide whether or not to participate. Your parents have given their permission for you to take part in this study. Even though your parents said "yes," you can still decide not to do this.

7. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop. You will still be required to complete the math unit.

8. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can call me (217) 276-3278 or ask me next time I am at the school.

9. Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

____
Signature of Subject

______________________________ _______________
Printed Name of Subject Date

Indiana State University
Institutional Review Board
APPROVED
IRB Number: 6107
Approval: 2/10/06
Expiration Date: EXEMPT

APPENDIX G

LESSON PLANS

Lesson Plan Day 1
Independent Events

Materials: PowerPoint, pennies, cups, movie clip of successful/unsuccessful model rocket launches

Anticipatory Setting: How many of you have ever built a rocket? Is anyone interested in rocketry? Unfortunately not everyone is always successful in getting their rocket launched every time. Show movie clip of successful/unsuccessful model rocket launch attempts.

Objective: Students will be introduced to basic probability terms. The students will predict how many times a rocket will launch with 30 attempts using coin tosses.

Instructional Input: Math Terms

Provide PowerPoint slide definitions to students for:
Probability, Independent events, Theoretical Probability

Modeling: We are going to use coins to model the rocket launches.

1. Can anyone tell why using a coin would be a good model?
    a. 2 sides to a coin (heads/tails) 2 choices for the rocket launch (successful/ unsuccessful)
    b. Coin is independent event – does not matter if we get heads 1st time, does not affect next attempt.
2. Demonstrate how to use cups to toss coin. Have students make chart with two columns, label one column heads and the other tails and number from 1 to 30.
3. Teacher will do 10 attempts, record results.
4. Show how to find average of attempts, example: 45% Heads, 55% Tails.

Check for Understanding:

1. Does anyone have any questions?
2. You are now going to try your attempts at launching your pretend rocket. Heads will be successful launch, tails unsuccessful.
3. Calculate averages. Remember what an appropriate toss is.

Guided Practice:

1. Pass out pennies and cups.
2. Students shake cup 5 times then turn cup upside down and record results of 30 tosses using a chart to keep track of results.

Students need to take their results and find the average attempts that were successfully launched. Clicker group uses clickers to record answers to coin tosses. Non-clicker group work with neighbors to see if they achieved similar results.
What is the theoretical probability of the coin toss? Compare to coin toss experiment results; teacher records results on whiteboard and calculates averages for heads and tails using student results.

Lesson Plan Day 2
Possible Outcomes and Probability

Materials: PowerPoint, bulletin board display, dice, spinners. Bulletin board is divided into 4 sections. One section has a spinner with different colors, one section a deck of cards separated out by suits, one section has a group of mismatched colored socks, and one section has a graphic of a jar of colored marbles. Create several probability questions about each section and place them in a small pocket for each section of the display.

Anticipatory Setting: How many of you enjoy playing games? What are some of your favorite board games? Raise your hand if you know of a board game that uses a spinner? Raise your hand if you know of a game that uses a die? Today we are going to learn about possible outcomes.

Objective: The students will find possible outcomes using spinners and die (dice). The students will be introduced to a deck of cards. Students will determine probability of events given desired and possible outcomes.

Instructional Input: Math Terms

PowerPoint definitions for:

Possible outcomes – We are looking at how many outcomes are possible with a given situation.

Die – a small marked cube used in a game of chance. Dice is the word used for more than on die.

Spinner – a device used in games that one spins to choose the action.

Probability – a number which tells how likely it is that a certain event will happen. Desired outcome / Possible Outcomes

Modeling: Use PowerPoint to show the lesson. "We are going to look at three different ways during our lesson to find possible outcomes." Show the spinners on the bulletin board to discuss different situations. "If there are 6 yellow, 3 blue, 2 red, and 1 green sections on the spinner, what are the possible outcomes of spinning a blue (3/12 or ¼). How many possible outcomes are there? This would be the total colors (4). What is the possibility of spinning a yellow (6/12 or ½ or .5 or 50%)? Using the bulletin board display discuss a deck of cards. They will observe that there are 52 cards, 4 different suits, 13 cards with the same suit, and 4 out of each number and face card. Of possible outcomes, 4 are queens out of a total of 52 cards. What is the probability (4/52 or 1/13 or .076 or 7.6%)?

Check for Understanding: Through the modeling lesson, ask if anyone has any questions. Listen for the correct answers and redirect and give correct answers if student gives an incorrect answer.

Lesson Plan Day 2 (Continued)
Possible Outcomes

Guided Practice: Use the interactive questions to check for understanding. Have students discuss with peers what answer would be better and why? Then show the questions again.

Work-time Practice: Students are to complete the worksheet that contains Practice Set A questions relating to the lesson. Instruct students to take home for homework if they do not finished during class, students are to turn in Practice Set A for a grade. Clicker group will do first five practice set questions using clickers and peer instruction. Non-clicker group may ask for teacher help using the cup system.

Lesson Plan Day 3
Probability

Materials: Power Point, Bulletin board, socks, calculator, deck of cards.

Anticipatory Setting: Today we are going to learn about probability. It is an important part of math. It is important to understand probability to understand weather reports, medical findings, and politics and even state lotteries.

Objective: The students will be able to tell the probability of a single event using a deck of cards, die, socks, and a spinner.

Instructional Input: Math Terms

Card deck – 52 cards in all, 13 cards of 4 different suites, 2 red and 2 black suits.
Probability – a number which tells how likely it is that a certain event will happen. Desired outcome / Possible Outcomes

Modeling: Hand back yesterday's assignments and discuss. Clicker group uses clickers to review two most missed questions. For the non-clicker group teacher ask students for correct answer. Show the Power Point lesson. Let's imagine that your mom is making you clean your room. You are pulling dirty clothes out from under your bed. There are 8 socks without a match. Using the bulletin board to figure out each probability problem, students must set up a ratio between total # of outcomes and the specific question asked. If there are 2 red, 2 tan, and 4 black socks, what is the probability of reaching under the bed and pulling out a red sock (2/8 or ¼). Students then need to figure the probability as a decimal using their calculators. What is the probability of drawing a spade (13/52 or ¼ or .25 or 25%)? Using the bulletin board ask the students "if there are 32 marbles in a jar and 5 are blue, what is the possibility of reaching in the jar and drawing a blue marble (5/32)? A six-sided die is rolled. What is the possibility of rolling a 2 (1/6)?

Check for Understanding: Through the modeling lesson ask a variety of probability questions about a deck of cards using the bulletin board display questions. Ask if anyone has any questions. Listen for the correct answers and redirect and give correct answers if student give an incorrect answer.

Guided practice: Use the interactive questions to check for understanding. Have students discuss with peers what answer would be better and why? Then show the question again.

Work-time Practice: Students are to complete the worksheet that contains Practice Set B questions relating to the lesson. Instruct students to take home for homework if not finished during class, have students turn in Practice Set B for a grade. Clicker group will do first five practice set questions using clickers and peer instruction. Non-clicker group may ask for teacher help using the cup system.

Lesson Plan Day 4
Multiple Events

Materials: PowerPoint, Bulletin board, coins, spinner, dice

Anticipatory Setting: Today we will be talking about probability again and how to determine the probability of multiple events.

Instructional Input: Math Terms

Multiple events
Theoretical probability

Modeling: Hand back yesterday's assignments and discuss any questions. Clicker group use clickers for two review questions. Non-clicker group asked the same two review questions by the teacher. Show the PowerPoint lesson.

Guided Practice: Through the modeling lesson, ask if anyone has any questions. Listen for the correct answers and redirect and give correct answers if student gave an incorrect answer. Give examples of spinning a two color spinner twice. Rolling a die twice, have students use the chart below to complete possible outcomes of rolling a die two times in a row. Probability=desired outcome/possible outcomes Flip a coin twice and write down all possible outcomes on whiteboard. Ask if anyone can find a formula for multiple events? Review questions for posttest scheduled for tomorrow.

Work-time Practice: Students are to complete the worksheet that contains Practice Set C questions relating to the lesson and review questions. Instruct students to finish today and turn in for a grade. Return graded Practice Set C to students after recess time in the afternoon so students have to study for the posttest tomorrow. Clicker group will do first five practice set questions using clickers and peer instruction. Non-clicker group may ask for teacher help using the cup system.

A single six-sided die is rolled two times in a row. Using the table below fill in all the possible outcomes. How many possible outcomes are there?

	1	**2**	**3**	**4**	**5**	**6**
1	1,1	1,2	1,3	1,4	1,5	1,6
2	2,1	2,2				
3			3,3			
4				4,4		
5		5,2				
6	6,1					6,6

Lesson Plan Day 5
End of Unit Test

Materials: End of Unit Test on Probability

Anticipatory Setting: We have spent the week learning about possible outcomes, probability, independent events, and theoretical probability. Today we will take our test over the probability unit.

Objective: The students will take a posttest for the probability unit.

Modeling: Ask if there are any questions before passing out the test. Hand out test.

Give students as long as needed to complete the end of unit test.

Hand out Clicker Survey to clicker group once all students have finished and have the students complete the Clicker Survey.

APPENDIX H

PRACTICE SETS

Section: ____ Desk Number: _____

Probability Unit
Practice Set A

Please circle the letter of the correct answer. Reduce all fractions to simplest form.

1. The probability of an event happening is **.6**
What is the probability of the event **not** happening?

[A] **4** [B] **1** [C] **.4** [D] $\frac{1}{4}$

2. The theoretical probability for a coin landing on Heads is $\frac{1}{2}$

If a coin is tossed 10 times in a row, how many times would you expect the coin to land on Heads?

[A] **10** [B] **5** [C] **6** [D] **2**

3. The probability of an event happening is $\frac{1}{3}$

What is the probability of the event **not** happening?

[A] $\frac{1}{3}$ [B] **3** [C] $\frac{2}{3}$ [D] **1**

4. The probability of a model rocket launching is $\frac{1}{5}$

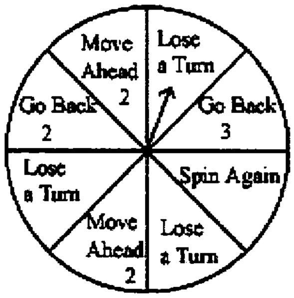
How many times would you expect the model rocket to launch if you were given 20 attempts?

[A] **8** [B] **10** [C] **5** [D] **4**

5. A 12-sided colored die is rolled once. It has two green sides, six red sides, three yellow sides, and one purple side. Identify the number of outcomes possible and the most likely outcome.

[A] 6; a red side [B] 4; a red side
[C] 12; a yellow side [D] 4; a green side

6. For a game it is Bill's turn to spin the spinner. How many possible outcomes are there?

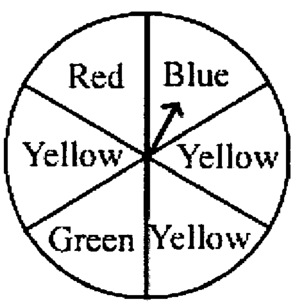


[A] **8** [B] **6** [C] **5** [D] **1**

7. How many Clubs are there in a standard deck of 52 playing cards?

[A] **8** [B] **4** [C] **12** [D] **13**

8. For a game it is Lisa's turn to spin the spinner. How many possible outcomes are there?



[A] **4** [B] **6** [C] **3** [D] **1**

9. A single six-sided die is rolled once. How many possible outcome(s) are there?

[A] **1** [B] **9** [C] **2** [D] **6**

10. How many Kings are there in a standard deck of 52 playing cards?

[A] **8** [B] **4** [C] **13** [D] **1**

Section: ____ Desk Number: _____

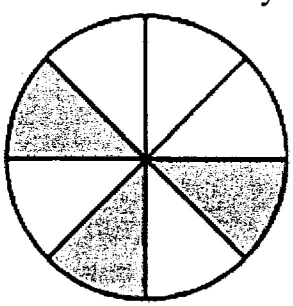
Probability Unit
Practice Set B

Please circle the letter of the correct answer. Reduce all fractions to simplest form.

1. What is the probability of drawing a Spade from a standard deck of 52 playing cards?

[A] $\frac{4}{100}$ [B] $\frac{1}{4}$ [C] $\frac{1}{13}$ [D] $\frac{13}{100}$

2. A dart is randomly thrown at the board below.



What is the probability that the dart will hit the shaded region?

[A] $\frac{3}{5}$ [B] $\frac{3}{8}$ [C] 3 [D] $\frac{1}{5}$

3. A six-sided die is rolled once. What is the probability of obtaining an odd number?

[A] $\frac{1}{6}$ [B] $\frac{2}{3}$ [C] $\frac{1}{3}$ [D] $\frac{1}{2}$

4. What is the probability of drawing a Queen from a standard deck of 52 playing cards?

[A] $\frac{1}{13}$ [B] $\frac{4}{100}$ [C] $\frac{1}{52}$ [D] $\frac{1}{4}$

5. You are given a choice of playing two different games.

Game A has a probability of winning of $\frac{3}{4}$

Game B has a probability of winning of $\frac{3}{5}$

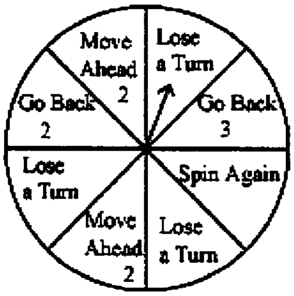
What game would you choose to have the best chance of winning?

[A] Game A [B] Game B [C] does not matter

6. A six-sided die is rolled once. What is the probability of rolling a 7?

[A] 1 [B] $\frac{1}{6}$ [C] 0 [D] $\frac{1}{7}$

7. For a game it is Jenny's turn to spin the spinner. What is the probability that Jenny will Move Ahead 2 spaces?



[A] $\frac{1}{8}$ [B] $\frac{1}{4}$ [C] $\frac{1}{3}$ [D] $\frac{3}{8}$

8. What is the probability of drawing a 6 of Clubs from a standard deck of 52 playing cards?

[A] $\frac{13}{100}$ [B] $\frac{1}{13}$ [C] $\frac{1}{4}$ [D] $\frac{1}{52}$

9. A six-sided die is rolled once. What is the probability of obtaining a number less than 3?

[A] $\frac{1}{6}$ [B] $\frac{1}{2}$ [C] $\frac{1}{3}$ [D] $\frac{1}{5}$

10. A jar contains 5 black marbles, 6 red marbles, 4 green marbles, and 5 white marbles. A marble is drawn at random. What is the probability of drawing a green marble?

[A] 4 [B] $\frac{1}{5}$ [C] $\frac{1}{2}$ [D] $\frac{1}{4}$

Section: ____ Desk Number: _____

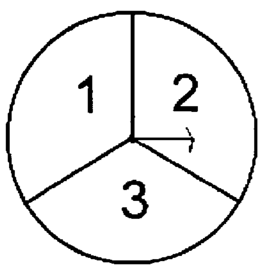
Probability Unit
Practice Set C

Please circle the letter of the correct answer. Reduce all fractions to simplest form.

1. How many different possible outcomes are there if you toss a coin two times in a row?

[A] **3** [B] **2** [C] **4** [D] **8**

2. How many possible outcomes are there if the spinner below is spun 3 times in a row?



[A] **16** [B] **3** [C] **9** [D] **27**

3. What is the probability of drawing a Heart from a standard deck of 52 playing cards?

[A] $\frac{1}{4}$ [B] $\frac{4}{100}$ [C] $\frac{1}{13}$ [D] $\frac{13}{100}$

4. How many possible outcomes are there if you toss a coin four times in a row?

[A] **4** [B] **32** [C] **16** [D] **8**

5. A six-sided die is rolled once. What is the probability of rolling a 5?

[A] **1** [B] $\frac{1}{6}$ [C] 0 [D] $\frac{1}{5}$