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PROMOTING PROBABILISTIC REASONING:

THE INTERPLAY OF LEARNER, TASK, AND TEXT

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Abstract

This dissertation was an investigation of misconceptions in probabilistic reasoning. Existing research cites misconceptions in probability as being common and pervasive (Shaughnessy, 1977). Moreover, research suggests that altering misconceptions in probability is an undertaking of paramount proportions (Konold, 1995). Specifically, the purpose of this study was to investigate mechanisms for enhancing college-age students' probabilistic reasoning and decreasing their inappropriate use of the representativeness heuristic when reasoning about the outcomes of uncertain events. R*epresentativeness* is defined as a heuristic often used in situations concerning an object belonging to a class, an event originating from a process, or the probability that a process will bring life to an event (Hirsch & O'Donnell, 2001).

The sample for this dissertation study included graduate and undergraduate students from two introductory educational psychology courses. The two methods employed as interventions for decreasing the inappropriate use of the representativeness heuristic were anchored scenarios and a text. While the anchored scenarios served as a potential intervention for this purpose, the text employed in this study appeared to have a more potent effect on the participants' inappropriate use of the representativeness heuristic over time. For instance, the participants in the *Text* condition demonstrated larger gains in scores on the representativeness instrument from the preintervention to the immediate postintervention and while all three conditions experienced decreases in scores from the immediate to the delayed postintervention times the participants in the *Text* condition experienced the slightest decrease. Results of the data analyses suggest that a

two-sided refutational text is a viable method for decreasing the inappropriate use of the representativeness heuristic in college-age students.

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CHAPTER 1

INTRODUCTION

Whether taking into consideration a high school freshman, or a medical student completing their residency, rest assured that the vast majority of people in this world are faced with the challenge of making countless decisions and judgments every day. Probability, encapsulated within statistics, is one area in mathematics which has customarily been considered unique as a result of its nature of cumulative knowledge (Crowe, 1992; Kitchener, 1992). These two domains, combined, form the foundation for almost all modern sciences and supply justification for nearly all purposeful societal activity (Kaplan & Kaplan, 2006). As compared to other domains such as history, accumulation of knowledge in probability and statistics follows a sequential progression. Achieving success or even simple comprehension in the mathematics domain requires more than just an acquisition of content knowledge, which in and of itself may be a feat. Achievement in any area of mathematics also includes such factors as recognition of the processes by which mathematics knowledge is acquired, advanced, and confirmed, and an acquaintance through which the domain views ideas or concepts (Perkins & Simons, 1988; Rector, 1993). An individual's ability to solve problems is certainly not the sole determinant for their success in probability or statistics. Other factors exist that are equally if not more salient. For instance, knowledge and beliefs concerning the domain are considered important factors in problem-solving. In the domain of mathematics, the conceptual and procedural knowledge required for competence is often difficult for students to acquire (e.g., Glass & Hopkins, 1986; Warcholak, Gushka, & Kulikowich, 2005), and attempts to do so are often met with repeated failure (Shaughnessy, 1977). Failing to acquire knowledge in probability hinders individuals' abilities to make informed decisions in their everyday lives.

In 1971, Slovic and Lichtenstein regarded decisions as "…frighteningly more important and more difficult than ever before." These two researchers cited the technology of their time as grounds for developing effective aids in the decision-making process. Arguably, the complexity and dynamic nature of everyday decision making is even more difficult today given unbridled proliferation of information and possibilities. As such, the question becomes what resources do individuals employ when considering the seemingly infinite variables contributing to even banal decisions. Such decisions are often made based upon the person's prior experiences, knowledge, and beliefs. While some judgments and decisions are simple enough to reach that individuals do not even realize they have made them, others require more care, time, and careful consideration of all options. The conclusion of any decision is at least partially based upon our beliefs concerning the unknown outcome of the specific situation or event in question. Generally, the nature of making decisions is uncertain, especially when regarding ambiguous situations. Given the uncertain nature of decision-making, individuals should utilize all of their resources when undergoing this procedure. Probability is one area of study that can assist in the entire decision-making process (Konold, 1995).

The principles undergirding probability theory are fundamental to the study of mathematics (Rowan, 2001). Students are formally taught about probability as early as the third grade, and potentially continue to acquire understandings about this content as they advance through the grades (Rowan, 2001). According to the National Council of Teachers of Mathematics (2000) expectations of pre-kindergarten through second grade students includes discussing likely and unlikely events and third grade through fifth grade students are expected to be conducting simple experiments and predicting the probability of their outcomes. Not only is the ability to reason about probability important in both in-school and out-of-school contexts, but it is also clear in the literature that acquiring such skills is extremely difficult (Eisenhart & DeHaan, 2005).

The principles (e.g., law of large numbers or independence) creating the foundation for probability theory are fundamental to both mathematics and statistics (Rowan, 2001), yet given the significance of this domain a somewhat small amount is known about effectively teaching its content (Garfield & Ahlgren, 1988). Probability is a content area in which students usually enter into a class with preconceived notions or beliefs of laws of probability based on life experiences and these beliefs are often incorrect. According to Garfield and Ahlgren (1988), changing these beliefs even with instruction has proven difficult. Although probability can be used as a tool in decision-making, individuals often employ heuristics based on habits or beliefs rather than laws of mathematical probability (Konold, 1995). Probabilistic reasoning has been defined as a person's ability to determine the probability of an event occurring (Fast, 1999) and also a person's cognitive response to any probability situation (Jones, Langrall, Thornton, & Mogill, 1999).

Probability and probabilistic reasoning are not new areas of interest. In 1748, David Hume had already written about probability and topics within this domain such as induction, deduction, reasoning, and chance. Hume wanted to know how people learn from experiences since the future is not necessarily reflective of the past. In other words, history will not necessarily repeat itself. Indeed, as a skeptic, Hume questioned the extent to which it was possible to attribute any one antecedent to a given consequence. He further asserted that even if a particular antecedent could be isolated as having caused a consequence in one instance that there is no reason or justification for assuming that the same chain of events will ever repeat itself. As such, he considered attempts to link antecedents with consequences in anticipation of them repeating themselves an illegitimate act. An example Hume gave was the belief that the sun will rise tomorrow. People generally hold this belief for the reason that it has happened for so many millions of years, but Hume asserted that this is not a sufficient enough reason to hold a belief and further, to act on it. Therefore, induction is a problem since individuals cannot be certain that an event will repeat itself simply because it has so many times previously.

According to Hume there is no such thing as chance. Hume attested to human ignorance of actual causes to various events. This ignorance often prompts people to form beliefs which come from the associations made between their ideas. Unaware of every possible reason for a specific event, people tend to attribute those reasons to chance. Simply stated, many events are occurring at the same time and humans cannot attend to each and every one of them. What an individual chooses to focus on becomes their sensory input. This piece of information that has become sensory input is what will become the focal point again and again although much more is occurring. A connection is made and a belief eventually forms attributing the cause of an event to a particular stimulus. The more often this connection is strengthened the stronger the belief becomes. This is essentially representativeness. Representativeness is a common heuristic people use in regards to probability. Someone utilizing the representativeness heuristic relies heavily upon their experiences in the past regarding a particular class or event (Tversky & Kahneman, 1974).

An individual's knowledge and beliefs which have been acquired through those experiences affect their decisions in mathematics and probability situations. For instance, many individuals make the mistake of believing that when a coin is tossed four times an equal distribution of heads and tails is more likely than a string of one or the other or in a slightly different scenario, if the first 3 tosses resulted in heads many individuals are likely to predict tails for the fourth toss (Tversky & Kahneman, 1974). In the latter scenario, individuals utilize their knowledge of the first 3 tosses and the belief that each of the two outcomes should be represented equally to incorrectly predict the outcome. What should be considered in this situation is that each toss of a coin is going to result in a 50% chance for either of the outcomes independent of previous outcomes and also that equal outcomes are not established after such a few number of tosses. In this case a person's knowledge and beliefs can very often hinder correct judgments being made.

Inaccurate knowledge and beliefs in probability are referred to as misconceptions. Once a person forms a misconception, research suggests that correcting it is enormously difficult (Vosniadou, 2001). These incorrect ideas or theories are commonly held in probability and often times obstruct correct judgments and future instruction in probability or statistics which provides ground for further investigation into knowledge, beliefs that contribute to misconceptions in probability and other mathematics knowledge.

A chief concern in mathematics education and educational research is the influence of students' knowledge and beliefs on their academic achievement in mathematics. Knowledge and beliefs both play a significant role in the learning process of any material (Alexander & Murphy, 1998). These constructs are strong correlates to what a learner will deem salient enough to process and recall when encountering information (Hidi, 1990). Teachers often attempt to facilitate knowledge acquisition for their students by utilizing an assortment of pedagogical practices. Merely attempting to input correct facts, data, and information into a student's knowledge network is not a sufficient enough means of facilitating students' true understanding and comprehension of material being presented in a classroom. Presenting and inputting information will not likely prompt a student to think deeply about the concept and connect it to their prior knowledge and beliefs (Hynd, 2003).

The conceptual change approach recognizes the role of prior knowledge and beliefs in the learning process and involves helping learners change what inaccurate knowledge and beliefs they may have in an effort to process new, accurate information. A major problem is realized when trying to alter the preexisting knowledge and beliefs because they are so highly resistant to change (Clement, 1982). Murphy (2001) refers to teachers as *change agents* responsible for helping students to become aware of their pre-existing knowledge and beliefs and then for challenging any and all of their misconceptions.

Texts are common and pervasive sources of information in and out of the classroom. From the time a child enters formal schooling, narrative or empirical texts can be found within the child's reach. If that child is fortunate enough his parents have made texts a normal part of his everyday life. They have been reading to him from various types of texts since the time he was still in his mother's womb and throughout his entire childhood until he can read them on his own. As adults, individuals encounter text in the form of newspapers, magazines, instruction manuals, novels, exposition, invitations, and even thank you notes almost everyday of our lives. It is for this reason that it seems intuitive to attempt to use text as in intervention in correcting misconceptions and achieving conceptual change.

Other mechanisms for achieving conceptual change of both knowledge and beliefs may be the use of hands-on activities as well as a combination of physical illustrations with scientific explanations. According to Murphy and Alexander (2007) these methods may serve as successful interventions in achieving the conceptual change process.

Statement of the Problem

According to current research, misconceptions in probability are common and pervasive (Shaughnessy, 1977). Moreover, research suggests that altering misconceptions in probability is an undertaking of paramount proportions (Konold, 1995). Probabilistic reasoning and decision-making are severely hindered in formal settings such as classroom situations as well as in informal settings such as individuals' daily lives, by inaccurate, commonly employed heuristics which often stem for misconceptions or inaccurate beliefs (Tversky & Kahneman, 1974). These beliefs are frequently gathered by individuals through experiences in their everyday lives. Although accurate information is presented in probability courses, students often fail to replace their inaccurate knowledge with what is being introduced in their class. Even more disconcerting is that individuals who use and employ accurate probabilistic reasoning learned in a formal setting often fail to utilize that same reasoning in their daily lives (Konold, 1995; Tversky & Kahneman, 1974; Kunoff & Pines, 1986). While research focused on misconceptions and heuristics in probabilistic reasoning exists, a small number of those studies have explored the use of an intervention in combating those misconceptions. Although text is one of the main forms of communication today and throughout history few, if any, studies have attempted to explore text as an intervention in correcting misconceptions in probability. That is, much of the existing research has either been theoretical in nature or has concentrated on using scenarios or problem solving equations as an intervention to promote conceptual change.

Purpose of the Study

The purpose of this study was to investigate the viability of mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. In essence, I investigated how learner variables, specifically knowledge and beliefs, interacted with text variables and anchored scenarios in minimizing misconceptions of representativeness. The dissertation study was conducted by means of two separate experiments with very similar research questions. Specifically, the research questions addressed in Experiment 1 of this study include the following:

1. To what extent did participants' probabilistic reasoning scores change over time from the preintervention to the immediate postintervention to the delayed postintervention as a result of participation in one of the study conditions (i.e., *Control*, *Anchored Scenarios*, and *Text*)?

2. To what extent did participants' probabilistic reasoning scores from the preintervention to the immediate postintervention vary by condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?
3. To what extent do changes in participants' probabilistic reasoning scores from the immediate postintervention to the delayed postintervention vary by condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

In Experiment 2, three overall research questions were addressed. The primary difference between Experiment 1 and Experiment 2 research questions is due to implementation of a *Non-Treatment Comparison* condition in place of the *Control* condition. The questions for this experiment again focus on changes over time in scores on the probabilistic reasoning instruments and possible covariates affecting those changes. The questions addressed in Experiment 2 of the dissertation study include the following:

1. To what extent did participants' probabilistic reasoning scores change over time from the preintervention to immediate postintervention to the delayed postintervention as a result of participation in one of the study conditions (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*)?
2. To what extent did participants' probabilistic reasoning scores from the preintervention to immediate postintervention vary by condition (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?
3. To what extent do changes in participants' probabilistic reasoning scores from the immediate postintervention to the delayed postintervention vary by condition (i.e., *Non-Treatment*

Comparison, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

Definition of Key Terms

Additive Law is used to determine the probability of two mutually exclusive events occurring in a single trial (Mendenhall & Beaver, 1994).

Beliefs refer to "…all that one accepts as or wants to be true. Beliefs do not require verification and often cannot be verified (e.g., opinions)" (Murphy & Mason, 2007, p. 6).

Combinations are unordered subsets or collections of unique elements (Bona, 2004).

Conceptual Change refers to a progression, which may be gradual or swift, by which an individual's initial understandings or beliefs are altered to more closely reflect what is accepted as scientifically true (Murphy & Alexander, 2007).

Discrete Distribution is one that is defined on a countable set. In other words, the sample spaces are countable and each value has a certain probability of occurrence that is between zero and one (Tijms, 2004).

Event is a subset of the sample space to which a probability can be assigned (Jones, Langrall, Thornton, & Mogill, 1999). For example, when tossing a coin, having the coin landing on "heads" is an event.

Expectation (expected value) is the sum of the probability of each possible outcome of the trial multiplied by its value. (Williams, 1991) In other words, this is the average or mean amount that a person expects to gain per trial if the trial is repeated numerous times and if the odds are the same each time.

Gambler's Fallacy is an incorrect belief that the odds of an event with a set probability increase or decrease based on recent events (Fischbein & Schnarch, 1997; Derks, 1963). This idea is believed to be caused by the representativeness heuristic (Tversky & Kahneman, 1971, 1974).

Heuristics have been defined by Tversky and Kahneman (1974) as principles which reduce the complexity evaluating probabilities of uncertain events and predictions of values to simpler judgmental operations.

Independent Events occur when one event does not change the probability of the other event (Quinn, 2001). For instance, when an individual tosses a fair coin 3 times and the outcome is a head on all 3 tosses, the outcome of the fourth toss cannot be determined by taking the previous tosses into account. The outcome of the fourth toss is independent of the previous 3 tosses.

Knowledge refers to "…all that is accepted as true that can be externally-verified and can be confirmed by others on repeated interactions with the object (i.e., factual)" (Murphy & Mason, 2007, p. 6).

Law of Large Numbers describes the reliability of a sequence of independent, random variables when enough opportunity is present. This law states that as a sample size increases its statistics will begin to resemble the true properties of the population (Tversky & Kahneman, 1971, 1974).

Law of Small Numbers explains the inaccurate belief or expectation that outcomes of an uncertain, random event will "even out" and theoretical distribution will be realized with a small sample size. For example, the misconception that a mixed distribution will be realized when a coin is tossed only four times (Tversky & Kahneman, 1971, 1974).

Misconceptions have been described as inaccurate beliefs or naïve theories based on an individual's experiences or ideas (Hynd & Guzzetti, 1993; Vosniadou, 1994). This study specifically focuses on misconceptions in probabilistic reasoning.

Multiplicative Law is employed to determine the probability that independent events will occur in sequence (Mendenhall & Beaver, 1994).

Mutually Exclusive Events refer to propositions that logically cannot both be true (Ballman, 1997). So, two events are mutually exclusive if the incidence of one event automatically implies the nonoccurrence of the remaining event.

Permutations are the unique ordering of objects or symbols into distinguishable sequences (Bona, 2004).

Probabilistic Reasoning has been generally defined as a person's cognitive response to any probability situation (Jones, Langrall, Thornton, & Mogill, 1999) and more specifically as a person's ability to determine the probability of an event occurring (Fast, 1999).

Probability refers to the study of uncertain events or the likelihood of an event occurring (Halpern, 1996). In this particular study, probability is conceptualized as the chance of something occurring or the chance that an object belongs to a class.

Probability of an Event equals the number of occurrences possible for an event divided by the number of total outcomes possible in the entire sample space. (Mendenhall & Beaver, 1994). For instance, the probability of the event of an odd number when an individual rolls a fair, six-sided die would be 3/6 since 3 sides of the die are odd and each has the same probability of occurring with each toss.

Random Variable refers to a measurable function from a sample space that assigns a unique numerical value to every variable, or outcome of an experiment (Williams, 1991). The unique values vary from trial to trial as the experiment is repeated. For example, a flashlight is turned on until the batteries die. The random variable X is its lifetime in hours X can take any positive numerical value.

Representativeness a heuristic often used in situations concerning an object belonging to a class, an event originating from a process, or the probability that a process will bring life to an event (Hirsch & O'Donnell, 2001).

Sample Space refers to the set of all possible outcomes (Tarr, 2002). For example, the sample space of tossing a fair coin is {heads, tails}.

CHAPTER 2

REVIEW OF RELEVANT LITERATURE

The purpose of this review was to provide a theoretical framework from which to examine the viability of mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. Specifically, interrelations of common misconceptions in probabilistic reasoning, text, readers' knowledge and beliefs, and argument for conceptual change were reviewed. In an effort to explore the literatures relating to misconceptions in probabilistic reasoning, text, readers' knowledge and beliefs, and argument this review synthesizes theoretical and empirical works from education, philosophy, cognitive psychology, and social psychology. Specifically the following review is divided into five major sections. The first section examines probability from philosophical and mathematical perspectives and how probability is taught in the curriculum, while the second section explores contemporary perspectives in probabilistic reasoning cited within the extant literature. The third section explores conceptual change, methods of altering misconceptions in probability as well as in other domains and offers information pertaining to the learner; specifically knowledge, beliefs, and text processing. The fourth section presents information concerning arguments, while the final section summarizes issues for further investigation.

Probability

"The science of uncertainty is probability; it deals with what is repeated but inconsistent" (Kaplan & Kaplan, 2006, p.8). Probability is an area that has been scrupulously pondered over and repeatedly investigated by philosophers for centuries (Hume, 1748). This may partially be due to its fundamental ties to mathematics, or to its pervasive nature in our everyday lives. People in this world are faced with the challenge of making countless decisions and judgments every day. These decisions are often made based upon the person's prior experiences, knowledge, and beliefs (Konold, 1995). The probability of the outcome of an uncertain event occurring is often what individuals base decisions on. “Probability is the study of likelihood and uncertainty. It plays a critical role in all of the professions and in most everyday decisions” (Halpern, 1996, p. 242).

Philosophical reflections. Discussions concerning sensory information and the attainment of knowledge can be reliably dated at least as far back as Plato (ca. 427-347 B.C.). Plato is known as a rationalist and a nativist. He is identified as a rationalist because of his emphasis on the active involvement of the mind in attaining knowledge and a nativist because of his belief that our mental attributes are a result of our soul’s experiences prior to becoming one with our bodies. According to Plato everything in the world able to be physically experienced also has an abstract form and it is this abstract form that brings rise to the physical object. For instance, the abstract idea of *table* interacts with matter to generate what people call a table. Therefore, a person’s senses will deceive them if attempts to achieve greater amounts of knowledge are through those senses. Plato believed that individuals do not gain knowledge from the environment, but that knowledge is innate to the mind so it is something that people inherit. According to Plato people are able to reason through events without drawing on the physical world. In other words, to gain further knowledge or determine probability of the outcome of an uncertain event, an individual simply need to reflect on the contents of their mind. Other philosophers differed from Plato’s stance on knowledge and its roots. Even a well-known philosopher who studied under Plato maintained divergent philosophies to his.

Aristotle (384-322 B.C.), perhaps Plato’s most well-known student, is generally considered an empiricist. Such thinking was considered a departure from Plato’s teachings. According to Aristotle, sensory information is not something that will deceive people, but rather, it is the basis of all knowledge. Aristotle held the belief that individuals should draw from the environment to gain knowledge and employ that knowledge in their lives. From a person's sensory perception, the mind is used to discover the world's laws through reasoning, therefore, Aristotle heavily emphasized sensory experiences and reasoning. He asserted that relations between objects can be determined by the similarities they share and advised in methods of achieving fairness in relationships in life. He saw the world as one that is infinitely attempting to rebalance itself, providing equal results to equal trials.

An application of Aristotelian thinking regarding probability might take the following form. When an individual flips a fair coin multiple times equal outcomes of both heads and tails are attained. As indicated by Aristotle, conclusions concerning uncertain future events can be made in light of previous events and he suggested that judges make rulings based on what is *likely* to be true, not only what *must* be true. Aristotle devised what he called the laws of association. The laws of association describe how ideas or experiences are connected. According to Aristotle, when two objects or events are repeatedly experienced together, recalling or experiencing one will rouse recall of the other. Following this method, individuals could conceivably be found evaluating probabilities based on the degree to which one object or event is representative of, or resembles another object or event. This process, as will be illustrated later in this chapter, is in many instances an inaccurate way of assessing probability.

Like Aristotle, John Locke (1632-1704) was also an empiricist. Locke subscribed to the idea of a tabula rosa, contending that upon birth the human mind is a blank slate. He was rather interested in revealing the limits of human comprehension in respect to God, one's own self and various ideas. Locke postulated that experience leads to ideas and the concept of ideas being innate is incorrect. Locke supported this claim with the argument that if ideas were innate, the ideas of different cultures would not be so divergent. According to Locke, anything that exists in the mind must first be experienced by the senses; therefore, Locke believed that people only have knowledge of a small amount of information. Locke considered people inadequate of true probabilistic reasoning, stating the best a person can do is employ the mind to make judgments that will not be able to be proven as correct or incorrect. As mathematical probability was just making its way into Europe during his time, Locke is not referring to mathematical probability as much as to probabilistic reasoning.

David Hume, (1711-1776) had philosophies based in both empiricism and skepticism. According to Hume (1748) there is nothing about the physical world or ideas which people gather from it that they can be certain about because it is only through a person's ideas that they will indirectly experience the empirical environment. These ideas, memories, feelings and associations in the mind are simply generated by the individual and are not empirical. He saw the mind as an unreliable stream of human abstractness. Hume contended that humans attempt to attribute future occurrences to past events. In other words, in instances where our experiences with the past have been regular or customary, people come to expect similar outcomes of future events and fail to even consider otherwise. For instance, individuals should not count on the likelihood of the sun rising tomorrow simply because it has risen so many times in the past and to feel certain that it will rise is considered moral certainty, which Hume asserted was not possible to attain. Hume was rather skeptical of accepted laws and principles. Although some causes are somewhat consistent, others are more irregular and uncertain and it is these that particularly cause humans to misjudge outcomes of uncertain events, therefore, according to Hume, humans can be certain of nothing. Hume discounted laws of nature such as causation and claimed that what humans refer to as causes are nothing more than "habits of thought." According to Hume even laws of nature are simply generated by the mind and are not to be trusted or relied upon. In other words, Hume stressed that determining the probability of a future, uncertain event cannot be done based on experiences of many similar events in the past. Some of

Hume's ideas are evident in more contemporary perspectives in probabilistic reasoning which will be examined in an upcoming section. Next, probability as an area of study is more closely examined from a mathematics perspective. Fundamental, mathematics definitions pertinent to probability will be given and examples of those definitions will be provided.

Mathematical probability. In mathematics and statistics, the concept of *probability* is frequently employed to refer to the study of the likelihood of an event occurring (Halpern, 1996). The *probability of an event* equals the number of occurrences possible for an event divided by the number of total outcomes possible in the entire sample space (Mendenhall & Beaver, 1994) and the *sample space* is the entire set of all possible outcomes of an event (Tarr, 2002). For example, one such event of interest may be tossing a fair coin. In this example, the sample space would be the set {head, tail}. A *discrete distribution* is defined on a countable set. In other words, the sample spaces are countable and each value has a certain probability of occurrence that is between zero and one (Tijms, 2004). This type of distribution is most often in the form of positive integers.

A *random variable* refers to a measurable function from within sample space that assigns a unique numerical value to every variable, or outcome of an experiment (Williams, 1991). The unique values vary from trial to trial as the experiment is repeated. For example, a television is turned on until the tube inside that powers it's functioning becomes defective. The random variable X is its lifetime in hours. X can take any positive numerical value.

An expectation, or expected value, is the sum of the probability of each possible outcome of the trial multiplied by its value (Williams, 1991). In other words, this is the average or mean amount that a person expects to gain per trial if the trial is repeated numerous times and if the odds are the same each time.

Another common term used in probability is *event*. An event is a subset of the sample space to which a probability can be assigned (Jones, Langrall, Thornton, & Mogill, 1999). For example, a coin landing on "heads" when an individual tosses it is an event. Events can either be *independent* or *mutually exclusive*. Independent events are events where the outcome of one event has no effect on the outcome of another event (Quinn, 2001). Using the previous example of tossing a fair coin, the outcome of the first toss has no effect on the outcome of the second toss or any of the subsequent tosses. In other words, tossing a fair coin four times and getting heads each time will not have any effect on the fifth toss. Two events that are independent are not mutually exclusive (Ballman, 1997). Mutually exclusive events cannot occur at the same time and therefore have no outcomes in common. For example, a pair of dice is rolled. The events of rolling a total of a 7 with the 2 die combined and of rolling a double are mutually exclusive given that they have no outcomes in common. In other words, rolling a 7 and rolling a double cannot happen at the same time when rolling two die since the outcome of rolling a 7 can only occur with either rolling a 6 and a 1, a 5 and a 2, or a 4 and a 3. None of these options are outcomes involving doubles.

Various laws of probability allow individuals to predict the outcomes of such uncertain events as rolling a fair die and tossing a fair coin. The *additive law* is used to determine the probability of two mutually exclusive events occurring in a single trial, while the *multiplicative law* is employed to determine the probability that independent events will occur in sequence. Utilizing the additive law an individual can determine the probability of choosing a 3 or a 5 from a well shuffled deck of cards. Since the probability of drawing any card from a deck of cards is one in 52 and there are four opportunities to choose a 3 and 4 opportunities to choose a 5 the additive law states the probability of choosing a 3 or a 5 is 8/52. An example illustrating the multiplicative law of probability is determining the probability of drawing a one and a 3 from a well shuffled deck of cards. To find the probability of these two events the multiplicative law states that the separate probabilities of each event need to be multiplied, therefore, the formula for this particular problem is 1/52 X 1/52.

The *law of large numbers* describes the reliability of a sequence of independent, random variables when enough opportunity is present (Tversky & Kahneman, 1971, 1974). This law states that as a sample size increases its statistics will begin to resemble the true properties of the population (Tversky & Kahneman, 1971, 1974). Therefore, tossing a coin a measly four times is not nearly sufficient enough of a sample size to achieve the theoretical distribution. The *law of averages* or *law of small numbers* explains the inaccurate belief or expectation that outcomes of an uncertain, random event will "even out" and theoretical distribution will be realized with a small sample size (Tversky & Kahneman, 1971, 1974). For example, the misconception that a mixed distribution will be realized when a coin is tossed only four times. A formal fallacy that thwarts individuals when predicting outcomes is the *gambler's fallacy*. The gambler's fallacy is a misconception that the likelihood of the outcome of a random, independent event can be accurately calculated or guessed from previous, independent events (Derks, 1963). This fallacy is an incorrect belief that the odds of an event will increase or decrease in relation to recent events (Fischbein & Schnarch, 1997). In other words, the gambler's fallacy is a belief in runs of luck, whether those runs are good or bad. The gambler's fallacy can be illustrated by considering the following example. When tossing a fair coin, the chance of heads being the outcome is .5. The chance of heads being the outcome twice in a row is .5 X .5 = .25. The chance of the outcome being heads 3 times in a row is .5 X .5 X .5 = .125 or 1 in 8, and so on. If a fair coin has already been tossed 4 times and each outcome is heads an individual who believes in the gambler's fallacy may speculate that the chances the outcome would be heads again is 1 in 32. This is an incorrect conclusion because the probability of each independent toss remains .5. The run of heads is 1 in 32 only before the coin has been tossed each of those 5 times.

Another concept of interest to mathematicians and statisticians may include the various ways that objects can be arranged and the multiple combinations in which objects can be grouped. Specifically, *permutations* refer to the various ways that objects can be arranged or ordered without repetition based on the rules of probability (Bona, 2004). Permutations can be helpful when individuals are interested in combining objects or making subsets from larger sets of objects. As a case in point, a grocery store owner might wonder: “How many different ways can I arrange 5 different brands of cereal on a shelf?” The problem can be easily answered by applying rules of probability on permutations. For 5 brands of cereal, there can be 5 x 4 x 3 x 2 x 1 different orderings or arrangements. In total, that makes 120 different unique patterns. In the end, the grocer will need to consider which arrangement of cereals will lead to the highest sales.

Mathematicians refer to subsets of objects as *combinations*. These subsets are unordered sets of unique elements whereas permutations are ordered collections (Bona, 2004). Consider the example of the grocery store owner once again. Suppose the owner is putting 10 different store items on sale including batteries, beef, chicken, eggs, ice cream, soda, toothpaste, trash bags, vitamins, and zip lock bags. As is often done in grocery stores, the owner wants to advertise the sales in the windows. She creates sale signs for all of the products to be placed in the window, but soon realizes that the windows are only large enough for 8 products. Strategically, the owner would need to think of the best combination of signs to put in the window. A mathematical procedure exists to help the owner figure out how many choices are possible to select the best collection, subset, or combination. Although mathematicians know the importance of probability and apply its principles in classrooms as early as elementary school (National Council of Teachers of Mathematics, 1989), it is often noted in the literature as a subject that is not easily conveyed effectively to students in a classroom (Shaughnessy, 1977). The next section looks more closely at this problem.

Teaching probability throughout the curriculum. According to the National Council of Teachers of Mathematics (2007) students as early as prekindergarten through grade two are expected to be able to discuss outcomes of events as being likely or unlikely. Students in third through fifth grade should be explaining conclusions and predictions based on data, considering degree of likelihood, predicting probability of uncertain outcomes of experiments and understanding that the likelihood of those outcomes is measured with numbers from 0 to 1. In sixth through eighth grade, students are supposed to be correctly describing complementary and mutually exclusive events, utilizing probability to generate test conjectures based on experiment outcomes, and assigning probabilities to simple compound events. By the time students reach the ninth grade, they are expected to understand sample space, generate empirical probability distributions, calculate and understand expected value of random variables and compound events, and also gain a conceptual understanding of conditional probability and independent events.

Although the importance of the principles of probability theory to both mathematics and statistics are well known (Rowan, 2001), more research needs to be conducted in an effort to learn methods of effectively teaching these principles for optimal learning (Garfield & Ahlgren, 1988). Probability is an academic area in which individuals gather experience throughout their everyday lives causing them to enter a course on probability with predetermined beliefs or theories about probability, which are often times incorrect. According to research these beliefs are very resistant to change even with instruction (Garfield & Ahlgren, 1988). Even when laws of probability can be used as a tool to make decisions people tend to rely much more heavily on heuristics regarding chance or what they believe chance should be (Konold, 1995).

Past recommendations have highlighted the significance of including instruction to foster an awareness of probability concepts and applications of those concepts to life (National Council of Teachers of Mathematics, 1989). Specifically, more current Principles and Standards for School Mathematics state that "instructional programs from prekindergarten through grade 12 should enable all students to understand and apply basic concepts of probability (National Council of Teachers of Mathematics, 2000, p.48). Corresponding with these standards, researchers have offered suggestions of methods to have teaching and learning of probability to coincide (e.g., Kunoff & Pines, 1986; Fennema et al., 1996).

Misconceptions in probability can cause many problems when an individual is attempting to learn principles and concepts in the domain of mathematics (Jones, Langrall, Thornton, & Mogill, 1999). For example, Konold (1995) has utilized the following scenario at the onset of statistics courses and workshops to measure the effect that instruction has on probabilistic reasoning:

Weather problem. The Springfield Meteorological Center wanted to determine the accuracy of their weather forecast. They searched their records for those days when the forecaster had reported a 70% chance of rain. They compared these forecasts to records of whether or not it actually rained on those particular days.

The forecast of 70% chance of rain can be considered very accurate if it rained on:

a. 95% - 100% of those days.
b. 85% - 94% of those days.
c. 75% – 84% of those days.
d. 65% - 74% of those days.
e. 55% - 64% of those days.

Prior to instruction, approximately 32% of the students chose the correct option, which is 75% -84%. The option chosen most often, 36% of the time was 95% - 100%, suggesting that many individuals enter into courses with misconceptions in probability. Following formal instruction only small to moderate gains were realized with only a 6% increase in correct student responses. According to Konold (1995), assisting students in overcoming informal conceptions by substituting those previously acquired conceptions with more mathematically accurate ones should be a main objective in introductory probability courses.

Given the magnitude of these problems that misconceptions can provoke, pedagogical frameworks have been created in an effort to prevent some of the common misconceptions from ever transpiring in the first place (Jones, Langrall, Thornton, & Mogill, 1999). An example of a pedagogical framework is *The Probabilistic Thinking Framework*. This is an eight-week academic program designed to facilitate instruction in probability for elementary school students. The framework consists of a mentor component where mentors consistently work with pairs of students throughout the duration of the program. An instructional component is also included, during which problem tasks focusing on key probability concepts such as sample space, probability of an event, probability comparisons, and conditional probability are provided for students to work through in groups. While students are working through these probability tasks featured in the instructional component of the framework, games involving spinners are employed. In one study, *The Probabilistic Thinking Framework* was implemented with 37 third grade students from two classes in one elementary school (Jones, Langrall, Thornton, & Mogill, 1999). Researchers found that as students progressed through the instruction their thinking levels increased from a simple subjective type of reasoning to a more complex level exhibiting connections among probability constructs (Jones, Langrall, Thornton, & Mogill, 1999). Prior to the instructional program, 51% of the students demonstrated levels of thinking not indicative of quantitative reasoning, yet following the program, those same students were found to be reasoning quantitatively. Results suggested that students were benefiting from realizing that a single outcome is not necessarily always certain in probabilistic situations.

In another recommended method of teaching probability, Kunoff and Pines (1986) suggested teaching the elementary theory of probability differently than other areas of mathematics for enhanced comprehension of the material. According to Kunoff and Pines elementary probability has the advantage of having historical aspects that can be appreciated prior to receiving instruction in the more complex mathematical aspects. For example, if probability is introduced historically by representing problems that were pondered long ago students may become motivated to study the mathematical features knowing that they are working on some of the same problems that date back to 3500 B.C. Showing how basic probability problems were developed thousands of years ago illustrates to students that some of these problems have been struggled with many times before, which may serve as a cornucopia of motivation for some students. Interventions aside, these are the only two methods of teaching probability found in the literature.

Commonly, individuals subjectively make decisions by assessing the probability of the outcome of an uncertain event using inadequate and invalid data (Tversky and Kahneman, 1974). Many times, in an effort to reduce the complexity of the judgment, a limited number of heuristics are employed by individuals to process these data. Quite commonly these heuristics lead to critical and systematic errors (Tversky & Kahneman, 1974). This is often how people assess probabilities in uncertain situations rather than using probabilistic reasoning to guide their decisions and ultimately their behavior. Others may hold misconceptions which lead them to use inappropriate heuristics to assess a situation. Probability is taught because it is important for learning in mathematics and in everyday life decision-making. For example, when deciding whether to use a portion of a paycheck on the lottery or stock market to increase earnings to their greatest potential, employing probabilistic reasoning effectively could be highly beneficial. Teaching probability using a pedagogical framework or plan may help to reduce the existence of some incorrect intuitions or beliefs (Jones, Langrall, Thornton, & Mogill, 1999), yet given the fact that individuals manufacture beliefs based on life experiences, misconceptions in probabilistic reasoning will continue to thrive even with these efforts (Shaughnessy, 1977). The next section examines current perspectives found in the literature pertaining to misconceptions in probabilistic reasoning.

- Decisions are often made based upon the person's prior experiences, knowledge, and beliefs.
- Although the importance of the principles of probability theory to both mathematics and statistics are well known (Rowan, 2001), more research needs to be conducted in an effort to learn methods of effectively teaching these principles for optimal learning (Garfield & Ahlgren, 1988).
- Probability is often noted in the literature as a subject that is not easily conveyed effectively to students in a classroom (Shaughnessy, 1977).
- Given the fact that individuals manufacture beliefs based on life experiences, misconceptions in probabilistic reasoning are continuing to thrive even with efforts of instruction and interventions (Shaughnessy, 1977).

Contemporary perspectives in probabilistic reasoning

Despite our best efforts teaching probability, research on probabilistic reasoning has demonstrated that individuals typically endorse a somewhat limited collection of procedural heuristics in an attempt to simplify the process of predicting events (Hirsch & O'Donnell, 2001). When individuals are faced with events having uncertain outcomes common misconceptions in probabilistic reasoning thus hinder decision-making abilities and abilities to learn (Shaughnessy, 1977). Misconceptions in probability and probabilistic reasoning are cited as being common and pervasive (e.g. Fast, 1997, 1999; Hirsch & O'Donnell, 2001; Konold, 1995; Tversky &

Kahneman 1974, 1983). Not only are the misconceptions that hinder probabilistic reasoning widely found in students of all ages, but they also hinder decision-making, create stumbling blocks for further learning, and are highly resistant to change. These and other aspects of misconceptions in probabilistic reasoning will be examined in the following section.

Heuristics in probabilistic reasoning. Misconceptions are erroneous or inaccurate beliefs, or naïve theories based on experiences that an individual holds in regard to a given concept or idea (Hynd & Guzzetti, 1993; Vosniadou, 1994). Essentially, a misconception is an alternate conception to what is accepted as an accurate understanding, idea, or piece of information in a given domain (Lin & Cheng, 2000). Once these misconceptions are formalized they become so fixed that changing them requires a great deal of effort. Researchers have suggested that the problematical nature of attempting to alter misconceptions comes from the cognitive effort necessary to modify the basic schema (Dole & Sinatra, 1998). The problem is not only in changing the existing misconceptions, but also in learning correct information that counters the misconceptions (Dole, 2000). As Peirce suggests, individuals want to continue believing just what they already believe which is much easier than putting forth the effort to alter their current beliefs to align with accurate information (Murphy, 2001).

These misconceptions also influence an individual's academic progress. For instance, if the misconception in mathematics continues going unnoticed and without correction, students may experience trouble progressing to an academic stage characterizing competent mathematical performance (Alexander, Murphy, Woods, Duhon, & Parker, 1997). An example of this in mathematics can be found with students in sixth through eighth grades. Students in these grades are expected to have knowledge of complementary and mutually exclusive events according to the standards set forth by The National Council of Teachers of Mathematics (Rowan, 2001). If a student holds misconceptions concerning elementary probability concepts such as what a compound event is, how will that student comprehend how to compute the probability of a compound event which is an expectation of ninth through twelfth grade students?

Misconceptions are cited in the literature as being common place in learners in domains such as probability (Tversky & Kahneman, 1983) and science (Chinn & Brewer, 1993; Taylor & Kowalski, 2004). For more than three decades Kahneman and Tversky have contributed a great deal of research on misconceptions in probabilistic reasoning. In the probabilistic reasoning literature individuals are cited as maintaining naïve understandings and misconceptions about probability, most likely instigated by their prior experiences (Hirsch & O'Donnell, 2001; Tversky & Kahneman, 1971). This naiveté can often lead to poor judgments or decisions as a result of a person's misconceptions or inadequate information.

While a widespread investigation into the use of text as an intervention to alter individuals' misconceptions in probabilistic reasoning has not been conducted, a great deal of research has concentrated on probability and commonly held misconceptions in probabilistic reasoning (e.g., Fast, 1999; Hirsch & O'Donnell, 2001; Konold, 1995; and Tversky & Kahneman, 1974, 1983).

Through extensive research, Tversky and Kahneman (1974, 1983) have identified various heuristics people utilize as well as common fallacies and biases that result from these heuristics. Heuristics are essentially rules that an individual follows to simplify processing (Stiff, 1994). The heuristics that people inherently rely upon affect judgments or decisions concerning uncertain circumstances. Three heuristics in particular that have been repeatedly investigated are adjustment and anchoring, availability, and representativeness (e.g., Fast, 1997; Hirsch & O'Donnell, 2001; Konold, 1995; Tversky & Kahneman, 1974, 1983). There are times when these heuristics may be used to a person's advantage. In fact, skilled, knowledgeable experts in the domain of probability occasionally use these heuristics and benefit from their use (Tversky &

Kahneman, 1974). This only occurs when the heuristics are used appropriately and correctly. When this is the case, the probabilistic reasoning used to determine the outcome of the ambiguous event is correct. At other times, however, these heuristics may also fool individuals, experts included, into making systematic errors since using them to make judgments causes a person to neglect any prior probabilities (Tversky & Kahneman, 1974). These are times when heuristics are ineffective and inappropriate. In the next sections specific types of heuristics and examples of each are examined.

Adjustment and anchoring. Adjustment and anchoring occur mainly in situations where numbers are to be predicted and an initial value is available to begin from (Tversky & Kahneman, 1974). Whether the numerical point to begin predicting from is implied or the product of a partial calculation, adjustments are characteristically insufficient. In other words, a variety of initial values provide assorted estimates, which are biased toward the number from which the estimate began. Essentially, individuals frequently estimate through adjustment of an initial value until an end result, or final value is reached. Often times, adjustments are biased toward the initial value, which is the anchor. This phenomenon is what Tversky and Kahneman refer to as anchoring. In one of the experiments in which Tversky and Kahneman (1974) demonstrate this particular heuristic participants consisted of Israeli high school students. These participants were asked to estimate various percentages. An example of this is the percentage of African countries belonging to the United Nations. Each participant separately viewed experimenters spinning a wheel numbered from 0 to 100 to determine the initial value. Participants were asked to first estimate whether the actual number was higher or lower than the number produced by the spin of the wheel. Next, they were instructed to calculate the value of the actual percentage by moving upward or downward from the number on the wheel. The random numbers produced by the spinner had an effect on the percentage estimated by the participants. For example, those receiving 10 and 65 as initial values generated 25 and 45 as median estimates respectively. This demonstrates that even a payoff offered to participants did not diminish the anchoring heuristic.

Kristensen and Garling (1997) demonstrated the anchoring heuristic through the use of simulated price negotiations of condominiums with seventy-two undergraduate students who were randomly assigned to perform the role of buyers or sellers. The participants were tested in pairs of buyers and sellers. Each pair of participants was separated into different rooms and provide with accurate information regarding price ranges of local condominiums. Following this, buyers and sellers were asked to provide researchers with the highest and lowest prices that they believed they could respectively buy or sell a condominium. This particular task was for the purpose of acquainting participants with price ranges they were about to encounter. At this point, buyers were to try to buy a condominium at the lowest possible price while sellers were attempting to sell at the highest possible price. Buyers were then provided with three different initial offers for the condominiums from the seller and a reserved bid either higher or lower than the initial offer. Participants completed twelve negotiations. Findings suggested that the first counteroffer was influenced by the anchor points and at times when the initial offer was perceived by the buyer to be a gain they bought at a higher price and the number of offers made decreased. These results suggest that anchors have an effect on an individual's assessments through and anchoring-and-adjustment process.

The anchoring heuristic also occurs when an individual bases an estimate on a partial calculation. Tversky and Kahneman (1974) asked two groups of 20 to 40 Israeli high school students to estimate the product of the two following numerical expressions:

8 X 7 X 6 X 5 X 4 X 3 X 2 X 1

1 X 2 X 3 X 4 X 5 X 6 X 7 X 8

Each of the groups was given one of the above problems and five seconds to examine the problem and provide the answer. To give this type of answer so quickly Tversky and Kahneman speculate that participants typically perform several of the steps and then estimate the answer using adjustment, which usually results in underestimation. They also hypothesized that in the descending problem where the first several steps produce a higher number, participants should evaluate the product to be higher. As evidenced in the following results, Tversky and Kahneman (1974) supported both of these hypotheses. The participants estimating the product of the ascending problem generated 512 as a median estimate and those estimating the descending problem generated 2,250 as the median estimate. The correct answer to the problem is 40,320. These results illustrate not only that participants did indeed greatly underestimate the product, most likely due to the adjustment heuristic, but they also estimated the descending problem to produce a higher answer.

Availability. The availability heuristic, which leads to judging the frequency of a class or probability of something occurring based upon how easily an instance or occurrence can be evoked, is a common heuristic cited by Tversky and Kahneman (1974, 1983). In some cases evaluating occurrences and likelihoods can be aided by this heuristic since evoking memories of bigger classes is easier than memories of smaller classes. Tversky and Kahneman (1974) use frequency of heart attack in middle age people as an example of this how this heuristic can be used correctly. An individual may be able to recall more heart attacks in middle-aged friends, family and acquaintances than in younger people in the same classes. Since the availability heuristic allows an individual to recall instances of larger classes faster and more effectively, this heuristic is, at times, efficient at assessing frequency or probability because larger classes are more are more frequent and therefore do have a higher probability of occurring. Heart attacks usually occur more in middle-age individuals, meaning that the heuristic worked in this instance, however, Tversky and Kahneman indicate that probability is not always accurately ascertained simply by recalling familiar events or incidents, which is why the availability heuristic is often utilized. The availability heuristic may be useless when class size is determined by availability of its occurrences. For example, an individual may have a great deal of experience with a particular class, giving that person the illusion of that class being more numerous than it is in reality. Reliance upon the availability heuristic causes common, inevitable biases due to retrievability of instances, effectiveness of a search set, imaginability, and illusory correlation. The source of the problem is the mental availability (Tversky Kahneman, 1974, 1983). What is mentally available to an individual may be affected by issues or items other than the frequency with which the class occurs. For instance, in the case that an individual has generated a particularly strong association between two objects, people, or events they are apt to deduce that they have been paired often, which may not be the case. Tversky and Kahneman (1974) demonstrated use of this heuristic when they asked participants to estimate whether a list of names contained more women or men. Some participants received lists containing more famous women than men while other participants received lists of more famous men than women. Invariably, the participants estimated the gender belonging to the more famous names to be the gender more often represented on the list. These results can be attributed to participants experiencing less of a challenge when recalling the names of famous people (Tversky & Kahneman, 1974, 1983). The more easily retrievable names will appear to belong to a larger class. Recent experiences that an individual has had may also bring about the use of the availability heuristic. For example, if a person witnesses a plane crash, their subjective assessment of the frequency with which plane crashes occur will appear higher.

Representativeness. Representativeness is another very common and pervasive heuristic cited by Tversky and Kahneman (1974). This heuristic is generally relied upon in situations concerning an object belonging to a class, an event originating from a process, or the probability that a process will bring life to an event. It refers to the degree to which a sample has the properties of its population. Simply stated, representativeness is most heavily relied upon in circumstances when probabilities are determined by the degree to which A represents or bears a resemblance to B. In other words, this heuristic is one in which a commonality between objects that share similarities is assumed. In relation to events rather than objects, representativeness occurs when individuals judge the probability of an event by locating an analogous and familiar event and assuming the probabilities will be comparable. Representativeness has been utilized to account for biases such as the gambler's fallacy and insensitivity to sample size (Tversky & Kahneman, 1971, 1974). The gambler's fallacy is a mistaken yet logical belief that the odds of an event with a set probability increase or decrease based on recent events (Fischbein & Schnarch, 1997). For instance, a person playing roulette may expect the wheel to stop at black next if it had already stopped at red the last 8 times. In reality, the outcomes of the first 8 spins of the wheel have no bearing on the outcome of the ninth spin of the wheel. The representativeness heuristic is believed to be the source of the gambler's fallacy (Gilovich, Vallone & Tversky 1985) which will be further explored in the following section.

The representativeness heuristic emerges when a misinterpretation of the Laws of Small or Large Numbers occur (Tversky & Kahneman, 1971, 1974). A familiar example of this is the misconception that when an individual tosses a fair coin an equally mixed sequence of both heads and tails (H T H T) is the more common outcome than one of four heads (H H H H) or four tails (T T T T). This conclusion can be attributed to the two latter sequences not being representative of the theoretical distribution of possible events, which is an even assortment of both heads and tails. Individuals falling prey to the gambler's fallacy would be more likely to bet that the mixed sequence is the more common outcome. This bet would be a function of their inaccurate belief that many outcomes of heads should set in motion a somewhat similar number of tails in future tosses. The mixed sequence is usually misinterpreted by individuals as being more random and representative of the theoretical distribution of tosses of a coin since that sequence features a 50% chance of heads appearing as well as a 50% chance of tails appearing. An individual choosing the mixed sequence as being the more common outcome fails to recognize or believe in the law of large numbers. In actuality, the sample space necessary for the theoretical distribution to occur is much larger than just four or even forty coin tosses (Tversky and Kahneman, 1974). This is also referred to as a misconception of chance (Tversky & Kahneman, 1974). It is a misconception to perceive the concept of chance as a course of action that corrects itself as it progresses, thereby representing the essential characteristics of the event. In the case of the coin that would connote equal appearances of heads and tails throughout the tossing. This is an incorrect belief. Chance does not correct itself or seek equilibrium. These departures from equal appearances just become diluted as the sample increases not corrected. In other words, an individual may flip a coin a small amount of times and each time the outcome is the same, yet this uneven representation of possibilities of outcomes diminishes as the individual conducts more trials by flipping the coin more times. The uneven representation does not correct itself; it merely becomes reduced once more trials are introduced.

Consider the following scenario:

All families of six children were surveyed. In 72 families *exact order* of births of boys and girls was G B G B B G.

What is your estimation of the number of families surveyed in which the *exact order* of births was B G B B B B?

Although the sequence of births featuring 3 girls and 3 boys is more representative of the entire population of people, the two sequences are approximately equally likely. This scenario was shown to 92 high school students in college-preparatory courses in tenth, eleventh and twelfth grades in Israel (Kahneman, Slovic, & Tversky, 1982). Out of the 92 participants, 75 participants determined the second sequence of 5 boys and only 1 girl to be less likely because it is less representative of the population. This is just one example of how the representativeness heuristic manifests itself in the decision-making process.

The representativeness heuristic is a common misconception which has been found to hinder students' understanding of probability and probabilistic reasoning (Kahneman & Tversky, 1972). This is because the similarity of two or more objects, people, or events is not influenced by some of the other issues that have an effect on decisions or judgments made based on probability. Tversky and Kahneman classically illustrate an example of how similarity could affect judgments in a way unaligned with probability by using a scenario in which Tom W. is described as "…of high intelligence, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems (1973, p. 238)." Following this description 65 participants were then asked to assess how similar Tom W. is to the typical graduate student from a list of nine academic areas of study, while a prediction condition consisting of 114 graduate psychology originating from three universities in the United States were told the personality sketch of Tom W. was assigned to him in high school, based on testing by a psychologist. Participants were then asked to rank the probability that the man being described is a graduate student in the nine areas of graduate studies listed. Some categories to choose from were business administration, computer science, engineering, humanities and education, and law. Results revealed that participants overwhelmingly use similarity rather than probability to predict likelihood (Tversky & Kahneman, 1973). Specifically, the correlation between predicted likelihood and similarity was .97 while the correlation between predicted likelihood and estimated base rate was much lower at .65.

Tversky and Kahneman (1974) use this same approach with a different scenario to again illustrate how the representativeness heuristic can emerge while making judgments when similarity is a factor. A man is described as "…very shy, withdrawn, invariably helpful, but with little interest in people or in the world of reality (1974, p. 1124)." Following this description, if people were then asked to assess the probability that the man being described is employed in a particular occupation they would most likely make the assessment based on similarity instead of base rate frequency (Tversky & Kahneman, 1974). Some categories to choose from may be farmer, salesman, airline pilot, librarian, or physician. As a result of the representativeness heuristic people would choose librarian for the reason that the man's personality is representative of or similar to how a librarian's personality is stereotypically considered being. If a person was to choose the shy man's occupation as a librarian, given that this occupation is typically thought of as being one for shyer, more introverted people rather than the rest of the occupations on the list; base-rate frequencies would be ignored. A librarian was not the occupation with the highest number of people belonging to it. What should be taken into account in the decision is how often these occupations are represented in society. In other words, the individuals would normally be taking into account the sample size of each of the occupations in the larger society when deciding what occupation the man had. The likelihood or probability of obtaining particular results from a sample is heavily influenced by the size of the sample. Not realizing that the size of a sample affects the results acquired from it is an insensitivity to sample size (Tversky & Kahneman, 1974). Base-rate frequency, or prior probability, does not have an effect on representativeness, whereas it does have an effect on probability.

Another case in which Tversky and Kahneman (1973) revealed the effects of representativeness can be witnessed through an experiment wherein prior probabilities were manipulated. Participants were told that personality profiles were generated for 100 engineers and lawyers that were randomly selected from the population. After viewing the profiles, participants were asked to estimate the probability that each profile belonged to either an engineer or a lawyer. In the first condition 85 low-engineers were told 70 engineers and 30 lawyers comprised the sample. Another condition consisting of 86 high-engineers was told the opposite, that is, the sample was composed of 30 engineers and 70 lawyers. By applying Baye's rule, which is a mathematical formula used for amending beliefs in light of new evidence, a ratio can be generated clearly showing that the odds of reading the profile of an engineer is higher in the first condition than in the second. Simply by looking at the numbers represented in each condition that conclusion should be somewhat obvious to the participants. Yet, in each condition, participants estimated the probability to be approximately the same. This suggests that as opposed to taking into consideration the number of professionals represented the participants took into consideration the degree to which the profile epitomized that of the stereotype of an engineer or a lawyer. This is an example of insensitivity to prior probability outcomes. Specifically, participants were not taking into consideration the probability of choosing an engineer or lawyer based the number of engineers and lawyers they were previously told make up the sample.

From the research, it is apparent that misconceptions in probability are common. Although some attempts to alter these misconceptions common to probability and misconceptions in other domains have been made, only a small number of interventions have specifically been created and implemented for the purposes of altering misconceptions in probabilistic reasoning. In the next section, the tremendous difficulty in altering misconceptions in science and probability as well as various methods of doing so found in the literature are detailed. Instruments created specifically to combat the representativeness and availability heuristics are investigated and explained. The conceptual change literature is explored from both a probability perspective and a science perspective.

- Individuals typically endorse a somewhat limited collection of procedural heuristics in an attempt to simplify the process of predicting events (Hirsch & O'Donnell, 2001).
- A widespread investigation into the use of text as an intervention to alter individuals' misconceptions in probabilistic reasoning has not been conducted.
- Although some attempts to alter these misconceptions common to probability and misconceptions in other domains have been made, only a small number of interventions have specifically been created and implemented for the purposes of altering misconceptions in probabilistic reasoning.

Conceptual Change

Many people experience difficulty transferring information learned in a classroom setting to real life and this is especially the case with probability and probabilistic reasoning (Shaughnessy, 1977). Many times individuals use common heuristics incorrectly when making decisions concerning the outcomes of uncertain events (Tversky & Kahneman, 1974). These individuals would benefit from instruction in employing probabilistic reasoning correctly. The probability literature has not yet extensively examined conceptual change (Hirsch & O'Donnell, 2001). According to an extensive meta-analysis collecting an initial pool of 67 studies and thoroughly investigating a final compilation of 47 studies conceptual change is recognized as a progression, which may be gradual or swift, by which an individual's initial understandings or beliefs are altered to more closely reflect what is accepted as scientifically true (Murphy & Alexander, 2007). The following section investigates misconceptions commonly found specifically in the domain of probability. This section is a review of research on altering misconceptions in probabilistic reasoning and interventions created for the purposes of altering those misconceptions.

Altering misconceptions in probability. From the existing research in probability, it appears that individuals holding one or more of the common misconceptions in probabilistic reasoning are typically unsuccessful in altering those misconceptions even after receiving instruction in the laws of probability (Shaughnessy, 1977), or evidence contrary to their misconceptions (Hirsch & O'Donnell, 2001). Even with the research suggesting that probability is a topic which presents difficulty for students, and is wrought with misconceptions very few interventions have been created to enhance learning the laws of probability or alter the commonly found misconceptions.

In investigating students' levels of understanding, Konold (1995) has found that students enter into probability and statistics courses with intuitions or beliefs concerning probability that are incorrect and highly resistant to revision even following instruction on the very content in which the misconceptions are regarding. Students are often found leaving at the close of the semester with the same misconceptions they arrived with. An example of this type of outcome would be observed when students display a theory-driven behavior (Vahey, 1997). Students demonstrating this sort of behavior refuse to believe reputable data presented to them when it is inconsistent with their own theory. Their misconceptions are essentially blocking the new information from becoming a part of their knowledge base. Given individuals' staunch resistance to surrendering their misconceptions in probabilistic reasoning several interventions for altering these misconceptions have been explored.

Using analogies in conjunction with anchoring situations has been examined in an effort to alter students' misconceptions in probabilistic reasoning (Fast, 1997; 1999). Fast examined tenth, eleventh, and twelfth grade students' misconceptions in probabilistic reasoning to analyze the effectiveness of utilizing analogies in overcoming those misconceptions. Versions A and B of the *What Do You Think the Chances Are?* instrument were administered to participants within a week of each other. This instrument features multiple choice items pertaining to the likelihood of events. According to this line of research, anchoring situations analogous to areas of probability fostering common misconceptions (i.e. availability and representativeness) are useful in creating cognitive dissonance in students' resulting in a knowledge reconstruction process leading to abandonment in the long-term of the misconceptions in probabilistic reasoning. For the tenth and eleventh grade participants who agreed to partake in an interview six months later, a 65% retention rate was found, suggesting long-term effectiveness of analogies in conquering misconception in probabilistic reasoning.

Hirsch and O'Donnell (2001) created a reliable instrument in an effort to identify students' misconceptions in probability titled *A Test of Representativeness*. Their participants were 61 graduate students and 202 undergraduate students in educational psychology and statistics courses. Prior to the start of the study misconceptions of representativeness were cited as common for the students to hold. Hirsch and O'Donnell found that although instruction had an effect in reducing misconceptions a substantial number of students held onto their inaccurate beliefs. They also found that some of the students not displaying misconceptions on the first post test did indeed show evidence of misconceptions on the second post test. The data suggest that even after classroom instruction, students still exhibit misconceptions in probability (Hirsch & O'Donnell, 2001).

Current instruments assessing proficiency in probability tend to over-estimate students' comprehension of the subject matter (Shaughnessy, 1992). These results show support for the creation of instructional interventions in probability. Instructional interventions aimed at correcting probability misconceptions may be effective where formal instruction is lacking

(Hirsch & O'Donnell, 2001). In the literature many more attempts to alter misconceptions can be cited in the science domain than in probability. Moreover, as already underscored, only a handful of researchers have gone to the great lengths of creating interventions to alter misconceptions in probabilistic reasoning (Hirsch & O'Donnell, 2001). In light of this, the next section will draw on understandings from another academic area. Specifically, the following section investigates misconceptions in science and interventions created to alter those misconceptions to be more closely aligned with scientifically accepted information.

Altering misconceptions in science. Not all misconceptions come from equally inaccurate mental models (Vosniadou & Brewer, 1994). For example, in a review concerning children's knowledge about observational astronomy, Vosniadou and Brewer (1987) discuss two types of knowledge structuring. The first of these is weak restructuring. Weak restructuring consists of accumulating facts and forming new relations between existing concepts, which typically involve a small amount of cognitive effort. A second type of knowledge structuring involves changing core concepts, altering knowledge structures, and making modifications to a scientific phenomena being portrayed. This type is considered radical restructuring which involves a higher level of cognitive effort than weak restructuring does.

An example of radical restructuring in astronomy would be when children change their mental model of the sun as personified and needing to sleep at night to the sun as another star within the solar system. The initial mental model of the sun sleeping at night is a common misconception that children hold in the science domain concerning the day/night cycle (Vosniadou & Brewer, 1994). When examining sixty elementary school students' (i.e. 20 first grade students, 20 second grade students, and 20 third grade students) understanding of the day/night cycle, Vosniadou and Brewer (1994) found that students were employing a relatively small number of somewhat well-defined mental models of the earth, moon, and sun that were empirically accurate and logically consistent. According to Vosniadou and Brewer (1994), even the youngest of children displayed empirically precise, intuitively consistent mental models which exposed a level of awareness of simplistic descriptions and rationalizations. In this research, Vosniadou and Brewer used three of Kuhn's (1977) five criteria for assessing a theory. According to the criteria, accuracy within the domain, logical consistency within itself, and simplicity are all characteristics necessary for a scientific explanation to be considered a theory. The scientific explanations of these students were consistent with these criteria. Results suggest that student's initial, synthetic mental models act as barriers to learning physical world knowledge.

The typical mental models provided mostly by the youngest students (13 first graders, two third graders, and one fifth grader) were grounded in common, everyday experiences that they have had and objects they were familiar with. For example, these students credited the mountains and clouds with covering up the sun at night. These were considered initial models since they are conclusions based on everyday observations. The older students, a little more advanced, were able to generate synthetic mental models which consisted of a combination of both initial mental models and culturally accepted information concerning the day/night cycle. Some, yet not many, of the older students demonstrated a rather scientific mental model of the day/night cycle. These data support the idea that children are not simply blank slates or empty vessels when they enter a classroom, but individual minds with an array of varying experiences and explanations of their own.

Chinn and Brewer (2001) found similar results when examining 168 college undergraduates. The participants were predominantly pre-service teachers enrolled in educational psychology courses. In their investigation, participants demonstrated diverse responses when evaluating the same set of data. Participants generated a cognitive model comprised of actual features of the data that they evaluated as well as a theoretical interpretation.

Causing cognitive dissonance or disturbing an intuition or belief has been found to be a somewhat effective method for changing students' misconceptions in science (Chinn & Malhotra, 2002; Guzzetti, Snyder, Glass, Gamas, 1993). When investigating elementary school students' responses to anomalous scientific data concerning information in which those children held previously acquired conceptions Chinn and Malhotra (2002) found that a change in those previously acquired conceptions is frequently resisted. In this three-phase study, experiment one consisted of 228 fourth grade students enrolled in a science/mathematics/technology magnet school while experiments two and three consisted of 26 and 138 fifth and sixth grade students respectively in a kindergarten through sixth grade elementary school. Their method was to allow students to observe actual events in a classroom. These events were treated as science experiments. For instance, rocks of differing weights were dropped simultaneously to determine if one rock hit the floor prior to another and the temperature in a sweater was measured to determine if it was higher or the same as outside of the sweater.

For those participants in experiment one, Chinn and Malhotra (2002) found prior theories were dictating what was being observed. Essentially students don't get very far before they are rejecting a change in their conceptions based on what they are observing, especially when the observation is of an ambiguous nature. Although anomalous data were sees as facilitating belief change, the degree of change was small. The students in this experiment were allowing their previously acquired scientific conceptions or beliefs to cause them to make an incorrect observation, consequently, impeding a change in those misconceptions. Students expecting to observe the heavier rock hit the floor attested to observing just that.

Participants in experiment two experienced some belief change with less ambiguous data, while the more ambiguous data did not promote any belief change. In experiment three statistically significant effects on participants' beliefs were produced with anomalous data, however, when explanations were provided with the data students were much more likely to make correct observations. Results suggest providing explanations with data, such as that of a scientist's expectations and reasoning in reference to an experiment rather than simply providing a data-based experiment, facilitated misconceptions being altered in alignment with commonly agreed upon scientific knowledge (Chinn & Malhotra, 2002).

Science misconceptions are not only prevalent in children but are also found in college students. When assessing 90 incoming college freshmen enrolled in an introductory psychology course Taylor and Kowalski (2004) found on the first day of the semester students demonstrated only 38.5% accuracy of psychological information after controlling for guessing on a questionnaire. When tested again during the last week of class students demonstrated 66.3% accuracy after controlling for guessing. Although the misconceptions were reduced after taking an introductory psychology course they were still prevalent.

Another common misconception concerning science prevalent in children and adults alike is one regarding the seasons (Lindgren, 2003). While viewing *A Private Universe*, Lindgren was shocked at 21 out of 23 Harvard graduates, alumni, and faculty displaying misconceptions concerning seasons while being interviewed at a Harvard commencement showing even well-educated adults fall prey to some of these common misconceptions. Lindgren is an educator of preservice teachers in science methods courses and warns them of the challenge ahead of them in dealing with and conquering the misconceptions their students will inevitably possess. She introduces the conceptual change approach to her students in an effort to illustrate to them the importance of utilizing discrepant events and discussion groups.

Although quantum physics is a more complex scientific concept than seasons, it is an area in which adults are cited as having serious misconceptions (Kalkanis, Hadzidaki, & Stavrou, 2003). Through an examination of teachers' and students' prior knowledge it was determined that misconceptions were mainly originating from instruction prior to university as a result of the *overlapping/mix-up* of two incompatible and separate concepts, being classical physics and quantum mechanics. The suggestion for overcoming this misconception-laden area is to assist pre-service and in-service teachers in forming a conceptual structure keeping classical physics and quantum mechanics as completely separate and independent conceptual systems. Since this entails a radical conceptual change of the learners' current knowledge networks, an instructional model is proposed in which learners' prior knowledge is assessed, individual differences of the learners and their individual needs are identified, learners are provided a situation to reconstruct their knowledge, and finally conscious promotion of metacognition is emphasized. Results from Kalkanis and colleagues (2003) suggest that this is a viable instructional intervention for promoting a qualitative approach to physics. The following sections examine effective interventions for successful conceptual change and mediating variables that affect the extent of that success.

Effective interventions. Murphy and Alexander (2007) conducted an extensive meta-analysis of the available theoretical as well as empirical research on the conceptual change process. Specifically, the meta-analysis was an investigation of conceptual change of domain or topic beliefs, subject-matter knowledge, and learner interests. In the literature, text, explanations, and prediction techniques are examples of interventions employed to achieve topic belief change (Mason & Boscolo, 2004; Chinn & Malhotra, 2002). In K-12 students dual position texts were moderately effective at altering beliefs about genetically modified foods (Mason & Boscolo, 2004) and student generated predictions were moderately effective at altering beliefs about temperature and falling objects (Chinn & Malhotra, 2002). For example, in a study employing text structure as an intervention for achieving conceptual change in concepts of energy with 215 Cypriot sixth-grade students, those participants reading a refutational text outperformed participants reading an expository text as well as participants who read an expository text and received instruction (Diakidoy, Kendeou, Ioannides, 2003). In altering K-12 students' topic beliefs, strongest effects were found when data-based or explanation-based instruction was utilized as an intervention (Chinn & Malhotra, 2002).

While videos or conceptual assignments aimed at altering an individual's initial understandings appeared to be weak interventions to achieving conceptual change of knowledge, hands-on activities and combining physical illustrations with scientific explanations proved to be stronger methods in altering subject-matter knowledge (Murphy & Alexander, 2007). Diakidoy and Kendeou (2001) utilized textbook instruction and instruction aimed at preconceptions concerning the shape of the Earth and the day/night cycle with 63 fifth-grade students. The condition receiving the instruction targeted at the preconceptions displayed significant pre- post-test gains (p=.00). A number of characteristics of the learner and the environment are recognized in the literature as mediating variables affecting the conceptual change (Schur, Skuy, Zietsman, & Fridjhon, 2002; Kardash & Scholes, 1995; Chinn & Brewer, 1993). In the next section several of these mediating variables will be examined.

- Very few interventions have been created to enhance learning the laws of probability or alter the commonly found misconceptions.
- Although misconceptions have been reduced after taking introductory courses they are still prevalent.

Mediating Variables

Learner. Each student that teachers encounter all over the world has individual differences that makes them a unique learner and sets them apart from other students. These distinctive characteristics unique to individuals impact the learning, problem-solving, and conceptual change processes. According to the educational psychology literature, two dimensions from which theses distinctive characteristics transpire and interact are from an individual's cognitive and affective traits (Pintrich, Marx, & Boyle, 1993). Although numerous cognitive and affective learner characteristics exist influencing learning, problem-solving, and the conceptual change process, for the purposes of this review I particularly focus on a learner's knowledge and beliefs.

Knowledge. Knowledge has been generally defined as factual, proven information that can be gained in school or some type of academic setting (Alexander & Dochy, 1995). After an extensive review of research in the cognition and literacy literature, Alexander et al. (1991) defined *knowledge* as "...an individual's personal stock of information, skills, experiences, beliefs, and memories...knowledge encompasses all that a person knows or believes to be true, whether or not it is verified in some objective or external way (p. 317)", whereas in the field of epistemology the term *knowledge* is referring to absolute truths. What an individual knows directly determines what and how they will learn from various situations and mediums (Alexander & Murphy, 1998; Glaser, 1984). This is no longer a question within the literature. Researchers now realize the power that prior knowledge holds over future acquisitions of knowledge as well as problem solving and processing information.

Acquiring knowledge is an ongoing process involving changes to previously acquired structures as well as generation of new structures all together (Vosniadou & Brewer, 1987). These changes vary in amount of effort required to carry them out. Changes to existing knowledge structures entail less cognitive effort than the effort required to create completely new knowledge structures. One constructivist approach to learning emphasizes activity in the form of knowledge-building in conjunction with conflict with current knowledge structures (Chan, Burtis, & Bereiter, 1997). This methodology appreciates the importance of conflict for conceptual change to occur if the students are simultaneously actively engaged in treating the new, incoming information as causing disequilibrium and requiring clarification. Simply assimilating new information into current knowledge structures is not recognized as a viable pathway to conceptual change.

Even in the event that an individual is learning totally new knowledge, that person still needs some type of prior knowledge so the new knowledge can be accurately interpreted (Konold, 1995; Vosniadou & Brewer, 1987). For example when students are new to the concept of decimals their knowledge of whole numbers is utilized to comprehend the new concept (Moskal & Magone, 2000). This can be a problem, however, since it can promote misconceptions if students over-generalize the relation between the two concepts. An example of establishing a misconception this way in relation to decimals would be the assumption that a number with more digits is bigger. This is not necessarily the case with decimals. Another difficulty with prior knowledge occurs when new knowledge conflicts with prior knowledge even if the new knowledge is more accurate (Vosniadou, 1994). Vosniadou states when an individual is attempting to fit new information into an existing structure which is not receiving it very well due to conflicting prior knowledge, a scenario somewhat similar to fitting a round peg into a square hole, misconceptions arise.

Knowledge acquired through an individual's senses is often wrought with misconceptions because a person's senses so often fail them when knowledge is to be gained (Kaplan & Kaplan, 2006). Information perceived through the senses so heavily depends on an individual's field of attention, which is frequently skewed or biased, that the obtained knowledge must be applied cautiously. This is where probability serves a salient purpose. Once utilized, probability refocuses an individual's attention at times when inaccurate knowledge may serve as a distraction (Kaplan & Kaplan, 2006), however in the case of inaccurate knowledge of probability, an individual is not afforded the opportunity to refocus attention and make a correct judgment. According to Konold (1995), prior knowledge in probability often obstructs the acquisition of new knowledge in that domain and many times that prior knowledge is inaccurate. Even in a situation concerning inaccurate knowledge, once knowledge is acquired it is highly resistant to change or alteration, even in the face of correct and opposing information (Konold, 1995; Shaughnessy, 1992). Multiple times in the literature, prior knowledge in probability, often acquired through informal, life experiences, is cited as a powerful barrier to attaining new, accurate knowledge in probability (e.g., Shaughnessy, 1992; Hirsch & O'Donnell, 1995; Konold, 1995).

While investigating American and Singaporean ninth grade students' and their teachers' perceptions of knowledge and beliefs Alexander, et al. (1998) found most participants representing knowledge and beliefs as overlapping. Regardless of the culture or stage in life (i.e., student or teacher) the participants' responses were quite similar. When given a choice of representing knowledge and beliefs as one of five diagrams or as a self-generated diagram a large percentage of participants in each group (i.e., 38% Singaporean students, 40% American students, 46% Singaporean teachers, and 50% American teachers) chose to represent knowledge and beliefs not as separate constructs, but as overlapping. Beliefs are another individual characteristic of learners that make them unique to the learning process. The next section examines beliefs and how those beliefs can affect probabilistic reasoning.

Beliefs. It appears as though affect is a component in achieving success in probability. Beliefs would be one of the affective components playing a role (Burns, 2004). According to

Kaplan & Kaplan (2006) these two constructs are deeply intertwined. "Probability…gives us a method of defining a belief as it ought to exist in a reasonable mind: Truth within known limits…" (Kaplan & Kaplan, 2006, p. 9). In other words, numbers so central to probability afford a standard with which individuals can assess truth.

For instance, Tversky and Kahneman (1973) utilized a real-life situation depicting a car accident involving a taxi on winter night. Participants were told the only colors of taxis in town were blue and green and the company owning the green taxis possessed 85% of the taxis currently in use. Participants were then informed that a woman eye witnessed a blue taxi, yet independent testing suggests that this eyewitness will be correct 80% of the time. Next, participants were asked to say whether the taxi was blue or green. Most participants guessed that the taxi was blue, suggesting that they chose to focus on the reliability of the eyewitness rather than the percentage of taxis currently on the road in combination with how the eyewitnesses reliability affects that base fact (Tversky & Kahneman,). The actual probability that the taxi was blue was only 41%, which is not as likely an outcome as the taxi being green. This is just one example of how what an individual believes to be true can be further investigated through probability.

When examining 120 undergraduates', graduates', and published experts' conceptions of knowledge and beliefs across cultures (i.e., Netherlands and United States) Alexander and Dochy (1995) found the concept of a belief not as easy for most people to convey in words as the concept of knowledge. This may be a reason why such a large number of definitions can be found between and even within various literatures.

According to Hume (1748), beliefs are a result of associations individuals make between ideas by way of experience. Furthermore, our imagination and our beliefs are largely similar on all counts except our level of certainty with which objects or events are anticipated. Hume also found our beliefs to be strongly affected by our sentiments or feelings more so than from rational reasoning. Beliefs are typically thought of as subjective, personal truths regardless of substantiation and not necessarily based on evidence found in schools (Smith, Siegel, & McInerney, 1995). They can be largely unproven understandings or opinions with an element of some truthfulness or worthiness generated from a person's life experiences (Petty & Cacioppo, 1986; Vosniadou, 1994; Alexander & Dochy, 1995). Beliefs have also been operationally defined as "…inferences made by an observer about underlying states of expectancy" (Rokeach, 1968, p.2). While Kardash and Scholes (1995) have defined beliefs as an individual's dedication to or assessment of the accuracy of the prior knowledge they have others have identified beliefs as what a person holds as true concerning a given topic (Johnson, Lin, Symons, Campbell, & Ekstein, 1995). Although beliefs are not directly observable, their behavioral outcomes are. From this burgeoning area of research researchers can now conclude that beliefs indeed influence learning processes and outcomes (Schommer, 1994) and are also highly resistant to change (Chinn & Brewer, 1993; Slusher & Anderson, 1996).

Beliefs have a great impact on many aspects of academic as well as non-academic learning and development in various domains. An individual's beliefs determine their expectations concerning a given situation, the challenges they will face with particular tasks, the amount of effort necessary to expend for a challenging task as well as the amount of time to persevere to see a task to its end even when faced with small failures along the way (Bandura, 1977, 1997). These effects are far reaching enough to directly influence what knowledge a person gains and how that knowledge is used (Schoenfeld, 1985). For instance, if a high school senior believes that he does not excel in academics, then he is less likely to apply to college than a student that holds the belief that she surpasses her fellow students academically.

Children enter into school with pre-existing beliefs concerning scientific phenomena which are rather difficult to alter. Hayes, Goodhew, Heit, and Gillian (2003) investigated 132 six-year old elementary school students' concept of the shape of the earth. Instruction focused on the shape of the earth and the role of gravity. The *Control* condition received instruction challenging one of their beliefs while the experimental conditions received instruction challenging two of their beliefs. Hayes, et al., found students in both control and experimental conditions increasing their declarative knowledge, however, students receiving instruction challenging more beliefs were displaying higher rate of holding the concept of a spherical shaped earth.

The extent to which a concept or idea is entrenched is directly dependent upon how many beliefs concerning the idea or concept that individual has deeply embedded into their existing system of beliefs (Chinn & Brewer, 1993). A multitude of reasons for which beliefs become entrenched exist. For instance, the person holding the belief may have gathered support for it throughout their life, the belief explains other phenomena or events in addition to the concept or idea in question, or the reason can be as simple as the belief fulfills one or more robust goals for the individual. The attempt to change an individual's conceptions becomes increasingly difficult when the individual holding the concepts can offer rational explanations of why they hold their current beliefs pertinent to those concepts. For whatever reason, beliefs are directly involved in an individual's misconceptions and their reluctance to relinquish them. Anderson, Lepper, and Ross (1980) found individuals to be highly resistant to belief change even when confronted with strong contradictory empirical data and with only an inadequate empirical basis.

Although characteristics of the individual are salient factors when discussing learning and changing knowledge and beliefs, other mediating variables need to be taken into consideration (Alexander & Murphy, 1998). When an individual is learning from text an interaction between the learner and the text is occurring (Chambliss & Garner, 1996). This interaction, which may lead to knowledge or belief change may be facilitated or hindered by characteristics of the text. These characteristics, such as genre, structure, content, and the way(s) the text will interact with the learner are all factors affecting learning and conceptual change. In the next section these characteristics are examined.

Text processing. Text processing is an effortful, ongoing process on the part of the reader; however, effort is not the only variable to consider during the course of this event moreover the reader is not the only source from which factors of this process should be taken into account. For an individual to process information from within a text an interaction of their characteristics (i.e., knowledge and/or beliefs) and the characteristics of the text (i.e., genre, structure, and/or content) occurs (Alexander & Murphy, 1998; Kardash & Scholes, 1995). This interaction determines in part how well the learner will process the text. In the following section, types of text and text processing will be explored further.

- Prior knowledge in probability often obstructs the acquisition of new knowledge in that domain and many times that prior knowledge is inaccurate.

Text

Text is all around us and every form of it has a common thread. Texts are a method of conveying information to and between people. The information could be factual or fictional it could be for entertainment or for the purposes of saving someone's life. Whatever the reason, various forms of text have a common purpose, which is communication or expressing information. Although information is able to be conveyed through conversation, video or audio recordings, and various other sources, text is one mode of conveying information that is stationary, maintaining its original form, therefore allowing the receiver the opportunity to reexamine it as she sees fit in an effort to find truth (Chambliss & Garner, 1996). This is where an interaction between text and beliefs occurs. The beliefs an individual holds prior to reading a text affect what information that person attends to and takes away from the text. Moreover, particular types of texts affect beliefs in varying ways. For instance, although adults are more likely to buttress their prereading beliefs with information in a text, a text presenting one side of an argument has been found to be much less effective in changing an individual's strongly-held beliefs than a two-sided text in which opposing arguments on a topic are presented to the reader (Chambliss & Garner, 1996). Whatever the form, if a person has the ability to obtain information from various forms of text independent, lifelong learning is likely to occur (Diakidoy, 1999).

In light of the aforementioned research it is somewhat evident that attaining any level of success in changing an individual's conceptions is a challenging process. Text characteristics have been found to facilitate the conceptual change process. Following are the text characteristics which are most pertinent to the current study. These characteristics are (a) genre, (b) structure, and (c) content.

Genre. The genre of a text sets the tone for how the information in that text will be conveyed. Genres are partially determined by what the writer is trying to communicate to the reader. For instance, a narrative genre is not usually used for writing about the law of large numbers or energy and matter. Most often an expository genre is utilized in writing about probability or science information.

Three varieties of genres have been established and examined in the literature. The three types of genres cited in the literacy literature are narrative, expository, and mixed. A text utilizing a narrative genre is one in which the writer is attempting to tell a story and usually does so using consistent key elements (DuBravac & Dalle, 2002). These key elements (e.g., characters, setting, plot, and climax) are classically recognized in fairy tales. For example, Cinderella (character) who lived a difficult life with a stepmother and stepsisters (setting), was not allowed by those family members to go to the Prince's ball (plot), danced with the Prince at the ball and consequently they fell in love (climax) and finally proceeded to the ending in which they lived happily ever after. Frequently, the narrative genre is the genre in which individuals are most familiar with as children (Diakidoy, Stylianou, Karefillidou, & Papageorgiou, 2005). Whereas elementary school students find this text format helpful to the point of being necessary in achieving success while processing information, secondary school students no longer need this text genre for comprehension (Guzzetti, et al., 1993). While the familiarity of the genre aids elementary school students in text comprehension, the secondary school students have moved beyond requiring this assistance. The narrative text genre is also commonly recognized as the most popular for leisure-reading.

An expository genre is most often utilized when the writer is attempting to convey information to readers in a more objective or educational way. Sub-groups of the expository-type texts have been generated by multiple researchers (Anderson & Armbruster, 1984; Meyer, et al., 2002). Following a meta-analysis of instructional interventions commonly found in reading and science education Guzzetti et al. (1993) found that the majority of the studies included reflected expository texts. The typical structure of an expository genre consists of a main idea and supporting information. An example of this type of genre would be the typical science textbook used in high school chemistry or biology classrooms. Additional examples are the average newspaper or instruction booklet. Expository texts are sometimes thought of as more difficult for readers to process than a narrative text since the information contained within is usually further removed from everyday life, creating more of a challenge for readers to make inferences increasing comprehension (DuBravac & Dalle, 2002). The relations featured in expository texts are often times more abstract in nature which also serves to increase the difficulty of the text for readers (Stein & Trabasso, 1981).

A text in which a blend of both the narrative and expository genres are featured together is the mixed genre. This is a common type of text genre (Meyer & Poon, 2001) which can be found in a biographical excerpt or text in which personal information of an individual or individuals is embedded into an expository text (Alexander & Jetton, 1996). Quite often a history textbook is structured in this fashion. While information concerning a war or some type of historical event is featured, information pertaining to the people involved in the particular event is also offered to the reader.

Structure. Text structure represents the organization of a text revealing the logical connections throughout. When a text is well-structured, comprehending and recalling its contents are facilitated (Pearson & Dole, 1987). A well-structured text is one in which the organization inherently makes sense to the reader enough so that the reader does not become confused while reading regarding the order or purpose of the text. A well-structured text can enhance the generation of a well-structured mental representation (Williams, Hall, & Lauer, 2004). This likely and beneficial outcome of a well-structured text has implications for learning given an individual's understanding and recall of information is expedited and more successful when the relevant knowledge is held in a well-structured mental representation. A well-structured text also retains the innate benefit of requiring less prior knowledge of the reader. The reading comprehension skill of the individual reading the text is more heavily relied upon when the content of the text is well-organized and sufficiently explained. This allows those people not having had prior experiences with the content the opportunity to read and on some level comprehend the information within the text. In regards to text structure and arguments presented in text, Voss and Silfies (1996) investigated the interaction of both prior knowledge and comprehension skill with text structure. Findings suggest that when reading from a text with causal relations featured along with the argument participants' learning was related to comprehension skill and while reading from a text not including explicit causal relations with the argument participants' learning was related to prior knowledge.

Text structure impacts the amount and type of information a reader absorbs and retains from reading a text. Diakidoy, Kendeou, and Ioannides (2003) investigated sixth-grade students' responses to an expository text and a refutational text both written about the concept of energy. Both texts were integrated into regular classroom instruction. While the expository text presented factual information concerning energy the refutational text presented two common notions and ultimately refuted one of them. Diakidoy and colleagues found the refutational text superior to the expository text in facilitating scientific learning and conceptual change.

Content. As previously mentioned, characteristics of the text and characteristics of the learner interact during the reading process and this interaction subsequently affects how well and to what extent the text is processed. The content of the text is one of the text characteristics which are involved in the interaction (Alexander & Jetton, 1996; Chambliss & Garner, 1996). The content contained within a text interacts with the reader's knowledge and beliefs affecting the extent to which the reader puts forth effort for processing, moreover when a reader lacks knowledge from the domain in which the text is written about it is improbable that she will have the interest or even the ability to process the text in an sufficient enough manner for comprehension to occur (Alexander & Jetton, 1996). If the content of the text is more relevant to the reader elaboration, processing, and recall (Petty & Cacioppo, 1986) are more likely to occur. While investigating college students' knowledge of and interest in a text Alexander, Jetton, & Kulikowich (1995) found comprehension of a technical physics text was significantly predicted by those two constructs. The content of a text has been found to interact with readers on an individual and significant basis.

Although relevance of the content to the reader is an important characteristic of the text another equally salient characteristic is its level of interestingness. Kardash and Scholes (1995) presented 61 undergraduate students enrolled in educational psychology courses with a text on the transmission of AIDS. Their findings suggest that when participants reading the text rated the content as "very interesting" their beliefs were more likely to align with that of the information contained in the text after reading it. Furthermore, results indicate a person's beliefs prior to reading a text on a controversial topic will determine what they recall from that text concerning the controversial topic, but not the encoding of information related to those beliefs.

One of the goals of education is to alter students' pre-existing, incorrect knowledge to align with what is commonly accepted as true and correct. Often times, students enter into elementary school as young children, or even into college classes as adults with misconceptions (Shaughnessy, 1977). These can potentially cause a barrier for further learning to occur. Unfortunately, what is known about potential mechanisms for detecting and resolving individuals' misconceptions is inadequate. What researchers now realize is that changing an individual's misconceptions has proved to be a daunting and frequently time consuming task (Vosniadou & Brewer, 1994). These misconceptions are often deep-seated and encouraged by the subjective views of the learner (Jones, et al., 1999). It is obvious that individuals must perceive the need to change their conceptions. That is, conceptual change requires intentionality on the part of the learner (Murphy & Mason, 2006; Sinatra, Southerland, McConaughy, & Demastes, 2003). If learners do not realize they hold misconceptions, attending to them with the required effort to alter the misconceptions to align with correct information is not likely to occur.

Intention may not be the only element necessary for conceptual change to occur (Alexander, Murphy, Guan, & Murphy, 1998). Changing an individual's misconceptions may also be more likely to take place when the concept that is not correctly comprehended falls within a common area shared by knowledge and beliefs. By picturing knowledge and beliefs as a Venn diagram a portion of the two constructs overlap. It is potentially in this area that a learner holds a concept as conceivable as well as valuable which may be a conducive combination for the conceptual change process to transpire. Whether the misconception is considered knowledge or a belief restructuring a person's knowledge network to alter a misconception is a task in which levels of restructuring can occur (Vosniadou & Brewer, 1987).

- What is known about potential mechanisms for detecting and resolving individuals' misconceptions is inadequate.

Argument

Conceptual change and persuasion processes share philosophical and psychological roots (Dole and Sinatra, 1998; Murphy, 1998). Persuasion and conceptual change both focus on a person's knowledge, beliefs, and the change process. From the teachings of Aristotle more than 2,000 years ago conceptual change researchers have learned that argument is a significant aspect of persuading a person and the proof of the argument is the feature most responsible for that process (Cooper, 1932). Aristotle went on to testify to the power of argument in education and the process of learning. To this day, argument remains a prominent feature in the conceptual change literature (Chinn & Brewer, 1993; Kardash & Scholes, 1995). Aristotle believed that there are times in which people cannot be convinced of scientific arguments, even with the most accurate scientific data in hand. This is when the opportunity for providing proof of arguments is ripe. Argumentation is a device to be used time and again. Once the knowledge of argumentation and its uses are gained it becomes a tool in which the owner utilizes to view and consider multiple perspectives and to counter prejudiced arguments.

Engaging in argument has been purported as a means of promoting conceptual change in students (Dole & Sinatra, 1998). Investigation of 160 undergraduates enrolled in a general chemistry course provided data suggesting argumentation of scientific heuristic principles facilitate students' understanding of experiments (Niaz, Aguilera, Maza, & Liendo, 2002). The experimental conditions which participated in argumentation and discussions of alternative responses to six items and issues most salient in the experiments they had studied, but not conducted themselves showed considerable conceptual change three weeks and even six weeks after the intervention as compared to the control condition. Niaz and colleagues (2002) suggested providing students in science classrooms and laboratories with the history and philosophy of science experiments and the opportunity to discuss and reflect up on them rather than simply a collection of facts to facilitate comprehension and conceptual change to scientifically accepted concepts.

Nussbaum and Sinatra (2003) found similar results while examining individuals' concepts in physics. Forty-one undergraduate students enrolled in educational psychology courses and considered to be naive in physics were asked to argue a physics topic. Specifically, students demonstrating a misconception regarding the path of a falling object were asked to argue an alternative path. At this point in the investigation the participants were unaware that they were arguing for the scientifically accepted explanation. Nussbaum and Sinatra (2003) found those participants engaging in argumentation concerning this particular scientific topic displayed a more thorough and improved level of understanding of the concept. They purport the reason for this is found in the nature of argumentation. Argumentation forces a person to consider both sides of an issue, explain any existing anomalies in their existing conception, and finally, to come into contact with any inconsistencies between their conception and the alternative. These are all methods recognized by successful interventions as ways of attaining conceptual change in learners.

Toulmin (1964) suggested that arguments are fashioned after a three-part structure. This first part is a claim in which a statement is made in the effort to activate the reader's beliefs on the topic. The second portion of this structure is comprised of the pertinent evidence or examples which has the sole responsibility of supporting the claim. The last component of Toulmin's structure is the warrant which has the purpose of linking the claim to the evidence. This portion is highly important and often determines the success or failure of the argument. Chambliss (1995) used Toulimn's three-part argument structure in a study with advanced, high school English students considered to be skilled readers. She found the students were much more easily able to locate the claim and evidence of the argument, which are the first two parts, but when it came to the warrant students were clearly less familiar with this aspect and experienced a difficult time in locating it.

Arguments could conceivably take one of two formats (Slusher & Anderson, 1996). The first, in which an explanation regarding the relationship represented within a theory is not given, is a noncausal argument. These arguments serve the purpose of citing the truthfulness of the relationship represented within a theory. Noncausal arguments or noncausal evidence tends to fail at changing conceptions and beliefs (Slusher & Anderson, 1996). Noncausal arguments in a text have also been found to interact with beliefs. The extent to which an individual's beliefs align with information contained within the text positively correlates with the amount of noncausal information they are able to recall after reading the text (Kardash & Scholes, 1995). A second type of argument is a causal argument. This type of argument presents information concerning the mechanism responsible for the relationship represented within a theory. A causal argument serves the purpose of explaining the truthfulness of the relationship represented within a theory.

Whereas causal arguments have been referred to as *strong arguments*, noncausal arguments have been recognized as *weak arguments* (Kardash & Scholes, 1995; Petty & Cacioppo, 1986). Causal texts have been found more effective than noncausal arguments in changing beliefs and less vulnerable to evaluation bias (1996). The term *causal text* is essentially the same as what Chinn and Brewer (1993) refer to as refutational texts.

Message sidedness is another aspect in the structure of an argument. Three types of message sidedness have received the most attention in the literature (Allen et al., 1990). A one-sided message is the most simplistic form in which only arguments supporting the position the source is advocating are presented to the reader. This type of message, however, has been found to be better able to facilitate conceptual change than a two-sided nonrefutational message. A two-sided nonrefutational message presents arguments that both contest and buttress the position being advocated by the source. Two-sided refutational texts are the type of message found to be most persuasive in changing the reader’s conceptions and as mechanisms for promoting cognitive dissonance and confronting misconceptions (Allen et al., 1990; Guzzetti, Snyder, Glass, & Gamas, 1993; Kardash & Scholes, 1995). These texts are also viewed as more credible than other types of messages (Murphy, 1998). Chambliss and Garner (1996) concur with this finding with their research suggesting individuals initial beliefs become more polarized after reading a text that presented both sides of an argument.

In considering the use of text for the purposes of conceptual change, the most effective argument structure, in part, depends on the individual reading the text. Buehl, Alexander, Murphy, & Sperl (2001) investigated 93 undergraduate students enrolled in human development courses. Various responses from undergraduate students to naturally occurring (i.e., major newspaper and news magazine) one-sided and two-sided nonrefutational texts were documented. These responses appear to rely on beliefs, knowledge, and interest of the reader. Results suggest the readers who began the study sharing the position represented in the text appeared to have reinforced or maintained their views after reading the one-sided text. The one-sided text was also found more effective in changing students' beliefs than the two-sided nonrefutational text. Those participants who began the study undecided on the issue represented in the text had their position reinforced after reading the two-sided nonrefutational text. The two-sided nonrefutational text was found more effective in altering students' knowledge than the one-sided text. These differences in changing individuals' conceptions based on prior knowledge and beliefs are not an uncorroborated finding. Individual differences have been repeatedly cited as having an effect on the conceptual change process. For example, Johnson (1994) found it somewhat easier to change an individual's conceptions when that person holds a small amount of knowledge on the subject and Wood and Kallgren (1988) found when individuals stimulate beliefs relevant to the subject the change process was facilitated.

- Although two-sided refutational texts are the type of message found to be most persuasive in changing the reader's conceptions and as mechanisms for promoting cognitive dissonance and confronting misconceptions this type of text has not been utilized in altering misconceptions in probabilistic reasoning.

Issues for Further Research

Based on this review of research in the areas of education, philosophy, cognitive psychology, and social psychology it is apparent that future empirical investigations are required to address what appear to be limitations in the current literature. Specifically, this proposed study investigates the viability of mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. Although an abundance of research examining common misconceptions in probabilistic reasoning exists, a small number of those studies have empirically explored interventions for the purposes of altering those misconceptions. Furthermore, none of the investigations reviewed for this study utilize text as an instructional intervention for altering students understanding of probability topics such as representativeness. Another oversight of the current literature is concerning need for cognition. Students' need for cognition has not been measured in the studies reviewed; leaving the researcher unsure if an intervention was the cause of any change or students' individual traits. As a result, the current study is designed to address the aforementioned limitations of the current literature.

CHAPTER 3

METHODOLOGY

The purpose of this research is to investigate the viability of mechanisms for altering students' use of the representativeness heuristic when reasoning about uncertain events. This study is comprised of two experiments. Each experiment is a preintervention, postintervention design. Experiment 1 employed one control condition and two experimental conditions in which participants were randomly assigned to one of two treatments. Because of the potential confound due to time between the measurement of probabilistic reasoning in Experiment 1, a second experiment was conducted in which a non-treatment comparison was utilized. Experiment 2 employed one non-treatment comparison group and two experimental conditions in which participants were again randomly assigned to one of two treatments. This section describes the sample, instruments and procedures utilized as well as a summary of data analyses for Experiment 1 and Experiment 2.

Experiment 1

Participants

Participants for Experiment 1 included one graduate and 195 undergraduate students (26 male and 169 female) enrolled in an introductory educational psychology course at a large land-grant university located in Northeastern United States. All students received extra credit for their participation in the study and participation was completely voluntary. A majority of respondents were female (86.7%) and Caucasian (92.3%) and represented a variety of majors within the larger university. Participants also represented various academic levels including first year (1.5%), sophomore (87.7%), junior (9.2%), senior (1%), and graduate students (.5%).

Instruments

Demographic Sheet. (see Appendix A) Students began by providing general information regarding gender, program and year of study, as well as the number of statistics courses they were currently enrolled in and names of specific statistics courses in which they were previously enrolled. Students also provided their level of confidence about their ability in statistics and in probability on two 10-point Likert-type scales ranging from *Low* (1) to *High* (10).

Need for Cognition. (see Appendix B) Need for cognition is a personal characteristic that makes individuals more or less likely to have the desire to take pleasure from engaging in the type of tasks requiring cognitive effort (Cacioppo, Petty & Kao, 1984). The *Short Need for Cognition Scale* (Cacioppo, Petty & Kao, 1984) is an 18-item Likert-type scale adapted from the original version created and validated by Cacioppo and Petty (1982). This scale was created in an effort to provide a more efficient instrument than the longer, original version. Specifically, the 34 items from the longer version were ranked according to their absolute value of their factor loadings in the experiment in which the scale was originally created. Chronbach's alpha was then calculated when each individual item was added. Following this step, a Scree plot was employed to establish which items would be utilized in the short version of the scale. The total number of items on the short version of the scale is brought to a close at 18 when Chronbach's alpha declined by adding the 19th item. Researchers then administered the *Need for Cognition Scale* and the *Short Need for Cognition Scale* to 527 students at the start of a semester to correlate the scores each individual received on each scale finding a high correlation between the two versions of the scale. Data suggest the 18-item S*hort Need for Cognition Scale* is efficient and reliable with a reported Chronbach's alpha coefficient of .90 as compared to .91 for the 34-item version (Cacioppo, Petty & Kao, 1984).

Participants in this study were instructed to "…please indicate whether or not the statement is characteristic of you or what you believe." The scale ranges from *extremely* *uncharacteristic of me* (1) to *extremely characteristic of me* (5) making the minimum possible score 18 and the maximum possible score 90. As was the case with the original instrument, several items were reverse-coded so that the higher number represented a high need for cognition. In this study, the instrument was administered after the demographic sheet and prior to any other instruments, texts, or tasks. The *Need for Cognition Scale* has typically been administered prior to any dependent measures when employed by Cacioppo and Petty (1982). The following is a sample item which was used in the present study.

> I would prefer a task that is intellectual, difficult, and important to me to one that is somewhat important but does not require much thought.

Understandings of Representativeness. Adapted versions of this instrument were administered at preintervention, immediate postintervention and delayed postintervention. Students' knowledge of representativeness was assessed via this 12-item, two part, multiple-choice instrument which was an adapted version of the original 20-item instrument created and validated by Hirsch and O'Donnell (2001), *A Test of Representativeness*. Prior to employing the instrument created by Hirsch and O'Donnell in this experiment the researcher piloted it several times.

The first pilot was conducted with 49 students enrolled in introductory educational psychology courses. Either the researcher or another graduate student recruited participants in the on-campus classrooms during the regularly scheduled class times. Participants were recruited by the researcher or another graduate student, using the recruiting script (see Appendix C) pre-approved by the on-campus Office of Research Protections.

The original items created by Hirsch and O'Donnell (2001) were used, but those items were split into a parallel preintervention instrument (see Appendix D) and immediate postintervention instrument (see Appendix E) version. The preintervention instrument was employed as the delayed postintervention instrument. Each version featured 10 items. Three of these items were short answer format and seven of the items were two-part, multiple-choice format. The delayed postintervention was administered two and a half weeks following the data collection. On the preintervention instrument, participants were first directed to respond to three short-answer items pertaining to tossing a fair coin just as in the original instrument (Hirsch and O'Donnell, 2001). Sample items appear below.

> What is the chance that the first toss of a fair coin results in a head?
>
> The first toss of the coin does result in a head, and the coin is tossed a second time. What is the chance that the second toss results in a head?

Next, participants were directed to circle the best answer from the options provided for seven two-part multiple-choice items just as in the original instrument. The first part of each item assesses participants understanding of probability and the existence of the representativeness heuristic. The second part of each item allows participants to provide their justification for which option they chose in the first part of the item. A two-part sample item appears below with an * following the correct answer.

> A fair coin is tossed, and it lands heads up. The coin is tossed a second time. What is the probability that the second toss is also a head?
>
> a. 1/4
> b. 1/2 *
> c. 1/3
> d. Slightly less than ½
> e. Slightly more than ½

Which of the following best describes the reason for your answer to the preceding question?

f. The second toss is less likely to be heads because the first toss was heads.
g. There are four possible outcomes when you toss a coin twice. Getting two heads is only one of them.
h. The chance of getting heads or tails on any one toss is always ½. *
i. There are three possible outcomes when you toss a coin twice. Getting two heads is only one of them.
j. Other____

Students' knowledge of representativeness was assessed again via a delayed postintervention which was parallel to the preintervention instrument already administered. On this instrument participants were first directed to respond to three short-answer items pertaining to rolling a fair die just as in the original instrument created and validated by Hirsch and O'Donnell (2001). Sample items appear below.

What is the chance that the first roll of a fair die results in a 6?

The first roll of the die does result in a 6, and the die is rolled a second time. What is the chance that the second roll results in a 6?

Following the short answer items participants were directed to choose the best answer from the options provided for seven two-part multiple-choice items just as in the original instrument. The first part of each item assesses participants understanding of probability and the existence of the representativeness heuristic. The second part of each item allows participants to provide their justification for which option they chose in the first part of the item. A two-part sample item appears below with an * following the correct answer.

If a fair coin is tossed four times, which of the following ordered sequences of heads (H) and tails (T), if any, is MOST LIKELY to occur?

a. H T H T

b. H H T H

c. T H H T

d. H H H H

e. All sequences are equally likely. *

Which of the following best describes the reason for your answer to the preceding question?

f. Since tossing a coin is random, you should not get a long string of head or tails.

g. There ought to be roughly the same number of tails as heads.

h. Since tossing a coin is random, the coin should not alternate between heads and tails.

i. Every sequence of four tosses has exactly the same probability of occurring. *

j. Other ______________________________________

The data from the first pilot study showed a need for adapting the representativeness instruments. The participants' scores from the pilot showed less variability than necessary. The items appeared to be too easy for participants. One issue that may have been at play was the content of the multiple-choice items featured on the instruments. Aside from two items which featured types of fruit or colored balls as the content the remainder of the items featured either dice or coins. Further, all but two of the items featuring the dice or coins asked participants to guess which sequence was most or least likely after either rolling a die or tossing a coin. The items differed simply by featuring a longer or shorter sequence of events, whether those events be tossing a coin or rolling a die. Neither the content nor the task varying much from item to item may have been too easy for these participants. Following analyses of these data the researcher adapted the representativeness instruments and conducted a second pilot study. Specifically, four items were added to the instruments assessing students' understanding of representativeness using objects with multiple surface features. For instance, different types of watches were used in one item. A sample two-part item appears below with an * next to the correct answer.

> A box has 12 watches: 4 men's, 4 women's, and 4 children's. Seven watches are picked, one at a time. Each time a watch is picked, the type of watch is recorded, and it is then put back in the box. If the first 6 watches were men's, what is the seventh watch MOST LIKELY to be?
>
> a. A men's
> b. A women's
> c. A children's
> d. A women's or a children's are both equally likely and more likely than a men's.
> e. A men's, women's, or children's are all equally likely. *

Which of the following best describes the reason for your answer to the preceding question?

f. This watch is just as likely as any other.

g. The men's seem to be lucky.

h. The picks are independent, so each watch has an equally likely chance of being picked. *

i. The seventh watch will not be a men's because too many have already been picked.

j. Other ___________________________________

The second pilot study was carried out using 7 students enrolled in an advanced doctoral seminar on advanced measurement and design in cognitive and educational psychology. The primary purpose of this pilot was to assess the validity of the representativeness instruments. Following this administration, the instruments were altered once more. Specifically, the short answer items were dropped resulting in the three final versions of the *Understandings of Representativeness* instruments consisting of 12 two-part, multiple choice items. These versions were Form A (see Appendix F) Form B (see Appendix G) and the delayed postintervention (see Appendix H). Form A has a Chronbach's alpha coefficient of .81. Form B has a Chronbach's alpha coefficient of .84. The delayed postintervention has a Chronbach's alpha coefficient of .86. Forms A and B were counterbalanced so that half of the participants received Form A as their preintervention instrument while the other half of the participants received Form B as their preintervention instrument. This was the same for the immediate postintervention. Half of the participants received Form A as the immediate postintervention while the other half of the students received Form B as the immediate postintervention. The delayed postintervention was generated using an equal number of items from Form A and Form B. Specifically, a table of specifications was created in which items were grouped by type (most likely, least likely), format (next, sequence), complexity (complex, simple) and item difficulty for each item on both forms and the delayed postintervention featured a variety of items and a similar item difficulty as Forms A and B. The first part of each of the items on all three varieties of the instrument assesses participants understanding of representativeness and the second part allows participants to provide a justification for the answer they chose in the first part of the item.

On the *Understandings of Representativeness* instruments, participants were directed to circle the best answer from the options provided for the 12 two-part, multiple-choice items just as in the original instrument created by Hirsch and O'Donnell. A two-part sample item from each version of the instrument appears below with an * following the correct answer.

Form A:

A hospital employs 20 nurses: 15 females and 5 males. Every hour a computerized system randomly assigns one of the nurses to take an inventory of the medicines dispensed during the hour. Each time the computer records only the gender of the nurse assigned. Which of the following ordered sequence of nurse genders, if any, is LEAST LIKELY to occur?

a. F F F F F
b. M M M M M *
c. F M F M F
d. M F F M F
e. All of the above sequences are equally likely.

Which of the following best describes the reason for your answer to the preceding question?

f. Since picking nurses is a random event, a result like that is very unlikely.
g. You are much more likely to get a mixture of different nurses than an ordered sequence.
h. All sequences of nurses have exactly the same probability of occurring.
i. There are more females to choose from in the hospital. *
j. Other ____

Form B:

A box contains 9 balls: 3 are red, 3 are white, and 3 are blue. Six balls are picked at random, one at a time. Each time a ball is picked, the color is recorded, and the ball is put back in the box. If the first 5 balls are red, what color is the sixth ball MOST LIKELY to be?

a. Red
b. White
c. Blue
d. Blue and white are equally likely and more likely than red.
e. Red, blue, and white are all equally likely. *

Which of the following best describes the reason for your answer to the preceding question?

f. The fourth ball should not be red because too many red ones have already been picked.
g. Every color has an equally likely chance of being picked. *
h. Red seems to be lucky.
i. This color might be just as likely as any other color.
j. Other ______________________________________

Delayed Postintervention:

A box contains 20 writing utensils: 5 pens and 15 pencils. Eight of the writing utensils are picked, at random, one at a time. Each time a writing utensil is picked, the type is recorded and the writing utensil is put back in the box. If the first 6 types of writing utensils are pencils, what type, if any, are the next two writing utensils MOST LIKELY to be?

a. Pen Pencil
b. Pen Pen
c. Pencil Pen
d. Pencil Pencil
e. All of the above writing utensils are equally likely.

Which of the following best describes the reason for your answer to the preceding question?

f. There are more pencils to choose from in the box.

g. The next writing utensils should not be pencils because too many pencils have already been chosen.

h. Every writing utensil has an equally likely chance of being picked.

i. These writing utensils are just as likely as any other writing utensils.

j. Other ______________________________________

The *Understandings of Representativeness* instrument includes 12 two-part, multiple-choice items. Each item as a whole is worth one point. To generate participants' scores dichotomous raw scores were generated for each item on the instruments. Participants received a score of 1 for each item answered correctly and a score of 0 for each item answered incorrectly. Next, composite scores were generated for the item pairs as a whole. This was done by creating a variable in SPSS which represented the two-part item as one item. Since it is possible that participants could have guessed on the first part of the item and have gotten it correct, the justification they provided for each item also had to be correct. This diminishes the 25% chance of guessing correctly on each item, thereby measurement error. The raw, dichotomous scores for item pairs were added together to generate one score per item pair. For instance, if a participant answered item number 7 correctly and item number 7a correctly that participant would have a score of 2 for item number 7, however, if a participant answered item number 7 incorrectly and item number 7a correctly their score for item number 7 as a whole would be a one. What this means is that a participant would receive a score of 2 on an item if both parts of the item were answered correctly. If only one part of an item was answered correctly the participant would receive a score of 1 for that item and if neither of the parts was answered correctly the participant received a 0 for that particular item. The next step in generating composite scores was to recode those scores into dichotomous scores once again. So, for any item that a participant had received a score of 0 or 1 for in the last step their score for that particular item would now be recoded to a 0. For any item that a participant had received a score of 2 for in the last step their score for that particular item would now be recoded to a score of 1. Having carried out these three steps makes it so that participants can only receive a score of 1 on each item if both parts of the item were answered correctly. This step makes the lowest possible score on each representativeness instrument a 0 and the highest possible score a 12.

Topic Knowledge. (see Appendix I) Declarative knowledge of probability was measured via a 10-item multiple-choice instrument used in a previous investigation (Zeruth, Kulikowich & Murphy, 2006). Prior to its initial use, the *Topic Knowledge* instrument was piloted with students enrolled in a doctoral seminar on advanced measurement and design in cognitive and educational psychology. The prerequisite for joining the class was a statistics sequence including intermediate statistics, analysis of variance, regression, and multivariate classes. This insured familiarity for all participants in the pilot test with the concepts and procedures. After completing the instrument, students were asked to make notes regarding face and concept validity. As a result of pilot testing, changes were made in the wording of several items. This declarative knowledge instrument is designed to tap students' understanding of basic terms (e.g., event) or concepts (e.g., "law of large numbers"). Correct responses were awarded 1 point, making the highest possible score on the knowledge instrument 20 points. The Chronbach's alpha reliability for the *Topic Knowledge* instrument was .30. Due to the low reliability of this instrument with these particular participants it was not included in the analyses. A sample item from the *Topic Knowledge* instrument appears below with an * following the correct answer.

A <u>sample space</u> is defined as:

a. a set where all outcomes of an experiment are represented as points. *

b. a proposition that has been proven.

c. a characteristic on which observable units differ.

d. a non-ordered, categorical or qualitative variable or classification.

Thinking about Probability. (see Appendix J) Past experiences thinking about or making decisions concerning outcomes of uncertain events were assessed via this 20-item questionnaire. These items were administered following the immediate postintervention. Participants were asked to "…fill in the corresponding circle below each item to indicate prior to today the extent to which you have experience with the concept or activity described in the statement." Following each item is a 10-point Likert-type scale for participants to indicate their degree of experience ranging from *not very experienced* (1) to *very experienced* (10) making the highest possible score on the instrument 200 points with higher scores indicating higher levels of experience. Sample items appear below.

Making decisions based on probability.

O-----O-----O-----O-----O-----O-----O-----O-----O-----O

not very experienced very experienced

Predicting the outcome of a sporting event.

O-----O-----O-----O-----O-----O-----O-----O-----O-----O

not very experienced very experienced

Interventions: Materials and Instruction

Anchored Scenarios. (see Appendix K) The goal of the *Anchored Scenarios* condition was to affect the participants' misconceptions in probability and replace those misconceptions with accurate knowledge by utilizing anchored scenarios aimed specifically at the representativenes heuristic. The way this has been done previously has been to utilize Fast's *What Do You Think The Chances Are?* instrument (1997). Through piloting, Fast revised the instrument six times to create a seventh edition. The intervention employed in this study is an adapted, two-part version of the original, two-part, 20-item, seventh edition version created and validated by Fast. Specifically, those items evaluating use of the availability heuristic were discarded and only the items assessing the representativeness heuristic are employed, thereby generating a two-part, 14-item instrument. Participants were instructed to circle the best answer for each question from the options provided making the highest possible score on the multiple-choice portion of the instrument 14 points. Following each item is a Likert-type confidence scale so participants could indicate their degree of confidence in the responses they provide to the multiple-choice items. This confidence scale ranges from *just a guess* (0) to *I'm sure I'm right* (3) making the highest possible score on the confidence scale portion of the instrument 42 points with higher scores indicating higher confidence ratings. A sample item appears below with an * following the correct answer.

A fair coin is tossed 5 times and the result is HHHHH. On the next toss, which outcome, if either, do you think has a better chance of occurring, H or T? (H=Heads, T=Tails).

a) H has a better chance of occurring.

b) T has a better chance of occurring

c) They both have the same chance of occurring.

Why?

I____________________I____________________I____________________I

just a guess   not very confident   fairly confident   I'm sure I'm right

Refutational text. (see Appendix L) Participants in the *Text* condition read a well-structured, two-sided, low-affect, refutational text focused on the representativeness heuristic.

This is a two and a quarter-page, single-spaced text, consisting of 78 sentences and 1,542 words, aligned with Fast’s (1997) anchored scenarios. It has a Flesch-Kincaid grade level of 11.9. Specifically, the text contains 11 total paragraphs including 1 introduction paragraph, 7 paragraphs citing information for using probability when making decisions and 3 paragraphs citing information against the use of probability during the decision-making process. The text was created using 3 examples employed in Fast’s (1997) *What Do You Think The Chances Are?* instrument. Those examples are birth order, coin tosses, and series of playoff games, which are common scenarios found in probability research (e.g. Fast, 1997; Hirsch & O’Donnell, 2001). The text is well-structured to facilitate comprehension and recall (Pearson & Dole, 1987), and is written as a two-sided refutational text to align with the literature citing its effectiveness in creating conceptual change (Diakidoy, Kendeou, & Ioannides, 2003).

Procedures

Participants for Experiment 1 were recruited from both sections of the Educational Psychology 014 class in the fall, 2007 semester. Recruiting took place in the on-campus classrooms at regularly scheduled class times. The researcher used a script pre-approved by the on-campus Office of Research Protections (Appendix M) to recruit participants and inform them of scheduled data collection sessions that they were able to attend.

Upon arrival to the data collection sessions, participants were randomly assigned to one of the three conditions within the same room. This was done by alternating the *Control*, *Anchored Scenarios* and *Text* pre-assembled packets to participants when they arrived, assuring approximately equal distributions of participants into each of the treatment conditions. The *Control* group was capped at 31 participants, the *Anchored Scenarios* condition included 84 participants, and the *Text* condition included 80 participants. An assortment of materials was administered to each participant in the study. Table 1 illustrates how materials were specifically administered to each of the three groups.

Table 1

Administration of Materials in Experiment 1

		Control	Anchored scenarios	Text
Preintervention assessments		Implied consent form	Implied consent form	Implied consent form
		Demographic sheet	Demographic sheet	Demographic sheet
		Need for cognition	Need for cognition	Need for cognition
	Counterbalanced	Topic knowledge	Topic knowledge	Topic knowledge
	Counterbalanced	Preintervention	Preintervention	Preintervention
			WDYTTCA	Text
Postintervention assessments	Counterbalanced	Immediate postintervention	Immediate postintervention	Immediate postintervention
		Thinking about probability	Thinking about probability	Thinking about probability
		Delayed postintervention	Delayed postintervention	Delayed postintervention

The materials were combined in packets with identification numbers on the outside of the packets and each participant, regardless of condition, received one packet containing the following materials: an implied consent for social science research form (see Appendix N), a demographic sheet, the *Need for Cognition Scale*, preintervention instrument, *Topic Knowledge* instrument, postintervention and the *Thinking about Probability* instrument. The preintervention instrument and the *Topic Knowledge* instrument were counterbalanced in each packet. The preintervention and postintervention were also counterbalanced in each packet. The delayed postintervention features items taken from the preintervention and immediate postintervention. This assessment was given at a later point in time and will be discussed in more detail below.

Those participants in the experimental conditions also received instructional materials. The participants in the *Anchored Scenarios* condition also received the adapted version of Fast's (1997) WDYTTCA instrument. In addition to the materials the *Control* condition received, the *Text* condition also received the two-sided, refutational text.

Fourteen to 21 days after the immediate postintervention was administered a delayed postintervention was given to the participants. In an effort to maintain a low attrition rate from participants the delayed postintervention was administered at the end of the regularly scheduled classes from which they were recruited. I emailed a copy of the delayed postintervention to any participant not attending class that day with a request that they complete it and either email it back to me or deliver it to my on-campus mailbox to further avoid a high attrition rate.

Experiment 2

Participants

Participants for Experiment 2 included 3 graduate and 192 undergraduate students (43 male and 152 female) enrolled in two introductory educational psychology courses at a large land-grant university located in Northeastern United States. All students received extra credit for their participation in the study and participation was completely voluntary. A majority of respondents were female (77.9%) and Caucasian (88.7%) and represented a variety of majors within the larger university. Participants also represented various academic levels including first year (28.2%), sophomore (52.8%), junior (10.3%), senior (7.2%), and graduate students (1.5%).

Instruments

The same instruments employed in Experiment 1 were utilized in Experiment 2 without any changes or modifications made to them.

Interventions: Materials and Instruction

The same interventions in Experiment 1 were utilized in Experiment 2 with two exceptions. A control group was not employed in this experiment. In place of the *Control* condition, a text was administered to a *Non-Treatment Comparison* condition and intervening tasks were employed prior to and following the interventions in each of the conditions in Experiment 2. These intervening tasks were utilized in Experiment 2 in an effort to create a comparable time for the *Non-Treatment Comparison* condition between preintervention and postintervention instruments as compared to the two experimental conditions.

Text. Participants in the *Non-Treatment Comparison* condition read a text (see Appendix O) on using discussion to promote achievement in the classroom. This is a two and a quarter-page, single-spaced text containing 74 sentences and 1,513 words. It has a Flesch-Kincaid grade level of 11.6. Specifically, the text contains 14 paragraphs citing information for using shared learning in the form of discussions as pedagogy in the classroom.

Intervening tasks. The intervening tasks were a card rotation task and a paper folding task (Ekstrom, French, & Harman, 1976). The card rotation task was administered prior to the intervention. This task assesses individual's ability to see differences in figures. The paper folding task was administered following the intervention. This task assesses individual's ability to imagine a folded piece of paper having a hole punched through it and deciphering where those holes would be once the paper was unfolded. Each of the two intervening tasks featured directions and practice problems. For a participant to read the directions and complete the practice problems and two tasks took approximately 4 minutes for each task.

Procedures

As in Experiment 1, participants for Experiment 2 were recruited from both sections of the Educational Psychology 014 class and all three sections of the Educational Psychology 010 classes in the fall, 2007 semester. Participants were also recruited from the three sections Educational Psychology 010 in the spring, 2008 semester. Recruiting took place in the on-campus classrooms at regularly scheduled class times. The researcher used the same script used in Experiment 1 pre-approved by the on-campus Office of Research Protections to recruit participants and inform them of scheduled data collection sessions that they were able to attend.

Upon arrival to the data collection sessions, participants were randomly assigned to one of the three conditions within the same room. This was done by alternating the *Non-Treatment Comparison*, *Anchored Scenarios* and *Text* pre-assembled packets to participants when they arrived, assuring approximately equal distributions of participants into each of the treatment conditions. The *Non-Treatment Comparison* group was capped at 31 participants, the *Anchored Scenarios* condition included 81 participants, and the *Text* condition included 82 participants. An assortment of materials was administered to each participant in the study. Table 2 illustrates how materials were specifically administered to each of the three groups.

Table 2

Administration of Materials in Experiment 2

		Non-treatment comparison	Anchored scenarios	Text
Preintervention assessments		Implied consent form	Implied consent form	Implied consent form
		Demographic sheet	Demographic sheet	Demographic sheet
		Need for cognition	Need for cognition	Need for cognition
	Counterbalanced	Preintervention	Preintervention	Preintervention
		Topic knowledge	Topic knowledge	Topic knowledge
		Intervening task	Intervening task	Intervening task
		Text Intervening task	WDYTTCA Intervening task	Text Intervening task
Postintervention assessments	Counterbalanced	Immediate postintervention	Immediate postintervention	Immediate postintervention
		Thinking about probability	Thinking about probability	Thinking about probability
		Delayed postintervention	Delayed postintervention	Delayed postintervention

The materials were combined in packets with identification numbers on the outside of the packets and each participant, regardless of condition, received one packet containing the following materials: an implied consent for social science research form, a demographic sheet, the *Need for Cognition Scale*, preintervention instrument, *Topic Knowledge* instrument, two intervening tasks, immediate postintervention and the *Thinking about Probability* instrument. The same preintervention, immediate postintervention and delayed postintervention utilized in Experiment 1 were utilized in Experiment 2 and the preintervention and postintervention were counterbalanced in each packet as in Experiment 1.

Participants in each of the conditions also received instructional materials. The participants in the *Non-Treatment Comparison* condition received the text on employing discussion in the classroom. As in Experiment 1 the participants in the *Anchored Scenarios* condition also received the adapted version of Fast's (1997) WDYTTCA instrument and the participants in the *Text* condition also received the two-sided, refutational text focused on the representativeness heuristic.

Fourteen to 21 days after the immediate postintervention was administered a delayed postintervention was given to the participants. In an effort to maintain a low attrition rate from participants in the sections of Educational Psychology 014 as well as Educational Psychology 010, the delayed postintervention was administered at the end of a regularly scheduled class. Any participant not attending class that day was then emailed a copy of the delayed postintervention and asked to complete it and either email it back to me or deliver it to my on-campus mailbox to further avoid a high attrition rate.

Data Analysis

The purpose of this study was to investigate the viability of a text and anchored scenarios in minimizing college-age students' use of the representativeness heuristic when reasoning about uncertain events. In order to answer the research questions in this study multiple data analyses procedures were utilized. Descriptive statistics (e.g., means and standard deviations) and repeated measures analysis of variance tests were employed to determine overall changes in participants' scores from the preintervention instrument to immediate postintervention and from immediate postintervention to delayed postintervention. The analyses were conducted from preintervention (time 1) to immediate postintervention (time2) and then, separately, from immediate postintervention (time 2) to delayed postintervention (time 3) due to the differences in the amount of time between the preintervention to the immediate postintervention and from the immediate postintervention to the delayed postintervention. Therefore, the assumption of equal time elapsing between administration of instruments was not met to allow conducting a repeated measures ANCOVA on all three time points together.

Specifically, the first research question addressed changes in participants' scores from the preintervention instrument to the postintervention instruments as a result of participation in one of the three study conditions (i.e., *Control*, *Anchored Scenarios*, and *Text*). Descriptive statistics (i.e., means and standard deviations) and repeated measures ANCOVAs were employed to determine overall changes in participants' probabilistic reasoning knowledge from preintervention to postintervention instruments. To examine these changes composite scores were generated for each of the three representativeness instruments in the three-step process listed above. Those instruments were the preintervention instrument, immediate postintervention instrument, and delayed postintervention instrument.

The second research question addressed changes in participants' scores on the probabilistic reasoning instruments from preintervention to immediate postintervention. To examine these changes composite scores were generated for each individual representativeness instrument in the same three-step process described above. Therefore, the second research question was addressed in the same way that the first research question was addressed. Repeated measures ANCOVAs were employed to determine whether the mean change in participants' scores differed from the preintervention to the immediate postintervention by condition.

The third research question addressed changes in participants' scores from the immediate postintervention to the delayed postintervention. To examine these changes composite scores were generated for each individual representativeness instrument in the same three-step process described above. Therefore, the third research question was addressed in the same way that the first and second research questions were addressed. Repeated measures ANCOVAs were employed to determine whether the mean change in participants' scores differed from the immediate postintervention to the delayed postintervention by condition.

CHAPTER 4

RESULTS AND DISCUSSION

The overall purpose of this study was to investigate the viability of mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. Essentially, I investigated how learner variables, in particular knowledge and beliefs, interacted with text variables and anchored scenarios in minimizing misconceptions of representativeness in the selected population. In Experiment 1 I utilized both a text focused on probabilistic reasoning, specifically the representativeness heuristic and anchored scenarios already used in the literature to reduce misconceptions of representativeness. Because of the potential confound due to time between the measurement of probabilistic reasoning, a second experiment was conducted. In Experiment 2 a non-treatment comparison was utilized to more closely examine that confound. The non-treatment comparison read a text of similar length to the text focused on probabilistic reasoning. In the paragraphs that follow, results for Experiments 1 and 2 are reported and discussed sequentially.

Experiment 1

The overall purpose of Experiment 1 was to investigate the viability of mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. Specifically, I investigated how knowledge and beliefs interacted with text variables and anchored scenarios in minimizing misconceptions of representativeness. To address this overarching purpose, three research questions were forwarded pertaining to changes in students' probabilistic reasoning scores over time and possible covariates accounting for unexplained variance in those changes, as well as the extent to which changes in students' scores varied by condition. It is important to note that the amount of time between the assessments of probabilistic reasoning was inconsistent. Specifically, students' probabilistic reasoning was assessed at preintervention, immediately following intervention, and following a two and a half week delay. As a result, changes over time are addressed in separate research questions. Specifically, the questions addressed in this study include the following:

1. To what extent did participants' probabilistic reasoning scores change over time from the preintervention to the immediate postintervention to the delayed postintervention as a result of participation in one of the study conditions (i.e., *Control*, *Anchored Scenarios*, and *Text*)?
2. To what extent did participants' probabilistic reasoning scores from the preintervention to the immediate postintervention vary by condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?
3. To what extent do changes in participants' probabilistic reasoning scores from the immediate postintervention to the delayed postintervention vary by condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

Descriptive and univariate, repeated measures analyses of covariance (ANCOVA) were employed to address the aforementioned research questions. Prior to submitting data to analyses, checks were made to assure that the data met the assumptions for the various procedures. The results from these examinations precede each research question.

Descriptive Changes over Time

The first research question in Experiment 1 addressed descriptive changes in students' probabilistic reasoning over time as a result of participating in the study. Univariate distributions on the various measures were normally distributed. Means and standard deviations for students' probabilistic reasoning scores for the various time points overall and by condition are reported in Table 3. Descriptive statistics for students' *Need for Cognition* and prior experience with probabilistic events overall and by condition are also reported in Table 3. As can be seen in

Table 3, despite random assignment to condition, there were minimal differences in students' representativeness scores by condition. For instance, aggregate scores from students assigned to the *Text* condition were higher than the *Control* and *Anchored Scenarios* conditions. Given the planned analyses (i.e., repeated measures ANCOVA), these initial differences are not problematic.

Aside from the initial differences in scores by condition, changes in students' scores also varied by condition. Specifically, while students in the *Anchored Scenarios* and *Text* conditions increased their scores by less than a point from preintervention to immediate postintervention, students in the *Control* condition evidenced a decrease in their probabilistic reasoning scores. Variation in students' reasoning scores by condition was also evident from immediate postintervention to delayed postintervention. That is, although scores across all three conditions decreased, students' scores from the *Text* condition exhibited the lowest decrease. Descriptively it would appear that participation in the *Text* condition was associated with retention of appropriate probabilistic reasoning. Clearly these descriptive results in no way imply causality. Nonetheless, these data offer moderately positive evidence pertaining to the viability of refutational text as an intervention.

Little variability existed across students' *Need for Cognition* scores by condition. Similarly, small differences can be seen in Table 3 between the three conditions in scores for prior experience with probabilistic situations. Given the planned analyses (i.e., repeated measures ANCOVA), these initial differences are not problematic. Students in the *Control* condition exhibited the highest scores on this instrument with the *Text* group scoring slightly lower despite random assignment. This would lead one to think that the *Control* and *Text* conditions would score highest initially on the representativeness instrument because of their scores on the prior experience instrument; however, this is not the case. As evidenced in Table 3, the students in the *Control* condition scored the lowest on the preintervention representativeness instrument of the three conditions and the students in the *Text* condition scored the highest of the three conditions.

Table 3

Means and standard deviations for various time points by condition and overall

Conditions	Representativeness instrument			Need for cognition *M* (*SD*)	Prior experience *M* (*SD*)
	Preintervention *M* (*SD*)	Immediate postintervention *M (SD)*	Delayed postintervention *M* (*SD*)		
Control (*n*=31)	7.19 (2.738)	7.13 (2.814)	6.39 (2.667)	56.77 (8.613)	78.06 (32.805)
Anchored scenarios (*n*=84)	7.27 (2.885)	7.99 (2.595)	7.06 (2.847)	57.92 (9.515)	73.12 (27.049)
Text (*n*=80)	8.21 (2.299)	8.80 (2.275)	8.00 (2.205)	57.50 (9.357)	77.23 (26.546)
Overall (*n*=195)	7.65 (2.664)	8.18 (2.562)	7.34 (2.628)	57.56 (9.274)	75.58 (27.775)

Note. Max scores: Representativeness instrument = 12, *Need for Cognition* = 90, Prior experience = 200.

Preintervention to Immediate Postintervention Changes

The second research question in this experiment addresses the extent to which participants' probabilistic reasoning scores from the preintervention to the immediate postintervention instruments vary by condition controlling for students' need for cognition and prior experience with probabilistic events. Prior to addressing the second research question, analyses were conducted to examine the extent to which the data adhered to the assumptions for both repeated measures and analysis of covariance. Specifically, for the repeated measures analyses that data were examined for normality, homogeneity of covariance, sphericity, and the linearity between the covariates and the dependent variable. The dependent variable, representativeness, appeared to be normally distributed. Homogeneity of covariances were analyzed using the Box test and results were nonsignificant (p=.319) suggesting equality of covariances. Similarly, Mauchly's test of sphericity was nonsignificant. These assumptions were met both with and without the covariates. Finally, repeated measures analyses assume that the covariates enjoy a known relation with the dependent variable and that the relation be linear. Results regarding the covariates are discussed in the paragraphs below within the ANCOVA assumption discussion.

As is the case with repeated measures analyses, ANCOVA analyses are governed by a number of assumptions including limited covariates, high reliability, linear or known relations between the dependent and covariates, and homogeneity of covariate regression (Garson, 2008). In this experiment, only two covariates were employed so as to align with the assumption of limited covariation. Moreover, separate models were tested for each covariate independently. Another assumption is that each covariate will be measured so as to reduce measurement error (i.e., high reliability) (Garson, 2008). In this study, *Need for Cognition* had a Cronbach's α reliability coefficient of .826 and prior experience had a Cronbach's α reliability coefficient of .886. These reliabilities are quite high. As was the case with the repeated measures analyses, it is assumed that the covariate enjoy a know relation with the dependent variable and that the relation be linear. The present study included two covariates, neither of which has been documented as relating to probabilistic reasoning. Rather, the covariates were selected due to their prominence in the persuasion literature and the known relation between these covariates and refutational text. Specifically, *Need for Cognition* (e.g., Petty & Cacioppo, 1986) and prior experiences (e.g., Murphy, Holleran, Long, & Zeruth, 2005) have repeatedly been shown to be related to engagement with and processing of text-based arguments. Given that the *Text* condition employs refutational text as an intervention, it was important that these constructs be included and tested in the model. That being said, the relation between these two constructs and representativeness is unknown. Given the lack of a known relation between the covariates and the dependent variable, it was particularly important that the assumption of linearity be met. Scatterplots were employed to assess the nature of the relation between each covariate and the dependent variable (Garson, 2008). As can be seen in the representative figures (Figures 1-3) below, the relations between the dependent variable and *Need for Cognition* as well as prior experiences with probabilistic situations were nonlinear. It is important to note that the data failed to meet this assumption at each time point (i.e., preintervention, immediate postintervention, delayed postintervention, and gains across the time points). Given that the covariates failed to meet this important assumption, they were omitted from any further analyses.

Figure 1.

Prior experience with probabilistic events by students' probabilistic reasoning by condition at preintervention

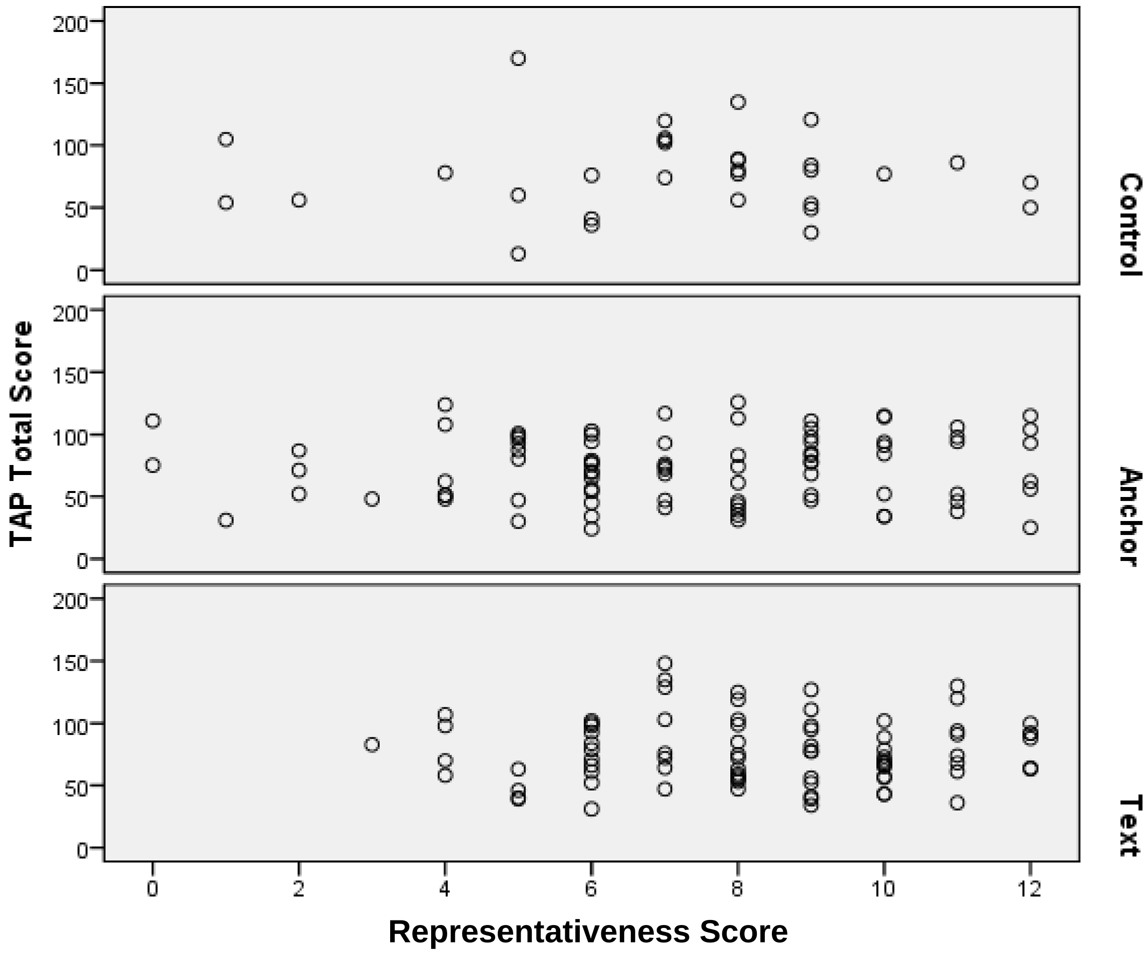


Figure 2.

Prior experience with probabilistic events by students' probabilistic reasoning by condition at immediate postintervention

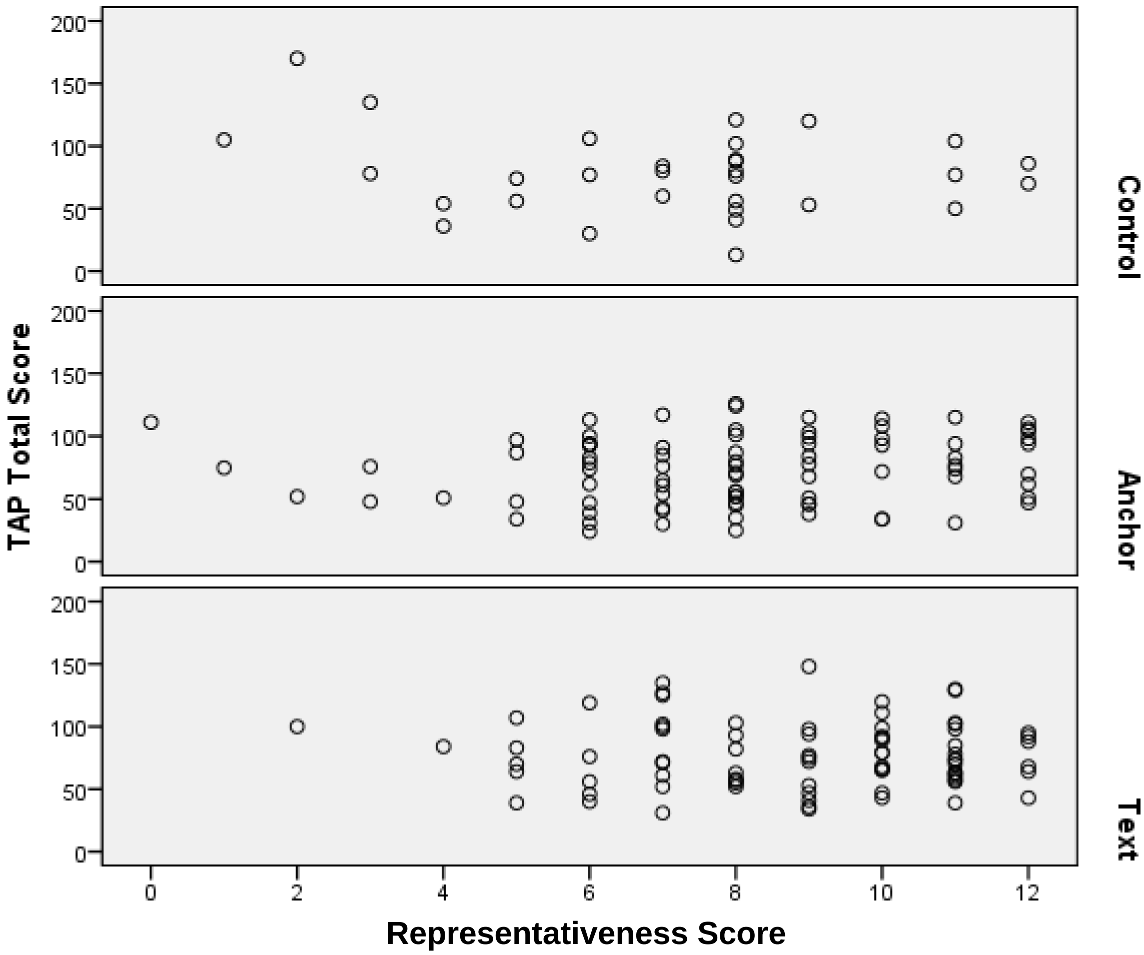
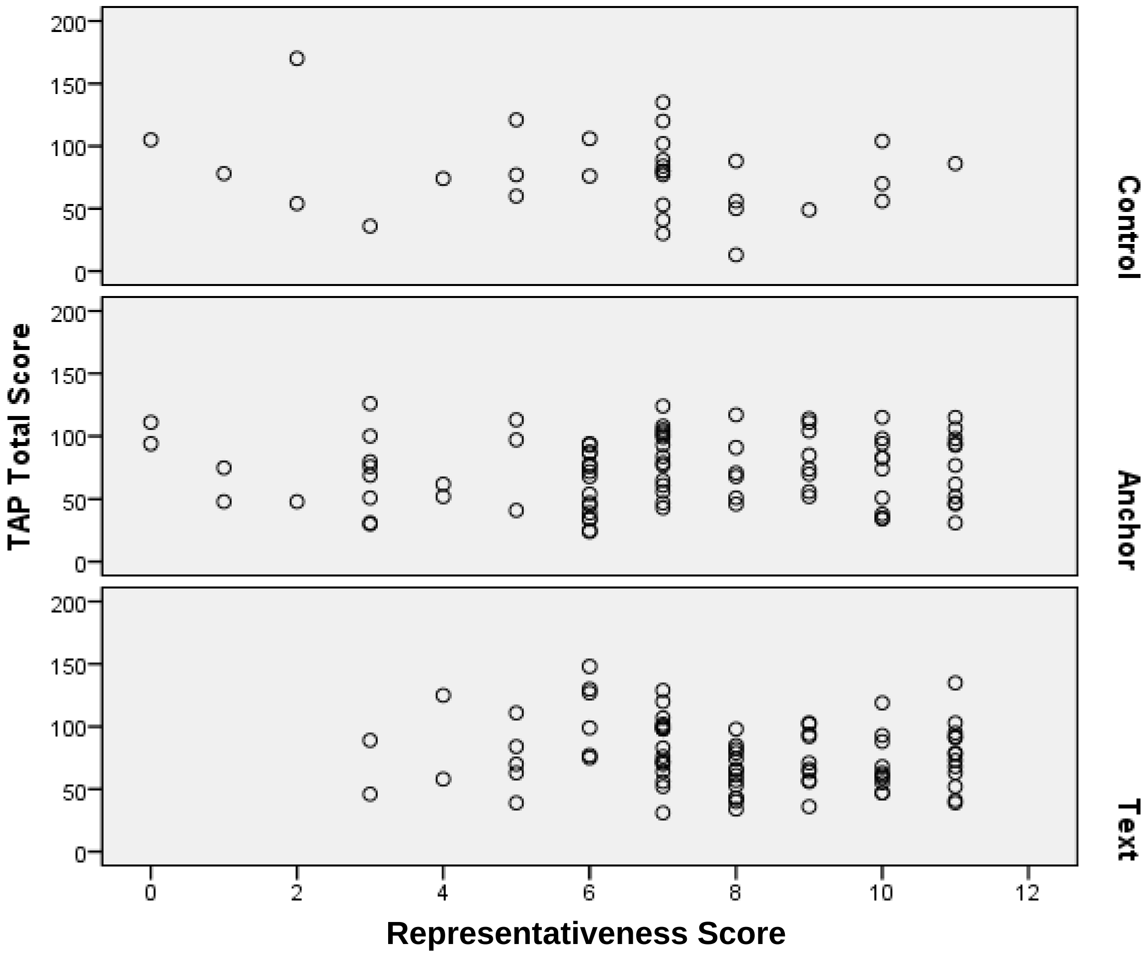


Figure 3.

Prior experience with probabilistic events by students' probabilistic reasoning by condition at delayed postintervention

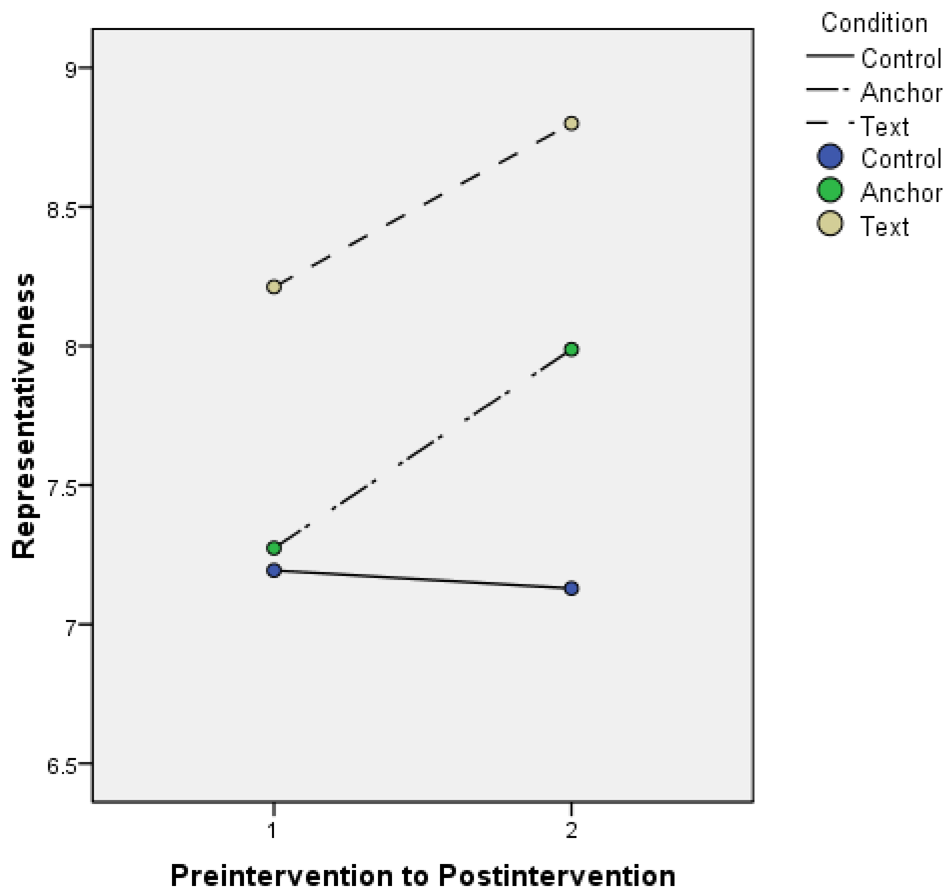


To address the second question in Experiment 1 of this study regarding changes in participants' scores from preintervention to immediate postintervention a repeated measures ANOVA was conducted with condition (i.e., *Control*, *Text*, and *Anchored Scenarios*) as the independent variable, scores on the probabilistic reasoning instrument served as the dependent variable, and time as the within-subject variable. A repeated measures ANCOVA was conducted to determine whether or not the conditions within the study were statistically significantly different following the intervention and whether any characteristics of the participants particularly need for cognition or previous experience with probabilistic situations would mediate those differences. Analyses showed that there was a statistically significant main effect for both time (Wilks' Lambda = .971, $F_{1, 192} = 5.787$, $p = .017$, $\eta^2 = .029$) and condition ($F_{2, 192} = 4.810$, $p = .009$, $\eta^2 = .048$). These results suggest that participants' scores on the probabilistic reasoning instruments changed statistically significantly from the preintervention to the immediate postintervention after receiving one of the interventions. As was the case for time, participants' scores varied statistically significantly depending on the condition in which they participated. The interaction between time and condition was nonsignificant. That is, increases over time do not statistically significantly vary by condition. Although no statistically significant differences emerged, the results of the descriptive analysis revealed that while students' scores from the *Control* condition remained stable over time, the scores of students participating in the experimental conditions increased over time.

Differences between conditions in scores on the representativeness instrument are demonstrated in Figure 4. Despite random assignment, the *Text* condition scores almost a point higher than the other two conditions on the preintervention instrument. While the *Anchored Scenarios* and *Control* conditions' scores are similar on the preintervention instrument, the *Anchored Scenarios* condition exhibits an increase from preintervention to immediate postintervention and the *Control* condition exhibits a decrease from preintervention to immediate postintervention. The *Text* condition also exhibits an increase in scores from preintervention to immediate postintervention. These results indicate the possible viability of the text and anchored scenarios as interventions in overcoming the inappropriate use of the representativeness heuristic.

Figure 4.

Estimated marginal means of measures from preintervention to immediate postintervention instruments



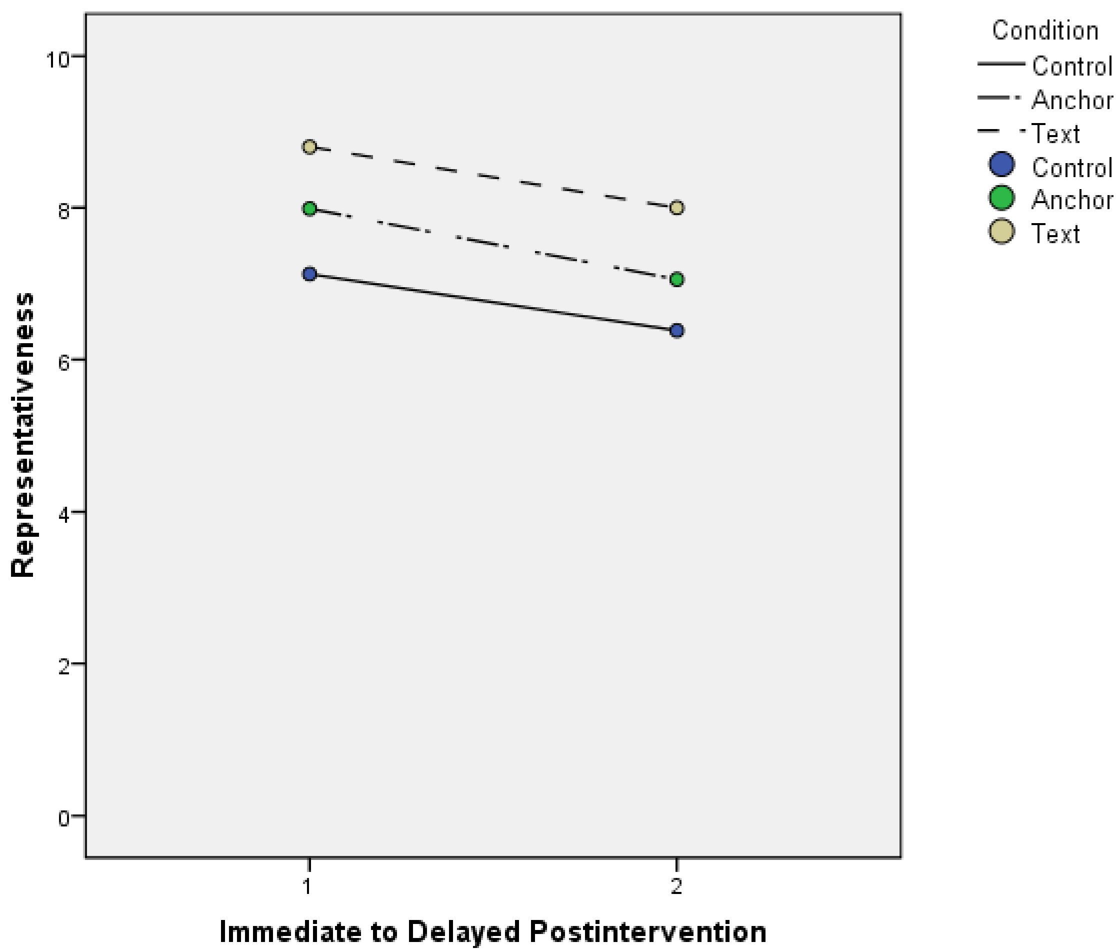
To further analyze differences due to condition, Fisher's Least Significance Difference (LSD) tests were employed. Results revealed that students' scores in the *Text* condition were statistically significantly different from those of students in both the *Control* condition (p=.007 with a 95% confidence interval [-.37 to 2.32]) and the *Anchored Scenarios* condition (p=.017 with a 95% confidence interval [-.16 to 1.59]). Specifically, students in the *Text* condition improved their scores on the representativeness instrument statistically significantly more from the preintervention to the immediate postintervention than students in either of the other two conditions. For example, the *Text* condition had a mean change of 1.34 higher than the *Control* condition and a .88 mean difference higher than the *Anchored Scenarios* condition, both of which are statistically significant. These results suggest that the text given to the participants in the *Text* condition of this experiment served as a more powerful intervention for decreasing the inappropriate use of the representativeness heuristic than the previously validated anchored scenarios given to the *Anchored Scenarios* condition.

The third question in Experiment 1 of this study is very similar to the second question. To address the third question regarding changes in participants' scores from the immediate postintervention to the delayed postintervention instruments a repeated measures ANOVA was conducted with condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) as the independent or between-subjects variable, scores on both the immediate postintervention and the delayed postintervention instruments as the dependent variables and time as the within-subject variable. Analyses showed that there were statistically significant main effects for both time (Wilks' Lambda = .887, $F_{1, 192} = 24.437$, $p = .000$, $\eta^2 = .113$) and condition ($F_{1, 192} = 6.416$, $p = .002$, $\eta^2 = .063$). These results suggested that participants' scores on the probabilistic reasoning instruments changed significantly from the immediate postintervention to the delayed post intervention after a two and a half week delay. As was the case for time, what appears to be happening is the condition, or the type of intervention participants received, varied outcomes on the probabilistic reasoning instruments; however, in this case the change in participants' scores resulted in a decrease from the immediate to delayed postintervention instruments. As in the second research question for this experiment, the interaction between time and condition was nonsignificant. These results suggest that the combination of time and condition do not interact to increase scores on the probabilistic reasoning instrument as the scores have decreased from immediate to delayed postintervention instruments.

Figure 5 illustrates the differences in means by condition from the immediate to the delayed postintervention. This figure demonstrates the decrease in scores that each condition exhibited on the representativeness instrument. While each of the conditions' scores decreased the *Text* condition scored the highest on the delayed postintervention instrument.

Figure 5.

Estimated marginal means of measures from immediate to delayed postintervention instruments



To further analyze differences due to condition, Fisher's Least Significance Difference (LSD) tests were employed. Results revealed that students' scores in the *Text* condition were statistically significantly different from those of students in both the *Control* condition (p=.001 with a 95% confidence interval [.68 to 2.61]) and the *Anchored Scenarios* condition (p=.016 with a 95% confidence interval [.16 to 1.59]). Specifically, students in the *Text* condition experienced the least amount of decrease in scores on the representativeness instrument from the immediate postintervention to the delayed postintervention as compared to students in either of the other two conditions. For example, the *Text* condition had a mean difference of 1.64 higher than the *Control* condition and a .88 mean difference higher than the *Anchored Scenarios* condition, both of which are statistically significant. This suggests that reading the text assisted students in overcoming some of the misconceptions they held in regards to the representativeness heuristic and that assistance was greater than what the previously validated anchored scenarios provided. Albeit the *Text* condition's scores decreased from the immediate to the delayed postintervention instruments; however, since their scores decreased less than the other two conditions it appears that more of what the participants in this condition learned concerning representativeness remained with them over the delay in time as compared to the participants in the other two conditions. These results suggest moderately positive evidence relevant to the viability of two-sided refutational text as an intervention.

Experiment 2

In Experiment 2, three overall research questions were addressed. These research questions were similar to the questions guiding Experiment 1 with one difference; in place of the *Control* condition a *Non-Treatment Comparison* condition was included. The reason for this design change was to examine the extent to which participants receiving no intervention, but an unrelated task that was similar to reading the refutational text, would perform in comparison to the experimental conditions. Specifically, I was wondering whether the availability heuristic was at play in the *Control* condition in Experiment 1. Since the participants in the *Control* condition in Experiment 1 were able to take the immediate postintervention immediately after the preintervention they may have been utilizing the availability heuristic while completing the immediate postintervention. Experiment 2 allowed me to look at three conditions which completed the preintervention followed by the immediate postintervention at comparable times. The questions for this experiment again focus on changes over time in scores on the probabilistic reasoning instruments and possible covariates affecting those changes. Specifically, the questions addressed in this portion of the study include the following:

1. To what extent did participants' probabilistic reasoning scores change over time from the preintervention to immediate postintervention to the delayed postintervention as a result of participation in one of the study conditions (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*)?
2. To what extent did participants' probabilistic reasoning scores from the preintervention to immediate postintervention vary by condition (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?
3. To what extent do changes in participants' probabilistic reasoning scores from the immediate postintervention to the delayed postintervention vary by condition (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

Descriptive and univariate, repeated measures analyses of covariance (ANCOVA) were employed to address the aforementioned research questions. Prior to submitting data to analyses, checks were made to assure that the data met the assumptions for the various procedures. The results from these examinations precede each research question.

Descriptive Changes over Time

As in Experiment 1, the first research question addressed descriptive changes in students' probabilistic reasoning over time as a result of participating in the study. Univariate distributions on the various instruments were normally distributed. Means and standard deviations for students' probabilistic reasoning scores for the various time points overall and by condition are reported in Table 4. Descriptive statistics for students' *Need for Cognition* and prior experience with probabilistic events overall and by condition are also reported in Table 4. As can be seen in Table 4 the differences at preintervention on the representativeness instrument were less than in Experiment 1. In this experiment the *Non-Treatment Comparison* condition scored the highest and the *Text* condition followed. Given the planned analyses, these slight differences are (i.e., repeated measures ANCOVA), not problematic.

Table 4 also illustrates the differences in scores from the preintervention to immediate postintervention instrument. One clear difference between conditions is the decrease that participants in the *Non-Treatment Comparison* condition experienced as compared to the increase that participants in both experimental conditions experienced from preintervention to immediate postintervention. The participants in the *Text* condition increased their scores to a greater extent than participants in the *Anchored Scenarios* condition. Variation in students' reasoning scores by condition was also evident from immediate postintervention to delayed postintervention. That is, scores across all three conditions decreased. While students' scores from the *Non-Treatment Comparison* condition exhibited the slightest decrease their mean score at delayed postintervention is lower than their mean score at preintervention. Students' scores from the *Text* condition decreased from immediate to delayed postintervention; however, their delayed postintervention mean score was still an increase from their mean score on the preintervention instrument. While the *Anchored Scenarios* condition also exhibited an increase in scores from the preintervention instrument to the delayed postintervention instrument their increase was smaller than the *Text* condition's increase.

Table 4

Means and standard deviations for various time points by condition and overall

Conditions	Representativeness instrument			Need for cognition *M* (*SD*)	Prior experience *M* (*SD*)
	Preintervention *M* (*SD*)	Immediate postintervention *M (SD)*	Delayed postintervention *M* (*SD*)		
Non-trt (*n*=31)	7.87 (2.540)	7.65 (2.787)	7.35 (2.678)	52.00 (4.590)	71.81 (25.793)
Anchored scenarios (*n*=81)	7.14 (2.691)	7.74 (2.995)	7.22 (2.941)	55.36 (8.744)	75.86 (25.956)
Text (*n*=82)	7.46 (2.812)	8.24 (2.925)	7.82 (2.583)	53.34 (7.446)	76.21 (28.064)
Overall (*n*=194)	7.39 (2.718)	7.94 (2.930)	7.49 (2.753)	53.96 (7.729)	75.36 (26.752)

Note. Max scores: Representativeness instrument = 12, *Need for Cognition* = 90, Prior experience = 200.

Preintervention to Immediate Postintervention Changes

As in Experiment 1, the second research question in Experiment 2 addresses the extent to which participants' probabilistic reasoning scores from the preintervention to the immediate postintervention vary by condition controlling for students' need for cognition and prior experience with probabilistic events. Prior to addressing the second research question, analyses were conducted to examine the extent to which the data adhered to the assumptions for both repeated measures and analysis of covariance. Analyses were conducted to be certain the data adhered to assumptions of repeated measures and ANCOVA. As was the case with Experiment 1, with some exceptions the data adhered. Specifically, for the repeated measures analyses the data were examined for normality, homogeneity of covariance, sphericity, and the linearity between the covariates and the dependent variable. The dependent variable, representativeness, appeared to be normally distributed. Homogeneity of covariances were analyzed using the Box test and results were nonsignificant (p=.265) suggesting equality of covariances. Similarly, Mauchly's test of sphericity was nonsignificant. These assumptions were met both with and without the covariates.

As in Experiment 1, in regards to linearity, the covariates and the dependent variable, exhibited a nonlinear relation in Experiment 2. A demonstration of this can be seen the representative figures (Figures 6-8) below. It is important to note that the data failed to meet this assumption at each time point (i.e., preintervention, immediate postintervention, delayed postintervention, and gains across the time points). As this is the case, the covariates were not used in the analyses and results will be reported below without them.

Figure 6.

Prior experience with probabilistic events by students' probabilistic reasoning by condition at preintervention

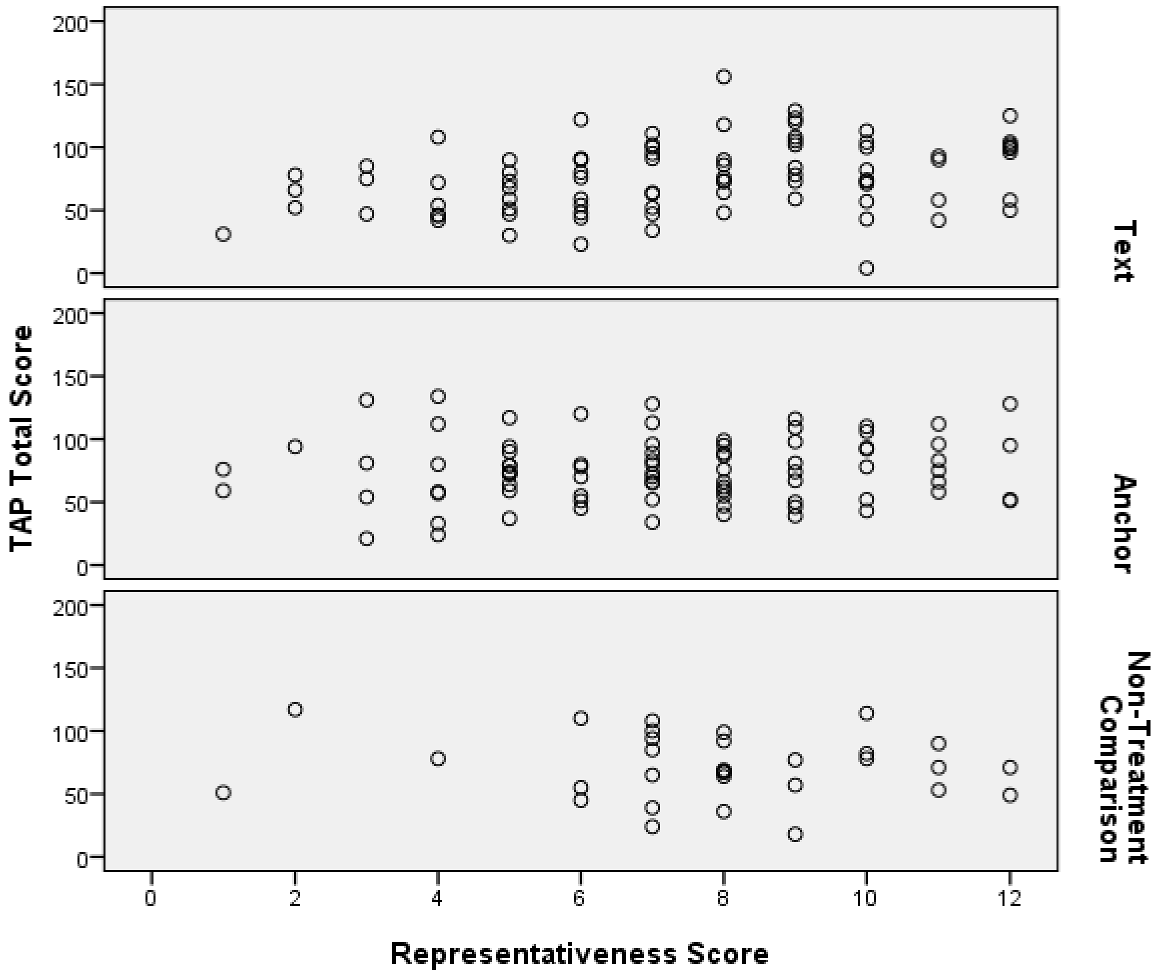


Figure 7.

Prior experience with probabilistic events by students' probabilistic reasoning by condition at immediate postintervention

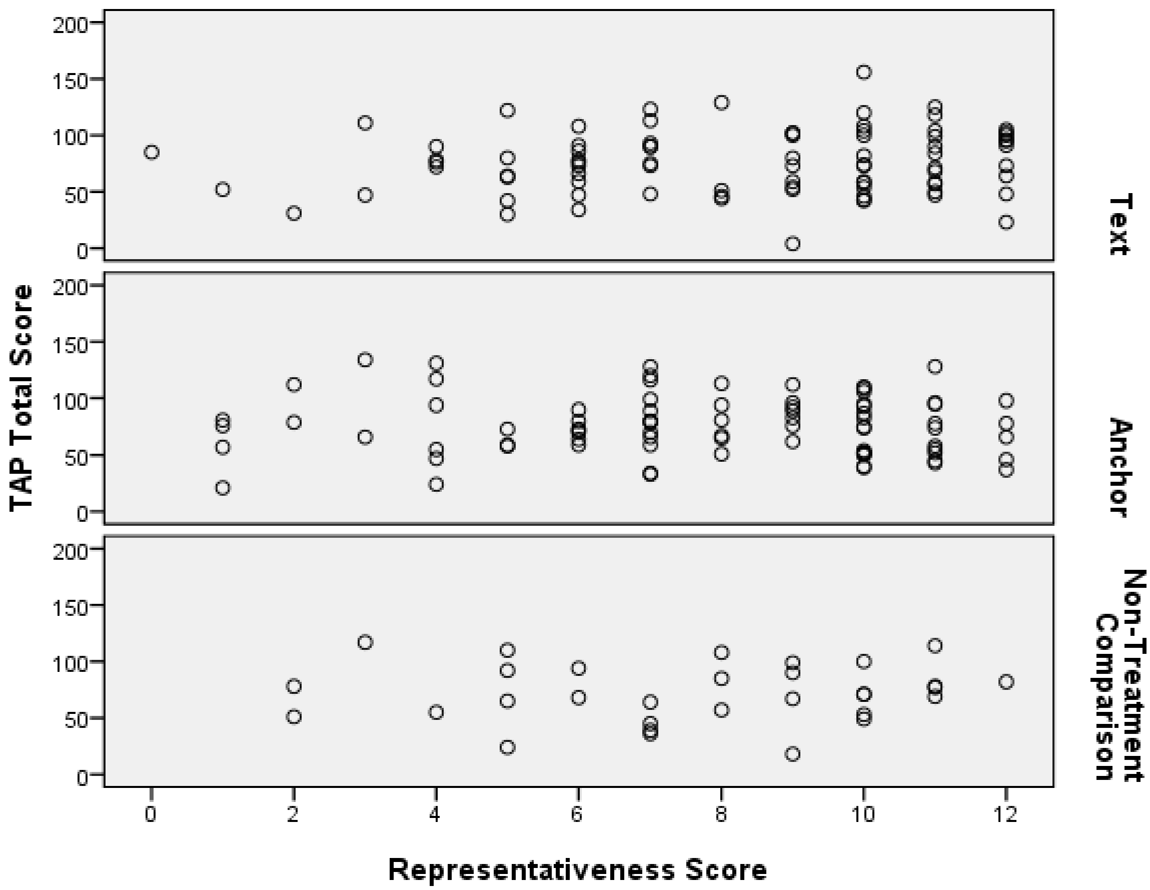
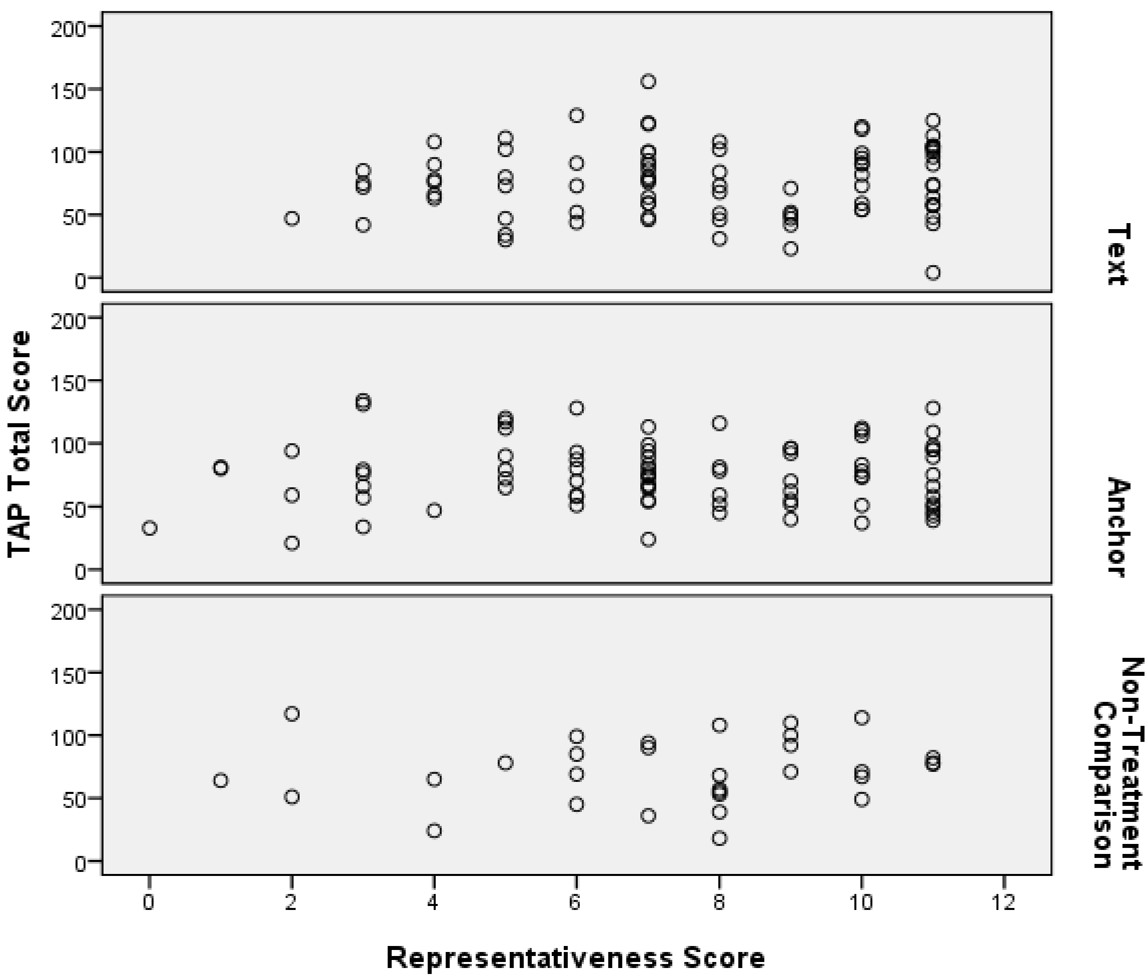


Figure 8.

Prior experience with probabilistic events by students' probabilistic reasoning by condition at delayed postintervention

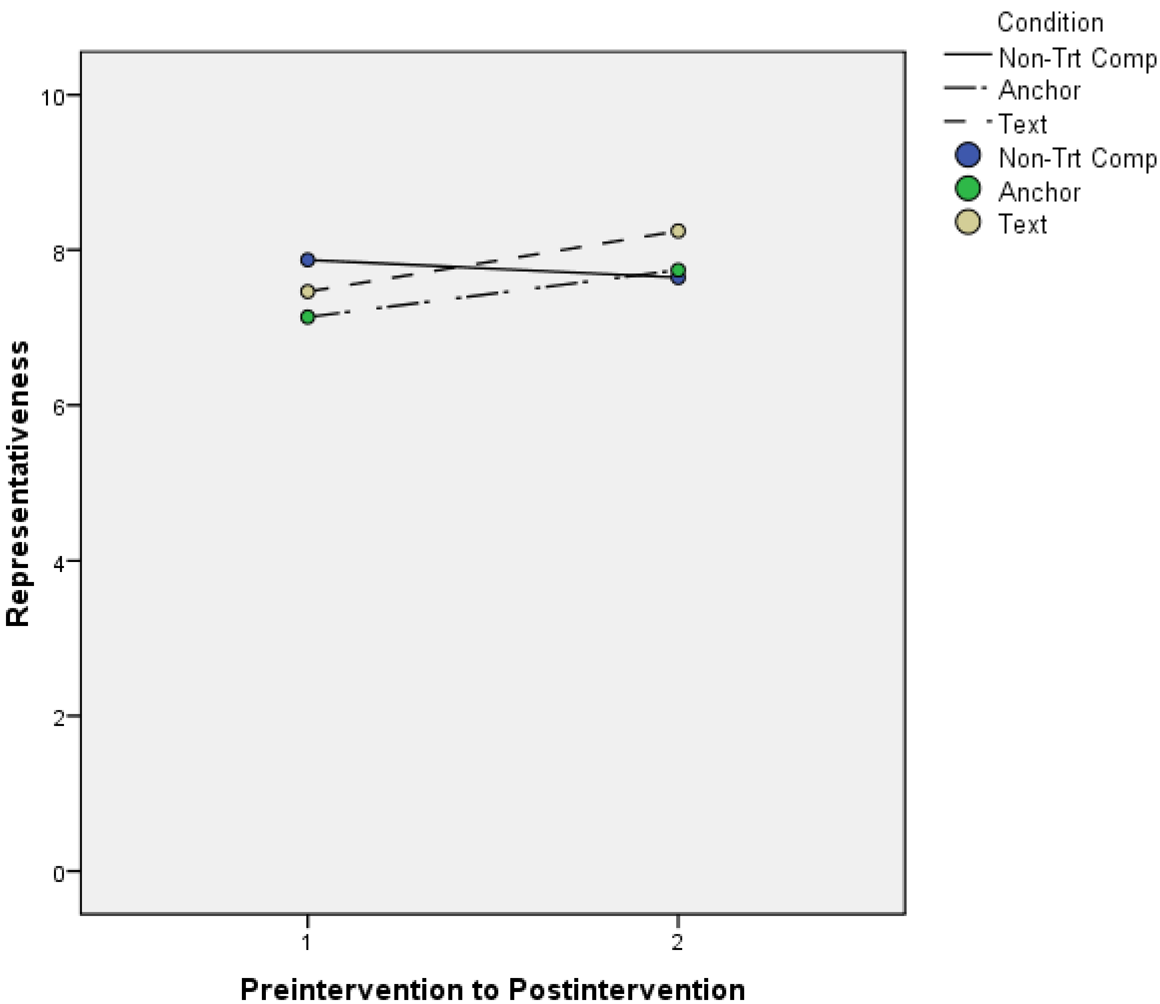


To address the second question in Experiment 2 regarding changes in participants' scores from the preintervention to the immediate postintervention a repeated measures ANOVA was conducted with condition (i.e., *Non-Treatment Comparison*, *Text*, and *Anchored Scenarios*) as the independent variable, scores on the probabilistic reasoning instrument served as the dependent variable, and time as the within-subject variable. Analyses showed that there was a statistically significant main effect for time (Wilks' Lambda = .979, $F_{1, 191} = 4.115$, $p = .044$, $\eta^2 = .021$). The main effect for condition ($F_{2, 191} = .560$, $p = .572$, $\eta^2 = .006$), as well as the interaction between time and condition were not statistically significant. These results suggest that the text and anchored scenarios employed as interventions in this experiment did have a statistically significant effect for time but not for condition in reducing participants' inappropriate use of the representativeness heuristic on the instruments from the preintervention to the immediate postintervention. Additionally, increases over time do not statistically significantly vary by condition.

Differences between conditions in scores on the representativeness instrument are demonstrated in Figure 9. Each of the conditions scores similarly on the preintervention instrument with the *Non-Treatment Comparison* condition scoring slightly higher than the other two conditions. While that is the case, the *Non-Treatment Comparison* conditions' scores decreased from preintervention, to the immediate postintervention and the other two conditions exhibited an increase in scores. These results indicate the possible viability of the text and anchored scenarios as interventions in overcoming the inappropriate use of the representativeness heuristic.

Figure 9.

Estimated marginal means of measures from preintervention to immediate postintervention instruments

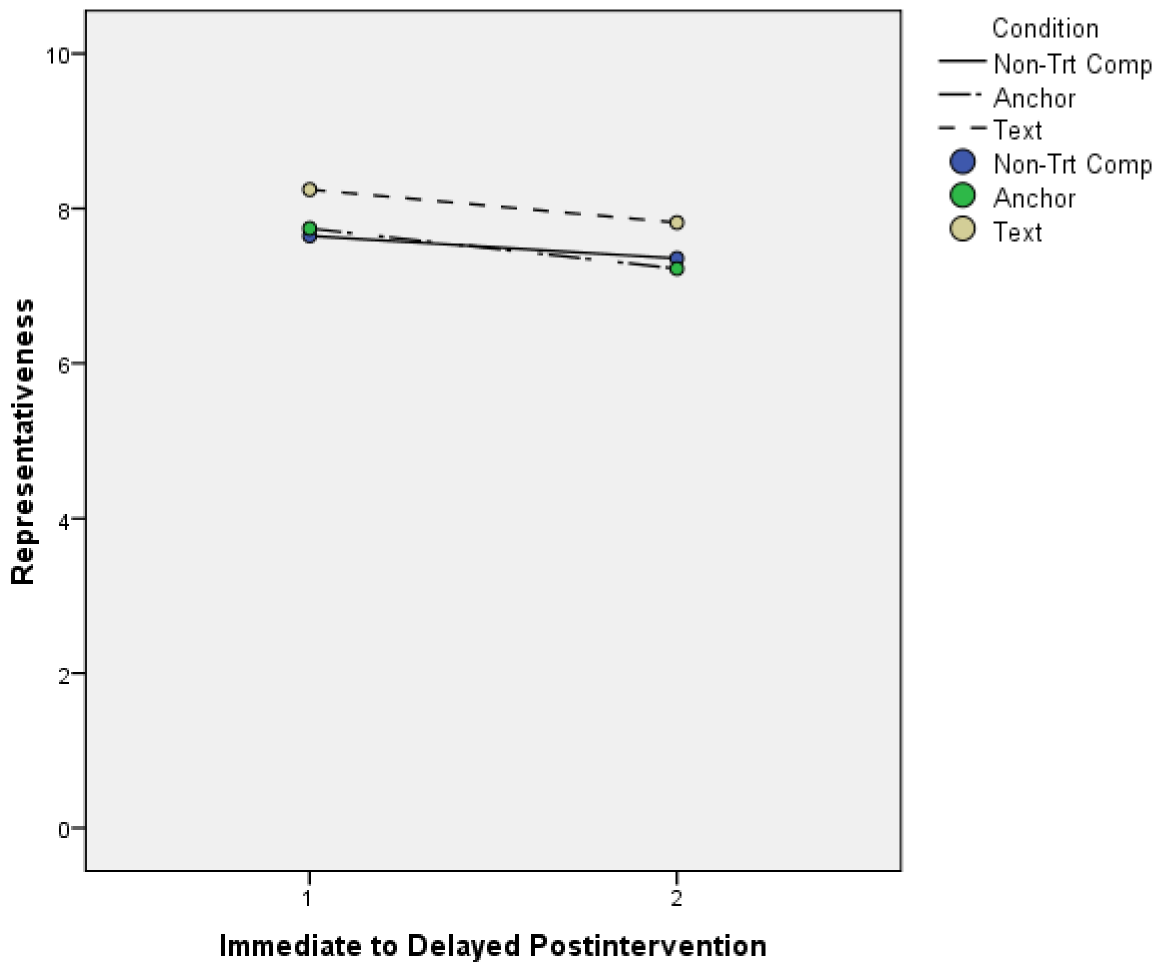


Question three of this experiment is focused on changes in participants' scores from the immediate postintervention instrument to the delayed postintervention instrument. To answer the third question a repeated measures ANOVA was conducted with condition (i.e., *Non-Treatment Comparison*, *Text*, and *Anchored Scenarios*) as the independent variable, scores on both the immediate postintervention and the delayed postintervention instruments as the dependent variables and time as the within-subject variable. Analyses showed that there was a statistically significant main effect for time (Wilks' Lambda = .969, $F_{1,\ 191}$ = 6.196, p = .014, η^2= .031) but not condition ($F_{1, 191}$ = 1.000, p = .370, η^2= .010). That is, the text and anchored scenarios employed as interventions in this experiment did have a statistically significant effect for time but not for condition in reducing participants' inappropriate use of the representativeness heuristic on the instruments from the immediate to delayed postintervention instrument. As in the second research question for this experiment, the interaction between time and condition was nonsignificant. These results suggest that the combination of time and condition do not interact to influence scores on the probabilistic reasoning instrument. One explanation for these nonsignificant results may be found in power. In essence, the effects were much lower than anticipated, and consequently, more participants are needed to detect differences due to condition.

In Figure 10, means on the representativeness instrument from the immediate to delayed postintervention instrument are illustrated. While the three conditions scored similarly on the immediate postintervention instrument, the participants in the *Text* condition scored the highest. The participants in the *Anchored Scenarios* condition scored only slightly higher than the participants in the *Non-Treatment Comparison* condition. Figure 10 also demonstrates the decrease in scores that all three conditions exhibited from the immediate to delayed postintervention instrument.

Figure 10.

Estimated marginal means of measures from immediate to delayed postintervention instruments



CHAPTER 5

FINDINGS, CONCLUSIONS AND IMPLICATIONS

The aim of this dissertation study was to focus on misconceptions in probability, specifically the representativeness heuristic and viable avenues for diminishing those misconceptions in the college-age population. The methods employed as interventions for decreasing the inappropriate use of the representativeness heuristic in this particular study were anchored scenarios and a text specifically aimed at that heuristic. In this chapter, the problem statement, methodology, analysis and results for both Experiment 1 and Experiment 2 will be summarized, implications for research will be forwarded and issues for further investigation will be discussed.

Summary of the Investigation

Review of the Problem

For many years research has consistently shown that misconceptions in probability are common and pervasive at almost any age (Kahneman & Tversky, 1972; Shaughnessy, 1977). Research also suggests that once these misconceptions are formed altering them is a highly unlikely result through either formal or informal instruction (Konold, 1995). This implies a serious limitation in the current literature and instruction in probability and probabilistic reasoning. Individuals may be forming misconceptions, perhaps through common experiences in their daily lives or countless other sources from a very early age. An enduring effect is hindered probabilistic reasoning and decision-making caused by inaccurate, commonly employed heuristics (Tversky & Kahneman, 1974). These hindrances to probabilistic reasoning and decision-making often stem for misconceptions or inaccurate beliefs that individuals form outside of a classroom setting. While an instructor may present accurate information in a course focused on probability, the students in that course often fail to replace their inaccurate knowledge with what is being introduced in their class. Even more disconcerting is that individuals who use and employ accurate probabilistic reasoning learned in a formal setting within that formal setting for purposes of assessments or in-class tasks those same people often fail to utilize that same reasoning in their daily lives (Tversky & Kahneman, 1974; Kunoff & Pines, 1986; Konold, 1995). It appears that probability learned in the classroom does not transcend to life outside of the classroom when the task is something other than providing an answer on a paper and pencil assessment.

Finding a method of improving probabilistic reasoning in individuals of all ages has potentially far-reaching effects. Teaching people to think probabilistically can improve the decisions they make by decreasing their flawed judgments. These types of errors in judgment underlie a number of problems in everyday life. For instance, individuals are often more concerned with being violently attacked when walking alone in the dark than they are with having material possessions stolen such as a purse or small items from a car. Violent crimes happen much less often; however people are much more on guard for them than they are the more common crimes such as petty theft that they can much more readily fall victim to. Teaching individuals to use probability correctly can increase their probabilistic reasoning and consequently improve their judgments and decisions.

Few studies in the current probability and probabilistic reasoning literature have investigated interventions aimed at diminishing those misconceptions in individuals. While text is a prevalent form of communication throughout the world today and in the past few, if any, studies have attempted to explore text as an intervention in correcting misconceptions in probability. Therefore, the majority of the existing research conducted on this topic has either been theoretical in nature or has directed attention to using scenarios or problem solving equations as an intervention. It is crucial to both theory and practice that viable interventions for diminishing the inaccurate use of the representativeness heuristic in individuals and improving their probabilistic reasoning and consequently decision-making be explored. Consequently, it is advantageous to this line of research that text be explored as a means for reducing misconceptions in probability and probabilistic reasoning in individuals.

Procedures

To address the research questions an instrument was developed to measure the extent to which college-age students incorrectly rely on the representativeness heuristic when thinking about situations with uncertain outcomes and if the inappropriate use of that heuristic decreases after reading a text or completing anchored scenarios specifically aimed at the heuristic. This instrument was revised as a result of two pilot studies and adaptations prior to using it to collect data for the dissertation experiments. In the following section, the sample, procedures performed to collect data and instrument design are reviewed.

Sample and procedures. This dissertation study began with an initial pilot study to gather data on the original representativeness instrument (*A Test of Representativeness*) created and previously validated by Hirsch and O'Donnell (2001). The items for the original instrument were used, but they were split in half to create the preintervention and postintervention instruments. Specifically, 49 primarily undergraduate students enrolled in two educational psychology courses in the summer, 2006 semester were asked to participate in the study in return for extra credit in the class where they were recruited. The first pilot study showed a need for revision to the representativeness instruments and ultimately a second pilot study. This study was carried out using 7 students enrolled in an advanced doctoral seminar on advanced measurement and design in cognitive and educational psychology. The primary purpose of this pilot study was to assess the validity of the representativeness instruments. Following this administration, the instruments were revised once more. Specifically, the short answer items were dropped resulting in the three final versions of the *Understandings of Representativeness* instruments consisting of 12 two-part, multiple choice items. These versions served as the preintervention instrument, immediate postintervention instrument, and delayed postintervention instrument.

Following the pilot studies Experiment 1 was performed. Participants for Experiment 1 (*n*=195) were recruited from an introductory educational psychology course in which they received extra credit for their participation. Participants for Experiment 2 (*n*=195) were recruited from two undergraduate educational psychology courses over the course of two semesters. These students also received extra credit for their participation in the study. Students in Experiments 1 and 2 were recruited and their data collected in the same way.

Participants attended data collection sessions at pre-determined times in on-campus classrooms. Up arrival participants were given a packet of materials and asked to complete the materials in the order in which they appeared in the packets. The packets were counterbalanced so that participants were randomly assigned to condition and conditional were comprised of approximately equal numbers of participants. Approximately 17 days after the initial data collection participants received the delayed postintervention instrument during the class that they were originally recruited from. The delayed postinterventions were completed by participants at the end of a regularly scheduled class. Any participant not attending class that day was emailed a copy of the instrument and asked to return it to me via email or my on-campus mailbox.

Instrument design. The original instrument intended for use in this dissertation study was an adaptation of the *A Test of Representativeness* instrument created and validated by Hirsch and O'Donnell (2001). This instrument was split in half to create a preintervention instrument and a postintervention instrument each with 10 items. Three of these items were short answer and seven of these items were two-part, multiple-choice. Upon completion of the first pilot study results showed ceiling effects. After adapting the instrument, a second pilot study was conducted for the purposes of assessing the performance of the instrument with this population. Finally, the *Understandings of Representativeness* instrument was finalized and three versions were created. These three versions were the preintervention instrument, the immediate postintervention instrument and the delayed postintervention instrument. The delayed postintervention instrument was generated using item difficulties from the preintervention instrument and immediate postintervention instrument, making the delayed postintervention instrument comparably difficult to the preintervention and immediate postintervention versions. For this dissertation study, the *Understandings of Representativeness* instrument was employed to measure the inaccurate use of the representativeness heuristic in the participants prior to and then twice after an intervention.

Research Questions

Several research questions were generated to guide the current investigation into viable mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. The current dissertation study was conducted by way of two separate experiments each with separate but similar research questions. Specifically, those research questions guiding Experiment 1 include the following:

1. To what extent did participants' probabilistic reasoning scores change over time from the preintervention to the immediate postintervention to the delayed postintervention as a result of participation in one of the study conditions (i.e., *Control*, *Anchored Scenarios*, and *Text*)?
2. To what extent did participants' probabilistic reasoning scores from the preintervention to the immediate postintervention vary by condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

3. To what extent do changes in participants' probabilistic reasoning scores from the immediate postintervention to the delayed postintervention vary by condition (i.e., *Control*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

The questions for Experiment 2 again focus on changes over time in scores on the probabilistic reasoning instruments and possible covariates affecting those changes. Specifically, the questions addressed in Experiment 2 include the following:

1. To what extent did participants' probabilistic reasoning scores change over time from the preintervention to the immediate postintervention to the delayed postintervention as a result of participation in one of the study conditions (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*)?
2. To what extent did participants' probabilistic reasoning scores from the preintervention to the immediate postintervention vary by condition (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?
3. To what extent do changes in participants' probabilistic reasoning scores from the immediate postintervention to the delayed postintervention vary by condition (i.e., *Non-Treatment Comparison*, *Anchored Scenarios*, and *Text*) controlling for students' *Need for Cognition* and prior experience with probabilistic events?

Findings and Conclusions

Over the years, research has demonstrated a severe need for further investigation into misconceptions in probability and methods of improving probabilistic reasoning in individuals of all ages (Tversky & Kahneman, 1971, 1974, 1983). Unfortunately, research also suggests that formal instruction is not sufficient in combating the pervasive nature of these misconceptions

(Konold, 1995). In the present study common misconceptions in probabilistic reasoning were examined. Again, the primary purpose of this study was to investigate the viability of mechanisms for altering college-age students' use of the representativeness heuristic when reasoning about uncertain events. Essentially, I investigated how learner variables, specifically knowledge and beliefs, interacted with text variables and anchored scenarios in minimizing misconceptions of representativeness. College-age students' use of the representativeness heuristic was examined and attempts were made to decrease the inappropriate use of that heuristic in the sample population.

Covariates. The present study included two covariates, Need for Cognition and prior experiences with probabilistic situations. While neither of which has been documented as relating to probabilistic reasoning specifically, research suggests that both of these variables influence how well and individual processes and engages text (e.g., Petty & Cacioppo, 1986; Murphy, Holleran, Long, & Zeruth, 2005). These two covariates were tested for adhering to assumption of both repeated measures and analysis of covariance. Both covariates violated the assumption of linearity and results were therefore forwarded without inclusion of Need for Cognition and prior experiences in probabilistic situations.

Measuring probabilistic reasoning. For the purposes of this study *Understandings of Representativeness* was created. This instrument measures the inappropriate use of the representativeness heuristic. This instrument measures both knowledge and beliefs by assessing participants' beliefs in the first portion of the items and then requiring them to justify their beliefs with their knowledge in the second part of each item. Hume (1748) asserted that all human beliefs, including those we label knowledge, are a result of repeated associations between past experiences. One type of belief that Hume acknowledged is mathematical knowledge which relies upon relations of ideas that are a result of associations formed in the mind. Matters of fact are a second type of belief that according to Hume (1748) can explain the nature of existing objects. Hume contended that information relies on our belief in matters of fact. To get at a person's knowledge their belief in such knowledge should be assessed.

Understandings of Representativeness is a much stronger instrument for this specific purpose than *A Test of Representativeness* (Hirsch and O'Donnell, 2001) as demonstrated by pilot studies and reported reliabilities conducted for this particular study. In addition to the strength of this instrument there are three versions; a preintervention, immediate postintervention, and delayed postintervention. The item difficulties of the preintervention instrument and immediate postintervention instrument were utilized in creating the delayed postintervention instrument, making the delayed postintervention instrument of comparable difficulty so that scores on all three versions could be reasonably compared and contrasted. It is worth noting that *A Test of Representativeness* (Hirsch & O'Donnell, 2001) was employed more than eight years ago. Since that time the National Assessment of Educational Progress (Grigg & Dion, 2007) now assesses students' probabilistic reasoning and probability knowledge to a greater extent. This assessment shift focuses the standard curriculum in schools more on this area of mathematics than in years past. Consequently, *A Test of Representativeness* is possibly easier for today's students as compared to similar students eight to ten years ago.

Crafting viable interventions. The current study fulfilled a need in the current literature. In the literature to this point in time, a text has not been utilized and reported as an intervention for increasing accurate probabilistic reasoning in students or decreasing their misconceptions in probabilistic reasoning. The results of the current experiments demonstrate the potential role that a text can play in altering the inaccurate use of the representativeness heuristic. The results of this study suggest that a text is a viable method for decreasing the inappropriate use of the representativeness heuristic in college-age students. While the anchored scenarios served as a potential intervention for this purpose, the text employed in this study appeared to have a more powerful effect on the participants' inappropriate use of the representativeness heuristic over time. For instance, the participants in the *Text* condition demonstrated larger gains in scores on the representativeness instrument from the preintervention to the immediate postintervention and while all three conditions experienced decreases in scores from the immediate to the delayed postintervention times the participants in the *Text* condition experienced the slightest decrease. This would indicate that the text that these participants read assisted them in overcoming the inaccurate use of the representativeness heuristic to a greater degree than the WDYTTCA instrument featuring the anchored scenarios. These results also suggest that the information that the participants gained in the *Text* condition stayed with them longer than the information learned by the participants in the *Anchored Scenarios* condition.

Variability of results across the experiments. Experiments 1 and 2 differed in regards to statistically significant findings for the interventions. Specifically, in Experiment 1 statistically significant results were found. In Experiment 2, however, effects were not substantive enough and the power was lacking for condition differences to be detected. At least two plausible explanations could explain these differences.

One such reason could be practice. In both experiments students received practice from the preintervention instrument to prepare them for the postintervention instruments, however, in Experiment 2 the preintervention instrument and immediate postintervention instrument occurred at a further apart from each other as a result of the intervening tasks which could possibly explain why gains in scores were not as great as in Experiment 1. The participants could have become so engaged in the intervening tasks that they may have lost some of that recent information in working memory from the preintervention instrument when taking the immediate postintervention instrument.

Similar to the practice explanation, the contrasts between the findings for the two experiments may be explained by the availability heuristic. In the availability heuristic an individual judges the frequency of a class or probability of something occurring based upon how easily an instance or occurrence can be evoked As such, the various aspects of the explanations or sample problems comprising the interventions may not have been *available* to the participants in working memory. Simply put, the greater time lapse between completing the preintervention instrument and the immediate postintervention instrument could have made the use of the availability heuristic more difficult for the participants in Experiment 2, resulting in the lower effect in this experiment. Determining between these two plausible explanations will require additional empirical investigations.

Implications for Educational Research and Practice

Several implications for educational research can be forwarded as a result of this particular study. Findings indicate that the text employed as an intervention in this study helped participants to reduce the inappropriate use of the representativeness heuristic. If a text is indeed a viable method for reducing misconceptions in probabilistic reasoning, instead of concentrating on representativeness, perhaps we should be crafting texts that address more simplistic misconceptions in probabilistic reasoning. In other words, providing texts to younger students focusing on more elementary topics that serve as a common source of confusion may reduce misconceptions in probabilistic reasoning in individuals at higher levels. Probability is taught as early as second grade. Texts could potentially be created for students at this level aimed at appropriate topics in probability. Possibly in doing this a number of misconceptions that are typically formed later in life may be avoided through formal instruction altogether from an early age.

While we would intuitively assume prior experience with probabilistic situations is related to an individual's probabilistic reasoning it did not have a strong linear relation in this particular study. This may possibly indicate that individuals are not relating what they experience in their own personal lives to probabilistic reasoning tasks in formal settings and vice versa. According to Konold (1995) this is a key problem. Even those students who learn probability concepts and correctly apply them to assessments in the classroom often fail to apply those same concepts correctly in their everyday lives. Aiming research efforts toward creating a method of instruction that encourages students to apply the information about probability and probabilistic reasoning that they learn in formal settings to their everyday lives would be advantageous.

In classroom practice, having teachers utilize texts as instructional instruments when teaching probability and probabilistic reasoning may facilitate learning. Even if students are only able to read and process a shorter text, instructing preservice teachers in how to use these texts as instructional instruments may prove a beneficial endeavor. The use of texts can therefore become a valuable contribution to overcoming or even avoiding misconceptions in probabilistic reasoning. The potential of this intervention as a valuable resource in increasing accurate probabilistic reasoning can only be determined through future research in this area.

More work still needs to be conducted in an effort to create an instrument which can successfully measure declarative-level, topic knowledge in probability. This declarative knowledge instrument employed in this study was designed to tap students' understanding of basic terms (e.g., event) or concepts (e.g., "law of large numbers") and while it was successfully utilized in a previous investigation (Zeruth, Kulikowich, & Murphy, 2006) the instrument had low reliability in this study with these particular participants, therefore it was not included in the analyses. Creating a better instrument for this specific purpose may prove very telling when attempting to identify the origin of students' misconceptions in probability and probabilistic reasoning.

A great need still exists for more interventions to be created that have stronger impacts on students' misconceptions in probabilistic reasoning. While Fast's (1997) WDYTTCA instrument featuring anchored scenarios seems to work toward decreasing misconceptions in probabilistic reasoning this may be in large part due to the availability heuristic. The availability heuristic leads to judging the probability of something occurring based upon how easily an instance or occurrence can be evoked (Tversky & Kahneman, 1974, 1983). In some cases evaluating occurrences and likelihoods can be aided by this heuristic since evoking recent memories or information is easier than older information. Since the availability heuristic allows an individual to recall instances of larger classes or instances of recent information faster and more effectively, this heuristic is, at times, efficient at assessing frequency or probability of an event. It would make sense that this heuristic could be temporarily assisting students in assessing the probability of the events in the multiple choice questions on the immediate delayed postintervention instrument since it was taken so soon after the preintervention instrument.

Limitations of the Present Study

While this study attempted to contribute to the literature on probabilistic reasoning by overcoming the limitations in the previous studies, it was also limited in several ways. For example, participants comprising the sample for the study were all college, primarily undergraduate, students attending a university in the Northeastern United States. It may be that individuals of other age groups or geographic regions may have responded differently than the participants in this study. For instance, perhaps the standardized tests that students are now required to take throughout elementary, middle and high school are enhancing their probabilistic reasoning. Younger individuals who are being prepared for these tests in their regular classes may be better equipped to perform well on the interventions than older individuals who were not required to take standardized tests in school. Since these tests vary by region, it could also be that students in one area of the country are better prepared for taking probability and probabilistic reasoning assessments than students in other areas of the country.

Several limitations of the measures should also be noted. For instance, the *Topic Knowledge* instrument had floor effects. While this instrument was used in a previous study with a similar population and detected variation in participants' knowledge it did not perform as well in this particular study. It may be that this instrument needs to be altered so that variance in participants' probability topic knowledge can be more easily detected.

Modifications of Fast's anchoring instrument can be considered another limitation. Specifically, the *What Do You Think The Chances Are*? instrument was altered so that only the items assessing the representativeness heuristic were utilized. Possibly using the instrument in its entirety would provide better results. In addition, this study utilized a group setting for all experimental and control conditions. It may be that an intervention implemented in a one-on-one situation may better suit the purpose of altering college-age students' use of the representative heuristic. Further, the interventions employed in this study were not ecologically embedded within a class. Therefore, any generalizations based on the results of this study should be made with these caveats in mind.

Future Directions for Research

With the previous mentioned limitations in mind, a number of suggestions for future research can be forwarded. A positive effect for the text condition in this study was observed, however, the practical significance was somewhat weak. This intuitively leads to examining the text more closely and making possible adaptations to it to achieve stronger differences in the future. For example, it may be that placement of the argument within the text may lead to meaningful changes in students' reasoning. Or, it may be that the text needs to be more effective at evoking the emotion of the student. At present, the text was crafted so as to align with the Fast measure which may have been a limiting factor. Creating a more emotive text may be more engaging for individuals thereby possibly enhancing their processing and learning outcomes.

Conducting this research with individuals of other ages and academic standings is another viable avenue of research. Perhaps investigating probabilistic reasoning in younger students would answer questions as to how inappropriate uses of the representativeness heuristic as well as other heuristics in probability can be avoided altogether. These misconceptions are formed in students prior to entering college. Since probability is introduced to students as early as second grade it seems intuitive to begin this line of research with a younger population and use what we know about probabilistic reasoning in older learners to help teach probability and correct misconceptions in younger learners.

A study that investigates the extent to which the availability and representativeness heuristics hinder decision making and probabilistic reasoning is another viable area of research. It may be that these two heuristics should not be separated for this type of investigation; rather they should be explored together. Using a an instrument and intervention that are aimed at both the availability and representativeness heuristics may be more telling as to where the root of these heuristics originates as well as more effective in eradicating them. Another possible alteration to the representativeness instrument lies in the nature of the items. The items in the representativeness instrument as it was utilized in this study are very rule based, meaning that numbers of objects are provided for participants to determine the probability of an event. In a future study, these items can be altered so that objects are used that do not require set numbers for participants to determine the probability of an event. For instance, as mentioned earlier, Tversky and Kahneman (1974) have given participants scenarios using occupations. These scenarios did not provide set numbers, thereby assuming that the participants could correctly generate a population base in a given society for occupations such as a librarian as compared to a doctor. The representativeness instrument could be altered to include items of this nature in place of or in addition to the existing items which are very rule based, providing set numbers of objects.

It may be that patterns of misconceptions can be found within the justifications that participants provided on the representativeness multiple choice items. Using the same representativeness instrument or another instrument created with a justification component could be telling as to where the misconceptions are most heavily concentrated. A researcher could code the types of justifications provided as well as which justifications are provided with higher frequency after the intervention. A study such as this could possibly guide the creation of another instrument for measuring misconceptions in probabilistic reasoning.

Finally, given that the text and anchored scenarios resulted in somewhat limited effects, I would also like to explore hands-on approaches. Using a game whose tenets rest heavily in probability, such as roulette, may prove a robust method for decreasing the use of the inappropriate use of the representativeness heuristic in individuals and increasing their accurate use of probability. Further, it may be that a hands-on approach coupled with explicit instruction in probability could be another powerful means of increasing students' understanding and consequently use of probability.

Summary

The experiments in this dissertation served as an investigation into college-age students' use of the representativeness heuristic when reasoning about uncertain events. An existing instrument was both adapted and piloted several times resulting in one of the interventions used in the current experiments. That instrument, *Understandings of Representativeness*, includes a preintervention, immediate postintervention, and delayed postintervention variants. This instrument specifically assesses an individual's use of the representativeness heuristic which is cited as a common misconception in the literature (Tversky & Kahneman, 1974). Not only do a very scant number of interventions for probabilistic reasoning exist, it is well documented in the literature that many common misconceptions in probabilistic reasoning are pervasive even in the face of instruction (Konold, 1995). As a small number of interventions have previously been employed and reported in the literature, the creation of the instrument used in these experiments is an important contribution to the literature on probabilistic reasoning.

In this particular study the methods employed as interventions for decreasing the inappropriate use of the representativeness heuristic were anchored scenarios and a text which was specifically aimed at that heuristic. The anchored scenarios employed were previously used and reported in the literature as a potential means for decreasing the inappropriate use of the representativeness heuristic in individuals (Fast, 1997, 1999). The results of the study show that using a text as an intervention is not only another viable method for reducing the inappropriate use of the representativeness heuristic, but a more powerful method than the anchored scenarios. While this study strengthens the existing literature on misconceptions probabilistic reasoning and the inappropriate use of the representativeness heuristic, it also extend s the possibilities for intervening and decreasing those misconceptions in college-age students. A large gap appears to exist in our knowledge base for correcting or altogether avoiding misconceptions in probabilistic reasoning. It is vital to continue focusing research efforts on optimal instruction in probability and means of improving probabilistic reasoning in students of all ages.

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Appendix A

DEMOGRAPHIC SHEET

<u>DIRECTIONS:</u> Please fill in the blanks or appropriate bubbles below.

Packet ID number: _________

Age: _____________

What is your gender?

O Female

O Male

O Other (please specify)________________

Ethnicity: ____

Major area of study: ____

Minor area of study: ____

Please indicate your college classification:

First Year	Certification
Sophomore	Masters
Junior	Ph.D.
Senior	Other____________________________

Please indicate your current university grade point average if applicable (GPA):___________

Please indicate your SAT score: ___________

Please indicate the number of statistics classes you are currently taking: _________

Have you take high school statistics?	O Yes	O No
Have you taken statistics 101?	O Yes	O No

How confident are you about your ability in statistics?

Low O-----O-----O-----O-----O-----O-----O-----O-----O-----O High

How confident are you about your ability in probability?

Low O-----O-----O-----O-----O-----O-----O-----O-----O-----O High

Appendix B

Short Need for Cognition Scale (from Cacioppo, Petty, & Kao, 1984)

INSTRUCTION: For each of the statements below, please indicate whether or not the statement is characteristic of you or of what you believe. For example, if the statement is extremely uncharacteristic of you or of what you believe about yourself (not at all like you) please place a "1" on the line to the left of the statement. If the statement is extremely characteristic of you or of what you believe about yourself (very much like you) please place a "5" on the line to the left of the statement. You should use the following scale as you rate each of the statements below.

1	2	3	4	5
extremely uncharacteristic of me	somewhat uncharacteristic of me	uncertain	somewhat characteristic of me	extremely characteristic of me

1.______	I prefer complex to simple problems.
2.______	I like to have the responsibility of handling a situation that requires a lot of thinking.
3.______	Thinking is not my idea of fun.
4.______	I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.
5.______	I try to anticipate and avoid situations where there is a likely chance I will have to think in depth about something.
6.______	I find satisfaction in deliberating hard and for long hours.
7.______	I only think as hard as I have to.
8.______	I prefer to think about small daily projects to long term ones.
9.______	I like tasks that require little thought once I've learned them.
10.______	The idea of relying on thought to make my way to the top appeals to me.
11.______	I really enjoy a task that involves coming up with new solutions to problems.
12.______	Learning new ways to think doesn't excite me very much.
13.______	I prefer my life to be filled with puzzles I must solve.
14.______	The notion of thinking abstractly is appealing to me.
15.______	I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.
16.______	I feel relief rather than satisfaction after completing a task that requires a lot of mental effort.
17.______	It's enough for me that something gets the job done; I don't care how or why it works.
18.______	I usually end up deliberating about issues even when they do not affect me personally.

Appendix C
Recruiting Script

I am currently working on my dissertation here at The Pennsylvania State University. The topic I am working on relates to decision making in adults and I would really appreciate your help. I am looking for participants who are over the age of 18 and wish to participate in the study. If you do choose to participate, please do your best on each of the instruments included in the study.

Participation consists of completing a demographic information sheet pertaining to your age, major & minor areas of study, GPA, & familiarity with statistics & probability. Following that is a brief assessment, a survey, and an activity. Finally, participants will complete an assessment and a survey. In this study you will have the opportunity to think about how you make decisions in your everyday lives and what you base those decisions on. Participation is anticipated to take approximately 40 minutes.

In return for your participation, you will receive 3 extra credit points as per your course syllabus. Everyone who participates will receive these extra credit points. There is another option to receive the extra credit. This option is to write a one-page paper on a topic relevant to your class. I will collect the papers. Your course instructor will only know who receives the extra credit points and only after final course grades have been determined. This extra credit report can be dropped off in my mailbox in 227 CEDAR Building before or on (date of the last scheduled data collection). Again, the amount of time needed for participating in the study or doing the extra credit writing assignment will be approximately 40 minutes.

Your participation is voluntary, and you may stop answering the questions at any time. Should you decide not to participate, there will be no penalty and it will in no way hurt your grade in this class. Responses will be recorded without any identifying information.

I appreciate your help!

Thank you,
Jill A. Zeruth
jag301@psu.edu

Appendix D

UNDERSTANDINGS OF REPRESENTATIVENESS (preintervention)

***Part I. Directions*:** **Please respond to the following questions.**

1. What is the chance that the first toss of a fair coin results in a head?

____

2. The first toss of the coin does result in a head, and the coin is tossed a second time. What is the chance that the second toss results in a head?

____

3. The coin is tossed a third time. What is the chance that the third toss results in a head?

____

***Part II. Directions*:** **Please circle the best answer for each question from the options provided.**

4. A fair coin is tossed, and it lands heads up. The coin is tossed a second time. What is the probability that the second toss is also a head?
   a. 1/4
   b. 1/2
   c. 1/3
   d. Slightly less than 1/2
   e. Slightly more than ½

4a. Which of the following best describes the reason for your answer to the preceding question?
   f. The second toss is less likely to be heads because the first toss was heads.
   g. There are four possible outcomes when you toss a coin twice. Getting two heads is only one of them.
   h. The chance of getting heads or tails on any one toss is always 1/2.
   i. There are three possible outcomes when you toss a coin twice. Getting two heads is only one of them.
   j. Other______________________________________

5. A bag has 9 pieces of fruit: 3 apples, 3 pears, and 3 oranges. Four pieces of fruit are picked, one at a time. Each time a piece of fruit is picked, the type of fruit is recorded, and it is then put back in the bag. If the first 3 pieces of fruit were apples, what is the fourth piece MOST LIKELY to be?
   b. A pear
   c. An apple
   d. An orange
   e. An orange or a pear are both equally likely and more likely than an apple.
   f. An apple, orange, or pear are all equally likely.

5a. Which of the following best describes the reason for your answer to the preceding question?
   g. This piece of fruit is just as likely as any other.
   h. The apples seem to be lucky.
   i. The picks are independent, so each fruit has an equally likely chance of being picked.
   j. The fourth piece of fruit will not be an apple because too many have already been picked.
   k. Other ______________________________________

6. If a fair coin is tossed five times, which of the following ordered sequences of heads (H) and tails (T), if any, is MOST LIKELY to occur?
    a. H T H T T
    b. T H H H H
    c. H T H T H
    d. Sequences (a) and (c) are equally likely.
    e. All of the above sequences are equally likely.

6a. Which of the following best describes the reason for your answer to the preceding question?
    f. Every sequence of five tosses has exactly the same probability of occurring.
    g. Since tossing a coin is random, the coin should not alternate between heads and tails.
    h. Any of the sequences could occur.
    i. There ought to be roughly the same number of tails as heads.
    j. Other ______________________________________

7. If a fair die is rolled six times, which of the following ordered sequences of results, if any, is MOST LIKELY to occur?
    a. 5 6 2 6 4 3
    b. 2 1 4 3 2 4
    c. 6 4 3 2 5 1
    d. 1 2 3 4 5 6
    e. All sequences are equally likely.

7a. Which of the following best describes the reason for your answer to the preceding question?
    f. All sequences of rolls have exactly the same probability of occurring.
    g. You are much more likely to get a mixture of different numbers than numbers that repeat.
    h. Since rolling a die is a random event, a result like that is very likely.
    i. You are much more likely to get a mixture of different numbers than an ordered sequence.
    j. Other ____

8. If a fair coin is tossed six times, which of the following ordered sequences of heads (H) and tails (T), if any, is LEAST LIKELY to occur?
    a. H T H T H T
    b. T T H H T H
    c. H H H H T T
    d. H T H T H H
    e. All sequences are equally likely.

8a. Which of the following best describes the reason for your answer to the preceding question?
    f. Since tossing a coin is random, you should not get a long string of head or tails.
    g. Every sequence of six tosses has exactly the same probability of occurring.
    h. There ought to be roughly the same number of tails as heads.
    i. Since tossing a coin is random, the coin should not alternate between heads and tails.
    j. Other ______________________________________

9. If a fair coin is tossed eight times, which of the following ordered sequences of heads (H) and tails (T), if any, is MOST LIKELY to occur?
    a. T T H H H H T T
    b. H H H H H H H H
    c. H T H T H T H T
    d. H H T H T H H H
    e. All sequences are equally likely.

9a. Which of the following best describes the reason for your answer to the preceding question?

f. Every sequence of eight tosses has exactly the same probability of occurring.
g. Since tossing a coin is random, the coin should not alternate between heads and tails.
h. There ought to be roughly the same number of tails as heads.
i. Since tossing a coin is random, you should not get a long string of head or tails.
j. Other ___________________________________

10. If a fair die is rolled eight times, which of the following ordered sequences of results, if any, is LEAST LIKELY to occur?

a. 2 3 4 5 6 1 2 3
b. 6 4 3 2 4 1 5 6
c. 5 6 2 6 3 5 4 2
d. 2 1 4 3 1 5 4 6
e. All sequences are equally likely.

10a. Which of the following best describes the reason for your answer to the preceding question?

f. You are much more likely to get a mixture of different numbers than an ordered sequence.
g. Since rolling a die is a random event, a result like that is very unlikely.
h. All sequences of rolls have exactly the same probability of occurring.
i. You are much more likely to get a mixture of different numbers than numbers that repeat.
j. Other ______________________________________

11. If a fair die is rolled six times, which of the following ordered sequences of results, if any, is MOST LIKELY to occur?

a. 5 6 2 6 4 3
b. 2 1 4 3 2 4
c. 6 4 3 2 5 1
d. 1 2 3 4 5 6
e. All sequences are equally likely.

11a. Which of the following best describes the reason for your answer to the preceding question?

f. All sequences of rolls have exactly the same probability of occurring.
g. You are much more likely to get a mixture of different numbers than numbers that repeat.
h. Since rolling a die is a random event, a result like that is very likely.
i. You are much more likely to get a mixture of different numbers than an ordered sequence.
j. Other ____

Appendix E

UNDERSTANDINGS OF REPRESENTATIVENESS (immediate postintervention)

Part I. Directions: **Please respond to the following questions.**

1. What is the chance that the first roll of a fair die results in a 1?

   ____

2. The first roll of the die does result in a 1, and the die is rolled a second time. What is the chance that the second roll results in a 1?

   ____

3. The die is rolled a third time. What is the chance that the third roll results in a 1?

   ____

Part II. Directions: **Please circle the best answer for each question from the options provided.**

4. The first roll of a fair die results in a 3. The die is rolled a second time. What is the chance that the second roll also results in a 3?
   - a. 1/36
   - b. 1/5
   - c. 1/6
   - d. Slightly less than 1/6
   - e. Slightly more than 1/6

4a. Which of the following best describes the reason for your answer to the preceding question?
   - f. There are thirty-six possible outcomes when you roll a die twice. Getting two 3's is only one of them.
   - g. The second toss is less likely to be a 3 because the first toss was a 3.
   - h. The chance of getting a 3 on any one roll is always 1/6.
   - i. Any of the other five numbers is more likely than a 3.
   - j. Other ____

5. A box contains 6 balls: 2 are red, 2 are white, and 2 are blue. Four balls are picked at random, one at a time. Each time a ball is picked, the color is recorded, and the ball is put back in the box. If the first 3 balls are red, what color is the fourth ball MOST LIKELY to be?
   - a. Red
   - b. White
   - c. Blue
   - d. Blue and white are equally likely and more likely than red.
   - e. Red, blue, and white are all equally likely.

5a. Which of the following best describes the reason for your answer to the preceding question?
   - f. The fourth ball should not be red because too many red ones have already been picked.
   - g. The picks are independent, so every color has an equally likely chance of being picked.
   - h. Red seems to be lucky.
   - i. This color is just as likely as any other color.
   - j. Other ____

6. If a fair coin is tossed six times, which of the following ordered sequence of heads (H) and tails (T), if any, is LEAST LIKELY to occur?
   a. H T H T H T
   b. T T H H T H
   c. H H H H T T
   d. H T H T H H
   e. All of the above sequences are equally likely.

6a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since tossing a coin is random, you should not get a long string of head or tails.
   g. Every sequence of six tosses has exactly the same probability of occurring.
   h. There ought to be roughly the same number of tails as heads.
   i. Since tossing a coin is random, the coin should not alternate between heads and tails.
   j. Other ______________________________________

7. If a fair die is rolled five times, which of the following ordered sequence of results, if any, is MOST LIKELY to occur?
   a. 3 5 1 6 2
   b. 4 2 6 1 5
   c. 5 2 2 2 2
   d. Sequences (a) and (b) are equally likely.
   e. All of the above sequences are equally likely.

7a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since rolling a die is random, numbers should not repeat until most of the numbers appear.
   g. Every sequence of five rolls has exactly the same probability of occurring.
   h. There ought to be a random mixture of numbers.
   i. Any of the sequences could occur.
   j. Other _____________________________________

8. If a fair coin is tossed four times, which of the following ordered sequences of heads (H) and tails (T), if any, is MOST LIKELY to occur?
   a. H T H T
   b. H H T H
   c. T H H T
   d. H H H H
   e. All sequences are equally likely.

8a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since tossing a coin is random, you should not get a long string of head or tails.
   g. There ought to be roughly the same number of tails as heads.
   h. Since tossing a coin is random, the coin should not alternate between heads and tails.
   i. Every sequence of four tosses has exactly the same probability of occurring.
   j. Other _____________________________________

9. If a fair coin is tossed twelve times, which of the following ordered sequences of heads (H) and tails (T), if any, is LEAST LIKELY to occur?
   a. H T H T H T H T H T H T
   b. H H T H T H H H T T H H
   c. T T H H T H T T H H T H
   d. H H H H H H H H T T T T
   e. All sequences are equally likely.

9a. Which of the following best describes the reason for your answer to the preceding question?
   f. There ought to be roughly the same number of tails as heads.
   g. Since tossing a coin is random, you should not get a long string of head or tails.
   h. Every sequence of twelve tosses has exactly the same probability of occurring.
   i. Since tossing a coin is random, the coin should not alternate between heads and tails.
   j. Other ______________________________________

10. If a fair die is rolled four times, which of the following ordered sequences of results, if any, is LEAST LIKELY to occur?
   a. 6 4 3 5
   b. 5 6 2 6
   c. 2 3 4 5
   d. 2 1 4 3
   e. All sequences are equally likely.

10a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since rolling a die is a random event, a result like that is very unlikely.
   g. You are much more likely to get a mixture of different numbers than an ordered sequence.
   h. All sequences of rolls have exactly the same probability of occurring.
   i. You are much more likely to get a mixture of different numbers than numbers that repeat.
   j. Other _______________________________________

11. If a fair die is rolled eight times, which of the following ordered sequences of results, if any, is MOST LIKELY to occur?
   a. 5 6 2 6 3 5 4 2
   b. 2 1 4 3 1 5 4 6
   c. 6 4 3 2 4 1 5 6
   d. 2 3 4 5 6 1 2 3
   e. All sequences are equally likely.

11a. Which of the following best describes the reason for your answer to the preceding question?
   f. You are much more likely to get a mixture of different numbers than an ordered sequence.
   g. Since rolling a die is a random event, a result like that is very likely.
   h. You are much more likely to get a mixture of different numbers than numbers that repeat.
   i. All sequences of rolls have exactly the same probability of occurring.
   j. Other ____

Appendix F

UNDERSTANDINGS OF REPRESENTATIVENESS (Form A)

Directions: **Please circle the best answer for each question from the options provided.**

1. A hospital employs 20 nurses: 15 females and 5 males. Every hour a computerized system randomly assigns one of the nurses to take an inventory of the medicines dispensed during the hour. Each time the computer records only the gender of the nurse assigned. Which of the following ordered sequence of nurse genders, if any, is LEAST LIKELY to occur?
   a. F F F F F
   b. M M M M M
   c. F M F M F
   d. M F F M F
   e. All of the above sequences are equally likely.

1a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since picking nurses is a random event, a result like that is very unlikely.
   g. You are much more likely to get a mixture of different nurses than an ordered sequence.
   h. All sequences of nurses have exactly the same probability of occurring.
   i. There are more females to choose from in the hospital.
   j. Other ____

2. If a fair die is rolled six times and the first five rolls result in the following sequence: 6 6 2 4 6. What is the next roll MOST LIKELY to be?
   a. 2
   b. 4
   c. 6
   d. 1
   e. All numbers are equally likely.

2a. Which of the following best describes the reason for your answer to the preceding question?
   f. The sixth roll should not be a 6 because too many 6's have already been rolled.
   g. Every number has an equally likely chance of being rolled.
   h. 6 seems to be lucky.
   i. This number might be just as likely as any other number.
   j. Other ____

3. A bag has 3 kinds of fruit: 1 apple, 1 pear, and 1 orange. Four pieces of fruit are picked, one at a time. Each time a piece of fruit is picked, the type of fruit is recorded, and it is then put back in the bag. If the first 3 pieces of fruit were apples, what is the fourth piece MOST LIKELY to be?
   a. A pear
   b. An apple, an orange, or a pear are all equally likely.
   c. An orange
   d. An orange or a pear are both equally likely and more likely than an apple.
   e. An apple

3a. Which of the following best describes the reason for your answer to the preceding question?
   f. This piece of fruit might be just as likely as any other.
   g. The apples seem to be lucky.
   h. Each fruit has an equally likely chance of being picked.
   i. The fourth piece of fruit will not be an apple because too many have already been picked.
   j. Other ____

4. A box contains 12 blocks with different patterns: 7 have polka dots, 3 have stripes, and 2 have squiggly lines. Four blocks are picked at random, one at a time. Each time a block is picked, the pattern is recorded, and the block is put back in the box. If the first 3 blocks are polka dot, what pattern is the fourth block MOST LIKELY to be?

   a. Polka dots
   b. Stripes
   c. Squiggly lines
   d. Squiggly lines and stripes are equally likely and more likely than polka dots.
   e. Polka dots, squiggly lines, and stripes are all equally likely.

4a. Which of the following best describes the reason for your answer to the preceding question?

   f. The fourth block should not be polka dots because too many polka dots have already been picked.
   g. Every pattern has an equally likely chance of being picked.
   h. Polka dot blocks seem to be lucky.
   i. There are more polka dot blocks to choose from in the box.
   j. Other ______________________________________

5. If a fair coin is tossed five times, which of the following ordered sequence of heads (H) and tails (T), if any, is LEAST LIKELY to occur?

   a. H T H T H
   b. T T H H T
   c. H H H H T
   d. H T H T H
   e. All of the above sequences are equally likely.

5a. Which of the following best describes the reason for your answer to the preceding question?

   f. Since tossing a coin is random, you should not get a long string of head or tails.
   g. Every sequence of five tosses has exactly the same probability of occurring.
   h. There ought to be roughly the same number of tails as heads.
   i. Since tossing a coin is random, the coin should not alternate between heads and tails.
   j. Other ______________________________________

6. A box contains 9 balls: 3 are red, 3 are white, and 3 are blue. Six balls are picked at random, one at a time. Each time a ball is picked, the color is recorded, and the ball is put back in the box. Which of the following ordered sequence of balls, if any, is LEAST LIKELY to occur?

   a. R R R B B B
   b. R W B R W B
   c. W W W W W W
   d. B R B R B W
   e. All of the above sequences are equally likely.

6a. Which of the following best describes the reason for your answer to the preceding question?

   f. Since choosing balls is a random event, a result like that is very unlikely.
   g. You are much more likely to get a mixture of different balls than an ordered sequence.
   h. All sequences of balls have exactly the same probability of occurring.
   i. You are much more likely to get a mixture of different balls than balls that repeat.
   j. Other ____

7. A bag has 6 candies: 2 candy bars (C), 2 lollipops (L), and 2 gum balls (G). Five candies are picked at random, one at a time. Each time a candy is picked, the type is recorded, and the candy is put back in the bag. Which of the following ordered sequence of candy, if any, is LEAST LIKELY to occur?
   a. C C C C L
   b. C L G C L
   c. L L L L L
   d. C L G G G
   e. All of the above sequences are equally likely.

7a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since choosing candy is a random event, a result like that is very unlikely.
   a. You are much more likely to get a mixture of different candies than an ordered sequence.
   b. You are much more likely to get a mixture of different candies than candies that repeat.
   c. All sequences of candy have exactly the same probability of occurring.
   d. Other ____

8. In a given day, 8 pregnant women were admitted to a hospital. If the first six babies born to these women were female what gender are the next two babies MOST LIKELY to be?
   a. F F
   b. M M
   c. F M
   d. M F
   e. F and M are equally likely.

8a. Which of the following best describes the reason for your answer to the preceding question?
   f. The next two births should not be female because too many females have already been born.
   g. Every sequence has an equally likely chance of occurring.
   h. Female seems to be lucky.
   i. This sequence might be just as likely as any other sequence.
   j. Other ______________________________________

9. A drawer contains the following buttons: square (S) 20%, round (R) 55%, triangular (T) 15%, octagonal (O) 10%. Six buttons are picked at random, one at a time. Each time a button is picked, the shape is recorded, and the button is put back in the drawer. Which of the following ordered sequence of buttons, if any, is LEAST LIKELY to occur?
   a. R R R R R S
   b. O S O S T O
   c. S S R S R R
   d. R R S T S S
   e. All of the above sequences are equally likely.

9a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since choosing buttons is a random event, a result like that is very unlikely.
   g. You are much more likely to get a mixture of different buttons than an ordered sequence.
   h. There are more round buttons to choose from in the drawer.
   i. You are much more likely to get a mixture of different buttons than buttons that repeat.
   j. Other ____

10. In a given community, people are engaged in the following occupations: salesperson 20%, librarian 10%, airline pilot, 15%, physician 55%. Steve, a member of the community, is very shy and withdrawn, invariably helpful, but with little interest in people or in the world of reality. A meek and tidy soul, he has a need for order and structure, and a passion for detail. According to the information provided, which occupation would you say Steve is MOST LIKELY engaged in?
    a. Librarian
    b. Airline pilot
    c. Salesperson
    d. Physician
    e. All the occupations are equally likely.

10a. Which of the following best describes the reason for your answer to the preceding question?
    f. There are more physicians to choose from in the community.
    g. The description sounds like a person with this occupation.
    h. All the occupations are equally likely.
    i. A man is likely to be in this occupation.
    j. Other ______________________________________

11. A box contains 20 writing utensils: 5 pens and 15 pencils. Eight of the writing utensils are picked, at random, one at a time. Each time a writing utensil is picked, the type is recorded and the writing utensil is put back in the box. If the first 6 types of writing utensils are pencils, what type, if any, are the next two writing utensils MOST LIKELY to be?
    a. Pen Pencil
    b. Pen Pen
    c. Pencil Pen
    d. Pencil Pencil
    e. All of the above writing utensils are equally likely.

11a. Which of the following best describes the reason for your answer to the preceding question?
    f. There are more pencils to choose from in the box.
    g. The next writing utensils should not be pencils because too many pencils have already been chosen.
    h. Every writing utensil has an equally likely chance of being picked.
    i. These writing utensils are just as likely as any other writing utensils.
    j. Other _______________________________________

12. In a small garden there are 96 wild flowers. Of the flowers, 11 are buttercups (B), 62 are daisies (D), and 23 are sunflowers (S). A bee keeper is interested in which type of flower attracts the most bees. Each time a bee lands on a flower she records the type of flower. The first 6 bee landings are recorded. Which of the following ordered sequence of landings, if any, is LEAST LIKELY to occur?
    a. B D S B D S
    b. B B B S S D
    c. B B B B B B
    d. S D S S S S
    e. A buttercup, daisy, and sunflower are equally likely.

12a. Which of the following best describes the reason for your answer to the preceding question?
    f. Since landing on a flower is a random event, a result like that is very unlikely.
    g. There are more daisies to choose from in the garden.
    h. All sequences of landings have exactly the same probability of occurring.
    i. You are much more likely to get a mixture of different landings than landings that repeat.
    j. Other _______________________________________

Appendix G
UNDERSTANDINGS OF REPRESENTATIVENESS (Form B)

Directions: **Please circle the best answer for each question from the options provided.**

1. If a fair coin is tossed ten times and the first eight tosses result in the following sequence: H T T T T T T H. What are the next two tosses MOST LIKELY to be?
    a. T T
    b. H H
    c. T H
    d. H T
    e. All sequences are equally likely.

1a. Which of the following best describes the reason for your answer to the preceding question?
    f. The next two tosses should not be T T because too many T's have already been tossed.
    g. Every sequence has an equally likely chance of being tossed.
    h. T seems to be lucky.
    i. This sequence might be just as likely as any other sequence.
    j. Other ____

2. A box contains 6 blocks with different patterns: 2 have polka dots (P), 2 have hearts (H), and 2 have stripes (S). Six blocks are picked at random, one at a time. Each time a block is picked, the pattern is recorded, and the block is put back in the box. Which of the following ordered sequence of blocks, if any, is LEAST LIKELY to occur?
    a. P H S P H S
    b. P P P S S H
    c. S H S S S S
    d. H H H H H H
    e. All of the above sequences are equally likely.

2a. Which of the following best describes the reason for your answer to the preceding question?
    f. Since choosing blocks is a random event, a result like that is very unlikely.
    g. You are much more likely to get a mixture of different blocks than an ordered sequence.
    h. All sequences of blocks have exactly the same probability of occurring.
    i. You are much more likely to get a mixture of different blocks than blocks that repeat.
    j. Other _______________________________________

3. A box contains 9 balls: 3 are red, 3 are white, and 3 are blue. Six balls are picked at random, one at a time. Each time a ball is picked, the color is recorded, and the ball is put back in the box. If the first 5 balls are red, what color is the sixth ball MOST LIKELY to be?
    a. Red
    b. White
    c. Blue
    d. Blue and white are equally likely and more likely than red.
    e. Red, white, and blue are all equally likely.

3a. Which of the following best describes the reason for your answer to the preceding question?
    f. The sixth ball should not be red because too many red ones have already been picked.
    g. Every color has an equally likely chance of being picked.
    h. Red seems to be lucky.
    i. This color might be just as likely as any other color.
    j. Other _____________________________________

4. In a given community, people are engaged in the following occupations: 20 % salesperson (S), 10% librarian (L), 15% airline pilot (A), and 55% physician (P). Everyday six members from the community come into the grocery store, at random, to purchase their food for the week. Each time a community member comes in their occupation is recorded. Which of the following ordered sequences of occupations, if any, is LEAST LIKELY to occur?
   a. P P P P P S
   b. L S L S A L
   c. S S P S P P
   d. P P S A S S
   e. All of the above sequences are equally likely.

4a. Which of the following best describes the reason for your answer to the preceding question?
   f. There are more physicians in the community.
   g. You are much more likely to get a mixture of different occupations than an ordered sequence.
   h. All sequences of occupations have exactly the same probability of occurring.
   i. You are much more likely to get a mixture of different occupations than occupations that repeat.
   j. Other ____

5. In a small forest there are 96 trees. Of the trees, 11 are elm, 62 are oak, and 23 are maple. An ornithologist is interested in which how many bird landings occur in the various types of trees. Each time a bird lands on a tree she records the type of tree. If the first 3 bird landings are as follows: oak, maple, maple, what type of tree is the fourth landing MOST LIKELY to be on?
   a. An elm
   b. An oak
   c. A maple
   d. An oak and maple are equally likely and more likely than an elm.
   e. An elm, oak, and maple are equally likely.

5a. Which of the following best describes the reason for your answer to the preceding question?
   f. There are more oaks in the small forest.
   g. Every tree has an equally likely chance of being landed on.
   h. The fourth tree should not be a maple because too many maples have already been landed on.
   i. Maple seems to be lucky.
   j. Other ______________________________________

6. If a fair die is rolled eight times, which of the following ordered sequences of results, if any, is LEAST LIKELY to occur?
   a. 2 3 4 5 6 1 2 3
   b. 6 4 3 2 4 1 5 6
   c. 5 6 2 6 3 5 4 2
   d. 2 1 4 3 1 5 4 6
   e. All sequences are equally likely.

6a. Which of the following best describes the reason for your answer to the preceding question?

f. You are much more likely to get a mixture of different numbers than an ordered sequence.
g. Since rolling a die is a random event, a result like that is very unlikely.
h. All sequences of rolls have exactly the same probability of occurring.
i. You are much more likely to get a mixture of different numbers than numbers that repeat.
j. Other ____

7. A hospital employs 20 nurses: 15 females and 5 males. Every hour a computerized system randomly assigns one of the nurses to take an inventory of the medicines dispensed during the hour. Each time the computer records only the gender of the nurse assigned. If the first 6 genders are male, what genders are the next two nurses, if any, MOST LIKELY to be?

a. F F
b. M M
c. F M
d. M F
e. All of the above sequences are equally likely.

7a. Which of the following best describes the reason for your answer to the preceding question?

f. There are more female nurses employed by the hospital.
g. Every gender has an equally likely chance of being assigned.
h. The males seem to be lucky.
i. These genders might be just as likely as any other genders.
j. Other _______________________________________

8. A bag has 3 kinds of fruit: 1 apple (A), 1 pear (P), and 1 orange (O). Six types of fruit are picked at random, one at a time. Each time a fruit is picked, the type is recorded, and the fruit is put back in the bag. Which of the following ordered sequence of fruit, if any, is LEAST LIKELY to occur?

a. A A A P P P
b. A O P A O P
c. P P P P P P
d. O A O A O P
e. All of the above sequences are equally likely.

8a. Which of the following best describes the reason for your answer to the preceding question?

f. Since choosing types of fruit is a random event, a result like that is very unlikely.
g. You are much more likely to get a mixture of different fruits than an ordered sequence.
h. All sequences of fruits have exactly the same probability of occurring.
i. You are much more likely to get a mixture of different fruits than fruits that repeat.
j. Other ____

9. A bag has 6 candies: 2 candy bars, 2 lollipops, and 2 gum balls. Five candies are picked, one at a time. Each time a candy is picked, the type of candy is recorded, and it is then put back in the bag. If the first 4 candies were lollipops, what is the fifth candy MOST LIKELY to be?

a. A candy bar
b. A lollipop
c. A gum ball
d. A candy bar or a gum ball is both equally likely and more likely than a lollipop.
e. A candy bar, lollipop, or gum ball are all equally likely.

9a. Which of the following best describes the reason for your answer to the preceding question?

f. This candy might be just as likely as any other.
g. The lollipops seem to be lucky.
h. Each candy has an equally likely chance of being picked.
i. The fifth candy will not be a lollipop because too many have already been picked.
j. Other ______________________________________

10. On a given day a hospital has 8 births. Which of the following ordered sequences of genders (male (M), female (F)), if any, is LEAST LIKELY to occur?

a. F F M M F F M M
b. F F F F F F F F
c. M M F M M M F M
d. M M M F M F F M
e. All of the above sequences are equally likely.

10a. Which of the following best describes the reason for your answer to the preceding question?

f. Since birth is a random event, a result like that is very unlikely.
g. You are much more likely to get a mixture of genders than an ordered sequence.
h. All sequences of genders have exactly the same probability of occurring.
i. You are much more likely to get a mixture of genders than genders that repeat.
j. Other ______________________________________

11. A drawer contains the following buttons: square 20%, round 55%, triangular 15%, octagonal 10%. Three of the buttons are picked, at random, one at a time. Each time a button is picked, the shape is recorded and the button is put back in the drawer. If the first 2 buttons picked are round what shape is the third button MOST LIKELY to be?

a. Square
b. Round
c. Triangular
d. Octagonal
e. All the shapes are equally likely.

11a. Which of the following best describes the reason for your answer to the preceding question?

f. The third button should not be round because too many round buttons have already been picked.
g. There are more round buttons in the drawer.
h. Round buttons seem to be lucky.
i. Every pattern has an equally likely chance of being picked.
j. Other ______________________________________

12. A box contains 20 writing utensils: 5 pens and 15 pencils. Eight of the writing utensils are picked, at random, one at a time. Each time a writing utensil is picked, the type is recorded and the writing utensil is put back in the box. Which of the following ordered sequences of writing utensils, if any, is LEAST LIKELY to occur?

a. pen pen pencil pen pen pen pen pen
b. pencil pencil pencil pencil pencil pencil pencil pencil
c. pencil pen pen pencil pen pencil pen pencil
d. pen pencil pen pencil pen pencil pen pencil
e. All of the above sequences are equally likely.

12a.Which of the following best describes the reason for your answer to the preceding question?

f. You are much more likely to get a mixture of different writing utensils than an ordered sequence.
g. Since choosing writing utensils is a random event, a result like that is very unlikely.
h. You are much more likely to get a mixture of different writing utensils than writing utensils that repeat.
i. There are fewer pens than pencils in the box.
j. Other ______________________________________

Appendix H
UNDERSTANDINGS OF REPRESENTATIVENESS (Delayed postintervention)

<u>Directions:</u> **Please circle the <u>best</u> answer for each question from the options provided.**

1. A box contains 9 balls: 3 are red, 3 are white, and 3 are blue. Six balls are picked at random, one at a time. Each time a ball is picked, the color is recorded, and the ball is put back in the box. Which of the following ordered sequence of balls, if any, is LEAST LIKELY to occur?
   a. R R R B B B
   b. R W B R W B
   c. W W W W W W
   d. B R B R B W
   e. All of the above sequences are equally likely.

1a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since choosing balls is a random event, a result like that is very unlikely.
   g. You are much more likely to get a mixture of different balls than an ordered sequence.
   h. All sequences of balls have exactly the same probability of occurring.
   i. You are much more likely to get a mixture of different balls than balls that repeat.
   j. Other ____

2. A bag has 6 candies: 2 candy bars, 2 lollipops, and 2 gum balls. Five candies are picked, one at a time. Each time a candy is picked, the type of candy is recorded, and it is then put back in the bag. If the first 4 candies were lollipops, what is the fifth candy MOST LIKELY to be?
   a. A candy bar
   b. A lollipop
   c. A gum ball
   d. A candy bar or a gum ball is both equally likely and more likely than a lollipop.
   e. A candy bar, lollipop, or gum ball are all equally likely.

2a. Which of the following best describes the reason for your answer to the preceding question?
   f. This candy might be just as likely as any other.
   g. The lollipops seem to be lucky.
   h. Each candy has an equally likely chance of being picked.
   i. The fifth candy will not be a lollipop because too many have already been picked.
   j. Other ____

3. A hospital employs 20 nurses: 15 females and 5 males. Every hour a computerized system randomly assigns one of the nurses to take an inventory of the medicines dispensed during the hour. Each time the computer records only the gender of the nurse assigned. Which of the following ordered sequence of nurse genders, if any, is LEAST LIKELY to occur?
   a. F F F F F
   b. M M M M M
   c. F M F M F
   d. M F F M F
   e. All of the above sequences are equally likely.

3a. Which of the following best describes the reason for your answer to the preceding question?
   f. Since picking nurses is a random event, a result like that is very unlikely.
   g. You are much more likely to get a mixture of different nurses than an ordered sequence.
   h. All sequences of nurses have exactly the same probability of occurring.
   i. There are more females to choose from in the hospital.
   j. Other ____

4. A bag has 3 kinds of fruit: 1 apple, 1 pear, and 1 orange. Four pieces of fruit are picked, one at a time. Each time a piece of fruit is picked, the type of fruit is recorded, and it is then put back in the bag. If the first 3 pieces of fruit were apples, what is the fourth piece MOST LIKELY to be?
   a. A pear
   b. An apple, an orange, or a pear are all equally likely.
   c. An orange
   d. An orange or a pear are both equally likely and more likely than an apple.
   e. An apple

4a. Which of the following best describes the reason for your answer to the preceding question?
   f. This piece of fruit might be just as likely as any other.
   g. The apples seem to be lucky.
   h. Each fruit has an equally likely chance of being picked.
   i. The fourth piece of fruit will not be an apple because too many have already been picked.
   j. Other ____

5. A box contains 20 writing utensils: 5 pens and 15 pencils. Eight of the writing utensils are picked, at random, one at a time. Each time a writing utensil is picked, the type is recorded and the writing utensil is put back in the box. If the first 6 types of writing utensils are pencils, what type, if any, are the next two writing utensils MOST LIKELY to be?
   a. Pen Pencil
   b. Pen Pen
   c. Pencil Pen
   d. Pencil Pencil
   e. All of the above writing utensils are equally likely.

5a. Which of the following best describes the reason for your answer to the preceding question?
   f. There are more pencils to choose from in the box.
   g. The next writing utensils should not be pencils because too many pencils have already been chosen.
   h. Every writing utensil has an equally likely chance of being picked.
   i. These writing utensils are just as likely as any other writing utensils.
   j. Other ____

6. A drawer contains the following buttons: square 20%, round 55%, triangular 15%, octagonal 10%. Three of the buttons are picked, at random, one at a time. Each time a button is picked, the shape is recorded and the button is put back in the drawer. If the first 2 buttons picked are round what shape is the third button MOST LIKELY to be?
   a. Square
   b. Round
   c. Triangular
   d. Octagonal
   e. All the shapes are equally likely.

6a. Which of the following best describes the reason for your answer to the preceding question?
   f. The third button should not be round because too many round buttons have already been picked.
   g. There are more round buttons in the drawer.
   h. Round buttons seem to be lucky.
   i. Every pattern has an equally likely chance of being picked.
   j. Other ____

7. If a fair coin is tossed ten times and the first eight tosses result in the following sequence: H T T T T T T H. What are the next two tosses MOST LIKELY to be?

a. T T
b. H H
c. T H
d. H T
e. All sequences are equally likely.

7a. Which of the following best describes the reason for your answer to the preceding question?

f. The next two tosses should not be T T because too many T's have already been tossed.
g. Every sequence has an equally likely chance of being tossed.
h. T seems to be lucky.
i. This sequence might be just as likely as any other sequence.
j. Other ____

8. A box contains 6 blocks with different patterns: 2 have polka dots (P), 2 have hearts (H), and 2 have stripes (S). Six blocks are picked at random, one at a time. Each time a block is picked, the pattern is recorded, and the block is put back in the box. Which of the following ordered sequence of blocks, if any, is LEAST LIKELY to occur?

a. P H S P H S
b. P P P S S H
c. S H S S S S
d. H H H H H H
e. All of the above sequences are equally likely.

8a. Which of the following best describes the reason for your answer to the preceding question?

f. Since choosing blocks is a random event, a result like that is very unlikely.
g. You are much more likely to get a mixture of different blocks than an ordered sequence.
h. All sequences of blocks have exactly the same probability of occurring.
i. You are much more likely to get a mixture of different blocks than blocks that repeat.
j. Other _______________________________________

9. In a given community, people are engaged in the following occupations: 20% salesperson (S), 10% librarian (L), 15% airline pilot (A), and 55% physician (P). Everyday six members from the community come into the grocery store, at random, to purchase their food for the week. Each time a community member comes in their occupation is recorded. Which of the following ordered sequences of occupations, if any, is LEAST LIKELY to occur?

a. P P P P P S
b. L S L S A L
c. S S P S P P
d. P P S A S S
e. All of the above sequences are equally likely.

9a. Which of the following best describes the reason for your answer to the preceding question?

f. There are more physicians in the community.
g. You are much more likely to get a mixture of different occupations than an ordered sequence.
h. All sequences of occupations have exactly the same probability of occurring.
i. You are much more likely to get a mixture of different occupations than occupations that repeat.
j. Other _______________________________________

10. In a small forest there are 96 trees. Of the trees, 11 are elm, 62 are oak, and 23 are maple. An ornithologist is interested in which how many bird landings occur in the various types of trees. Each time a bird lands on a tree she records the type of tree. If the first 3 bird landings are as follows: oak, maple, maple, what type of tree is the fourth landing MOST LIKELY to be on?

a. An elm
b. An oak
c. A maple
d. An oak and maple are equally likely and more likely than an elm.
e. An elm, oak, and maple are equally likely.

10a. Which of the following best describes the reason for your answer to the preceding question?

f. There are more oaks in the small forest.
g. Every tree has an equally likely chance of being landed on.
h. The fourth tree should not be a maple because too many maples have already been landed on.
i. Maple seems to be lucky.
j. Other ______________________________________

11. If a fair die is rolled eight times, which of the following ordered sequences of results, if any, is LEAST LIKELY to occur?

a. 2 3 4 5 6 1 2 3
b. 6 4 3 2 4 1 5 6
c. 5 6 2 6 3 5 4 2
d. 2 1 4 3 1 5 4 6
e. All sequences are equally likely.

11a. Which of the following best describes the reason for your answer to the preceding question?

f. You are much more likely to get a mixture of different numbers than an ordered sequence.
g. Since rolling a die is a random event, a result like that is very unlikely.
h. All sequences of rolls have exactly the same probability of occurring.
i. You are much more likely to get a mixture of different numbers than numbers that repeat.
j. Other ____

12. On a given day a hospital has 8 births. Which of the following ordered sequences of genders (male (M), female (F)), if any, is LEAST LIKELY to occur?

a. F F M M F F M M
b. F F F F F F F F
c. M M F M M M F M
d. M M M F M F F M
e. All of the above sequences are equally likely.

12a. Which of the following best describes the reason for your answer to the preceding question?

f. Since birth is a random event, a result like that is very unlikely.
g. You are much more likely to get a mixture of genders than an ordered sequence.
h. All sequences of genders have exactly the same probability of occurring.
i. You are much more likely to get a mixture of genders than genders that repeat.
j. Other ____

Appendix I
CONCEPTUAL UNDERSTANDINGS OF PROBABILITY

Directions: **Below you will see terms commonly used in statistics and probability. Circle the best possible definition for each term or concept.**

1. A sample space is defined as:
   a. a set where all outcomes of an experiment are represented as points.
   b. a proposition that has been proven.
   c. a characteristic on which observable units differ.
   d. a non-ordered, categorical or qualitative variable or classification.

2. The law of large numbers is defined as:
   a. the values of various descriptive measures computed for large populations.
   b. a very large population with a finite number.
   c. a sequential ranking of observational units in relation to amount of variables.
   d. the theorem that the average of a large number of independent measurements tends toward the theoretical average.

3. An expectation is defined as:
   a. the mean of a random variable.
   b. the expected probability of an event.
   c. characteristics of distributions.
   d. a rule of associating event A with event B.

4. An event is defined as:
   a. a proposition that has been proven.
   b. an observable happening.
   c. the degree of an attribute or a variable.
   d. the midpoint of each interval to denote frequency.

5. The term mutually exclusive indicates:
   a. sample points in common.
   b. a characteristic on which observable units differ.
   c. a characteristic on which observable units are alike.
   d. no sample points in common.

6. Independence is defined as:
   a. event X influencing the probability of event Y.
   b. event X NOT influencing the probability of event Y.
   c. event X and event Y influencing the probability of each other.
   d. event X NOT influencing the expectation of event Y.

7. The probability of an event is:
   a. a number between 0 and 1.
   b. equivalent to its certainty.
   c. equivalent to its mutual exclusiveness.
   d. an undetermined number.

8. A distribution is considered discrete if:
   a. it has a continuous distribution function.
   b. it has an exponential distribution function.
   c. it is defined on a countable set.
   d. it is defined on a practical set.

9. The law of averages states that:
   a. given enough opportunity, bizarre, or odd patterns will happen purely based on chance.
   b. everything is possible, but something must happen.
   c. in numerous trials, the fraction of occurrences gets closer to the probability in one trial.
   d. there is not enough opportunity for unlikely events to occur enough to be recorded.

10. A random variable is defined as:
   a. a function associating a numerical value with every outcome of an experiment.
   b. a non-negative number defining the spread of the values of a variable.
   c. a probability associated with each of the variables' possible values.
   d. a function giving the probability that the variable X is less than or equal to Y.

Appendix J
THINKING ABOUT PROBABILITY

DIRECTIONS*:** Please fill in the corresponding circle below each item to indicate ***PRIOR TO TODAY the extent to which ***you have experience*** with the concept or activity described in the statement.

1. Playing the state lottery.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
2. Going to a casino.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
3. Guessing the gender of an unborn baby.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
4. Predicting outcomes of rolls of a fair die.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
5. Playing games of chance.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
6. Making decisions based on probability.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
7. Predicting outcomes of coin tosses.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
8. Predicting the outcome of a sporting event.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
9. Predicting outcomes of organized horse races at a track.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**
10. Judging the outcome of an uncertain event.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O	
not very experienced	**very experienced**

11. Playing roulette at a casino.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
12. Playing along with Deal or No Deal on television.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
13. Attending organized horse races at a track.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
14. Predicting the outcome of a game based on the record of the two teams playing.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
15. Guessing which ball is randomly selected from a container based on the balls previously selected.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
16. Playing at a casino.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
17. Playing the board game Risk.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
18. Playing the game Yahtzee.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
19. Playing an arcade grab game.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**
20. Playing a 50/50 raffle.	
O-----O-----O-----O-----O-----O-----O-----O-----O-----O **not very experienced**	**very experienced**

Appendix K

WHAT DO YOU THINK THE CHANCES ARE? (Version A)

Directions: **Please circle the best answer for each question from the options provided.**

1. A fair coin is tossed 5 times and the result is HHHHH. On the next toss, which outcome, if either, do you think has a better chance of occurring, H or T? (H=Heads, T=Tails)
a) H has a better chance of occurring.
b) T has a better chance of occurring
c) They both have the same chance of occurring.

Why?

I____________________I____________________I____________________I

just a guess | not very confident | fairly confident | I'm sure I'm right

2. In families with five children, which birth order, if either, occurs more often: BGGBG or BBBBB ?
B = Boy and G = Girl.
a) BGGBG occurs more often.
b) BBBBB occurs more often.
c) They occur equally often.

Why?

I____________________I____________________I____________________I

just a guess | not very confident | fairly confident | I'm sure I'm right

3. Your sports team finishes first in its league at the end of the season, so you consider it the best team. However you must compete in a playoff series against the second place team in the league to determine the champion. Would a 5 game series or a 9 game series give you a better chance of winning the championship, or it does not make any difference?
a) a 5 game series gives you a better chance.
b) a 9 game series gives you a better chance.
c) it makes no difference.

Why?

I____________________I____________________I____________________I

just a guess | not very confident | fairly confident | I'm sure I'm right

4. Tom lives in the Yukon. He drives long distances, often on snow-covered roads and rough or muddy trails. Sometimes he must cross shallow rivers and climb steep hills with his vehicle. Which of the two statements below has a greater chance of being true?
a) Tom drives a truck.
b) Tom drives a 4-wheel-drive truck.

Why?

I____________________I____________________I____________________I

just a guess | not very confident | fairly confident | I'm sure I'm right

5. A large container is filled with numbered balls. The average (mean) of all the numbers on the balls is 100. Three balls are drawn with replacement from the container. If the numbers on the first two balls drawn are both 130, what is your best estimate for the average (mean) of the numbers on the three balls drawn?
a) 100 b) 115 c) 120 d) 130

Why?

I____________________I____________________I____________________I
just a guess not very confident fairly confident I'm sure I'm right

6. Suppose John Olerud has a batting average of .333 (1 hit in 3 times at bat) against Jimmy Key. In a certain game he comes up to bat 6 times against Key. He has no hits the first 3 times at bat. What is your best guess as to how many hits he will get in his last 3 times at bat?
a) 0 b) 1 c) 2 d) 3

Why?

I____________________I____________________I____________________I
just a guess not very confident fairly confident I'm sure I'm right

7. Jack is tall and muscular. He exercises frequently and prides himself on his strength and his running and throwing abilities. He is often seen at certain sports events and driving his fast sports car. Which of the two statements below has a greater chance of being true?
a) Jack is a farmer.
b) Jack is a professional football player.

Why?

I____________________I____________________I____________________I
just a guess not very confident fairly confident I'm sure I'm right

WHAT DO YOU THINK THE CHANCES ARE? (Version B)

1. A fair coin is tossed once and the result is H. On the next toss, which outcome, if either, do you think has a better chance of occurring, H (heads) or T (tails)?
a) H has a better chance of occurring
b) T has a better chance of occurring.
c) They both have the same chance of occurring.

Why?

I____________________I____________________I____________________I
just a guess | not very confident | fairly confident | I'm sure I'm right

2. In a lottery called Pick 4, a 4-digit number like 2798 is generated. To win, the participant must have chosen the same 4-digit number. Albert has chosen the number 2222 and Bill has chosen the number 2332. Compare their chances of winning.
a) Albert has a better chance of winning.
b) Bill has a better chance of winning.
c) They both have the same chance of winning.

Why?

I____________________I____________________I____________________I
just a guess | not very confident | fairly confident | I'm sure I'm right

3. Your sports team finishes first in its league at the end of the season and so you consider it is the best team. However you must compete in a playoff series against the second place team in the league to determine the champion. Would a sudden-death 1 game playoff or a 5 game series give you a better chance of winning the championship, or does it make any difference?
a) a sudden-death 1 game playoff gives you a better chance.
b) a 5 game series gives you a better chance.
c) it makes no difference.

Why?

I____________________I____________________I____________________I
just a guess | not very confident | fairly confident | I'm sure I'm right

4. You are driving down the highway when you are passed by a car. Which of the two statements below has a greater chance of being true?
a) The car is red.
b) The car is a red convertible.

Why?

I____________________I____________________I____________________I
just a guess | not very confident | fairly confident | I'm sure I'm right

5. A large container is filled with numbered balls. The average (mean) of all the numbers on the balls is 100. Two balls are randomly drawn with replacement from the container and their numbers are recorded but not seen by you. If you now draw a third ball, what is your best estimate for the number on this ball?
a) 40 b) 70 c) 100 d) 130 e) 160

Why?

I____________________I____________________I____________________I
just a guess | not very confident | fairly confident | I'm sure I'm right

6. Suppose Joe Carter has a batting average of .250 (1 hit in 4 times at bat) against Jimmy Key. In a game in June, Carter gets no hits out of 4 times at bat against Key. Two months later in August, Carter again comes to bat 4 times against Key. How many hits do you expect him to get this time? a) 0b) 1

c) 2 d) 3 e) 4

Why?

I____________________I____________________I____________________I

just a guess not very confident fairly confident I'm sure I'm right

7. If a person is chosen at random from the Canadian population, do you think it is more likely that the person is more than 100 years old or less than 100 years old?

a) The person is more than 100 years old.

b) The person is less than 100 years old.

Why?

I____________________I____________________I____________________I

just a guess not very confident fairly confident I'm sure I'm right

Appendix L

Decision making is a critical part of our day to day experiences. Whether taking into consideration a young toddler or a CEO of a major Fortune 500 company, the vast majority of people in this world are faced with the challenge of making countless decisions and judgments everyday. In 1971, Slovic and Lichtenstein regarded decisions as "…frighteningly more important and more difficult than ever before (p. 652)." The current world is certainly no less complex than in 1971. People of today find themselves in a very complex, decision-laden world. These daily decisions are often made based upon a person's prior experiences, knowledge, beliefs, and even intuitions. Some judgments and decisions are so easy to reach, they are almost instantaneous and individuals don't even realize that they have made them. Others, however, require more diligence, time, and careful consideration of all potential options.

The final outcome of any decision whether easily decided or initially struggled with is at least partially based upon our beliefs concerning the unknown outcome of the situation or event. Although the outcomes of some events can be clearer or murkier than others, the general nature of decision making is uncertain. This uncertainty is especially evident in ambiguous situations. Given the uncertain nature of decision-making, individuals should utilize all of their resources when involved in this process. Probability is one area of study that can assist individuals in effective decision making.

Probability is known as the study of likelihood and uncertainty. Philosophers have painstakingly pondered over and repeatedly investigated probability for centuries. This may partially be due to the fundamental presence of probability in our everyday lives. Individuals often base their decisions and behavior on their perception of the probability of an uncertain event occurring.

Making decisions concerning uncertain events would be easy if all it took was a little intuition and real-world experience, but probability can inform such decisions and experience with probability tells us that there is more to it than intuition. Unfortunately, too, many people hold common misconceptions, or incorrect knowledge and beliefs, concerning probability and probabilistic situations. The ability to reason efficiently and successfully about probability is essential for many practical concerns such as making everyday decisions. Numerous everyday situations exist in which this kind of reasoning is evident. Three common situations in which incorrect judgments are frequently made are listed below.

Consider the following scenario. A family consists of seven people; a mother, father, and five children. All five children are boys (B = Boy). The parents in this family have been trying to conceive a girl (G = Girl) since they had their first child. They are debating whether to try one more time. The expense of having a sixth child is weighing heavily on their minds, but the payoff of having a girl would far outweigh the cost. What would you suggest for these parents? Would you tell them that after having five boys they are more likely to have a girl? Intuitively, many people believe that the chance of having a girl in six attempts is more likely than having all boys. Some people can even recall situations familiar to them in their own lives when they have known at least one out of six children was a girl. These people believe that the more children you have the more likely you are to have both genders represented, so by the sixth time a girl would be more likely for these parents considering whether to have another child because BBBBBB is less likely than BBBBBG.

Now let's look at that same example from the mathematical standpoint of probabilistic reasoning. In that same family mentioned above with five children, which birth order, if either, would you judge to be more likely to occur: BGGBG, BBBBB, or do they both have the same chance of occurring? (B = Boy & G = Girl) Many individuals erroneously choose BGGBG, believing that this birth order is more representative of births occurring over time since both possible outcomes are more equally represented than in BBBBB. In actuality, both the birth orders occur equally often. Each birth has the same chance of producing a girl or a boy, regardless of the outcome, or gender, of the prior births. Also, five births is a small sample. We cannot assume that small samples are representative of the population from which they are taken.

Another example in which individuals commonly incorrectly determine the probability of the occurrence of an event is with coin tosses. This type of event occurs frequently at the beginning of a sporting event such as football to determine who receives the ball first. Let's say that at the last five games for the Philadelphia Eagles the coin toss has resulted in heads (H = Heads) and each time the player has chosen tails, causing the team to lose the coin toss and the decision whether to receive the ball first or after half-time. For the sixth toss the players are collectively trying to decide whether to choose heads or tails. What would you suggest they predict if one of the players were to ask you? Would you tell them that after a string of HHHHH the sixth toss has got to be a T? Many people believe intuitively that it doesn't take probabilistic reasoning to realize that tails is due! If they want to make the decision for ball possession the players should choose tails!

Now let's look at that same example from the mathematical standpoint of probabilistic reasoning. Assume that same fair coin is tossed five times for the Philadelphia Eagles and the result is HHHHH. On the next toss, which outcome, if either, do you think has a better chance of occurring, H or T, or do they both have the same chance? (H = Heads & T = Tails) Given this information, many people are likely to predict "tails" after a run of five "heads" in order to obtain a sample that is more representative of the theoretical 50-50 distribution of heads and tails in the population. The correct answer, however, is that they both have the same chance of occurring. Each toss of the coin has a 50% chance of being heads and a 50% chance of being tails regardless of prior outcomes. Once again, the sample is too small to be assumed representative of the 50-50 distribution.

A final illustration where incorrect judgments are commonly made can be examined through the possible outcomes of a series of playoff games. Consider a time when you were on a team or were rooting for a team that finished first in its league qualifying it for a playoff series against the team in second place. You would probably consider this team to be the best since it has a first place record in its league for the season. Without considering possible injuries, would you rather see this team in a five game series or a nine game series? Many people frequently assess the five game series and the nine game series as equal opportunities to reflect the fact that one is the better team. In making this assessment, people may contend that if your team performs better in nine games, it will also perform better in five games. These people believe if a team is in first place throughout their entire season they are better than the competition. Whether they play five games or nine games against the second place team, the second place team is not as good and will not win the series.

Now let's look at that same example from the mathematical standpoint of probabilistic reasoning. Let's say, for example, that same sports team from the example above finishes first in its league at the end of the season. Therefore, you consider it as the best team in the league. However that team must compete in a playoff series against the second place team in the league to determine the champion. Would a five game series or a nine game series give your team a better chance of winning the championship, or doesn't it make a difference? In reality, a nine game series is a more accurate representation of who is the better team. Even if yours is the better team, the team may lose a couple games in a series to another good team. However, if playing a nine game series, a couple of lost games will not matter in the final outcome. In short, the better team is more likely to win the majority of the games of a nine game series than a five game series.

Many people, unfortunately, go throughout their lives making decisions based solely on their beliefs, intuitions, and what they think they know to be true. Others choose to employ probability to assist them in decision-making. Although the examples listed above won't have serious consequences if an incorrect prediction is made, some judgments in life require careful consideration with accurate information. Probability can greatly assist individuals in making sound decisions. Although the ultimate choice of whether to utilize probability lies within the individual, the study of probability informs us that our decisions can be significantly improved not simply by "going with our gut" but also by applying probabilistic reasoning in our decision-making process. It is obvious that employing probability will greatly improve anyone's decisions.

Appendix M

PENNSTATE

Senior Vice President for Research
Office for Research Protections

The Pennsylvania State University
201 Kern Graduate Building
University Park, PA 16802-3301

(814) 865-1775
Fax: (814) 863-8699
www.research.psu.edu/orp/

Date: June 5, 2007

From: Tracie L. Kahler, IRB Administrator

To: Jill A. Zeruth

Subject: Results of Review of Continuing Progress Report - Expedited **(IRB #23399)**
Approval Expiration Date: June 3, 2008
"Investigating Misconceptions in Probabilistic Reasoning: An Intervention"

The Continuing Progress Report for your project was reviewed and approved by this office on behalf of the Social Science University's Institutional Review Board (IRB). By accepting this decision, you agree to obtain prior approval from the IRB for any changes to your study. Unanticipated participant events that are encountered during the conduct of this research must be reported in a timely fashion.

Enclosed is the dated, IRB-approved informed consent to be used when enrolling participants for this research. Participants must receive a **copy** of the approved informed consent form to keep for their records.

If signed consent is obtained, the principal investigator is expected to maintain the original signed consent forms along with the IRB research records for at least three (3) years after termination of IRB approval. For projects that involve protected health information (PHI) and are regulated by HIPAA, records are to be maintained for six (6) years. The principal investigator must determine and adhere to additional requirements established by the FDA and any outside sponsors.

If your study will extend beyond the above noted approval expiration date, the principal investigator must submit a completed Continuing Progress Report to the Office for Research Protections (ORP) to request renewed approval for this research.

On behalf of the committee and the University, thank you for your efforts to conduct research in compliance with the federal regulations that have been established for the protection of human participants.

TLK/tlk
Enclosure
cc: P K. Murphy

Please Note: The ORP encourages you to subscribe to the ORP listserv for protocol and research-related information. Send a blank email to: L-ORP-Research-L-subscribe-request@lists.psu.edu

ORP USE ONLY: IRB#23399 Doc. #2
The Pennsylvania State University
Office for Research Protections
Approval Date: 09/10/07 JKG
Expiration Date: 06/03/08 JKG
Social Science Institutional Review Board

Appendix N

IMPLIED CONSENT FOR SOCIAL SCIENCE RESEARCH

The Pennsylvania State University (Fall '07 with Audio)

Title of Project: Investigating Misconceptions in Probabilistic Reasoning: An Intervention

Principal Investigator: Jill A. Zeruth, M.Ed.
227 CEDAR Building,
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(814) 863-4472; jag301@psu.edu

Advisor: P. Karen Murphy, Ph.D.
229 CEDAR Building,
University Park, PA 16802,
(814) 863-2278; pkm15@psu.edu

1. *Purpose of the Study*: The purpose of this research study is to examine decision-making processes.

2. *Procedures*: You will be asked to provide general demographic information. You will then be asked to complete a number of assessments.

3. *Discomforts and Risks*: There are no risks in participating in this research beyond those experienced in everyday life.

4. *Benefits*: This study will give you the opportunity to learn about a common misconception in probabilistic reasoning. After becoming familiar with this misconception, you may possibly correct any of your own. The investigators hope the study will help instructors make better decisions about how they deliver their class content and acknowledge misconceptions classically cited in the literature.

5. *Duration*: If you agree to participate in this study, you will be asked to meet at a scheduled research session outside of class time. The study should take about 40 minutes of your time.

6. *Statement of Confidentiality*: The surveys do not ask for any information that would identify you. Responses will be recorded without any names or other identifiers. Researchers will collect names in order to provide lists to teachers for extra credit points, but will not keep either the originals or copies of these lists. The following may review and copy records related to this research: The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Social Science Institutional Review Board and the PSU Office for Research Protections. In the event of presentation or publication, your identity will not be associated with the data. Audio equipment will be used in each condition, however, identification of participants will not be possible via the recordings. Only the principal investigator will have access to the recordings. The recordings will be stored in a locked file cabinet, and they will be destroyed five years after recording takes place.

7. *Right to Ask Questions*: Please contact Jill A. Zeruth at 863-4472 with questions, complaints or concerns about the research. You can also call this number if you feel this study has harmed you. If you have questions about your rights as a research participant, contact Penn State's Office for Research Protections at (814) 865-1775.

8. *Compensation*: In return for your participation, you will receive 3 extra credit points per your course syllabus. There is another option to receive the extra credit. This option is to write a one-page paper on a topic relevant to your class. Ms. Zeruth will collect the papers. Your course instructor will only know who receives the extra credit points and only after final course grades have been determined. *Some participants will also be eligible to earn a certificate for an ice cream at The Creamery based on performance.*

9. *Voluntary Participation*: You do not have to participate in this research. You can stop your participation at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this study will involve no penalty or loss of benefits you would receive otherwise and will not hurt your grade.

You must be 18 years of age or older to consent to participate in this research study.
Completion and return of the research materials implies that you have read the information in this form and consent to participate in the research.
Please keep this form for your records or future reference.

Appendix O

USING SHARED LEARNING TO PROMOTE ACHIEVEMENT

As is the case with knowledge and motivation, the education literature is full of terminology related to shared learning. It would behoove teachers who are interested in initiating or expanding shared learning experiences in their own schools and classrooms to be familiar with some of the most central terms. Each signifies some level of shared learning, and each can be found in some form in today's effective schools. The first step in orchestrating social interactions in classrooms and schools is to understand the language of socially shared learning.

Discussions are at the heart of social learning. A *discussion* is loosely defined as a constructive conversation between students and teachers who are willing to listen and learn from one another. What makes a quality discussion is not just that multiple speakers interject their individual thoughts and ideas, but that those ideas become intertwined and interwoven together as shared understanding. Social psychologists who study group dynamics and communication see discussion as an invaluable educational tool that can occur with the whole classroom, a small group, or even in dyads. Moreover, discussions can be used to achieve several outcomes including to: (a) help students explore the personal relevance of issues or content; (b) make students more active participants in the learning process; (c) put greater responsibility for learning on students' shoulders; (d) improve social skills; (e) promote comprehension; and, (f) give teachers clues as to what students think or believe. Yet, if discussions are to achieve these laudable ends, teachers must understand certain basic principles of human communication that underlie effective verbal interchanges.

Anyone who has spent time in classrooms appreciates how difficult it is to foster quality discussions. In many cases, teachers dominate classroom discussions so that they are sure to cover the content and so that students do not spread misconceptions. The good news is that if teachers establish rules *a priori*, than this is far less likely to happen. Teachers cannot expect students, who have spent most of their time in traditional classrooms, to know how to engage in a meaningful discussion instinctively. Students must acquire good discussion skills through teacher explanation, modeling, and guided practice. Discussion rules should be somewhat simple and should be linked to the goals or purpose of the discussion. Students must know and abide by simple rules of acceptable conduct during discussions. While usually small in number, the discussion rules are closely adhered to during any class discussion, and are often restated as the discussion begins. Rules may include some of the following: listen carefully; make your ideas known; support your opinions; one person speaks at a time; show mutual respect; participate but do not dominate; look at the person you are talking to and speak directly to them; and, make no derogatory personal remarks. Many of these rules allow the teacher to become a participant in the discussion, rather than the focal point of the discussion.

Another key to good discussions are good questions. Almost all of the discussion approaches in the literature begin with some sort of question. Sometimes the question is a central or defining one. Other times discussion begins with a lower-level question about a topic. What is most important is that the question be real. A *real question*, or what Nystrand termed an "authentic" question, is one for which the answer is not already known or one the questioner is genuinely interested in exploring. In other words, the answer is not pre-specified.

According to Nystrand, almost all student questions can be assumed to be real by default. Quite frequently, real questions allow for a range of responses and generate several responses before another question is asked. In thinking of real questions, especially those that will frame the discussion, teachers must ensure that they are suitably controversial or open-ended, and that there is room for multiple perspectives and ideas. Real questions usually require some justification of respondents' positions. Questions should also be crafted so that students have sufficient knowledge and experience to bring in the discussion. Finally, the ages and backgrounds of students should be considered when crafting questions. For example, a teacher must decide whether her fourth grade class has enough background knowledge on the causes of the Civil War in order to engage in a productive discussion.

For instance, in accordance with No Child Left Behind guidelines, Mr. Lauer, an elementary principal, teamed with Dr. Friend, a professor from a nearby university, to help teachers learn to identify and ask clear, thought-provoking questions during class discussions. Both Mr. Lauer and Dr. Friend agreed that discussions were important pedagogical tools that were not being used as often or as effectively as they could be. During the professional development sessions on classroom discourse, teachers were given guidance on how to use questioning to initiate and maintain discussions around important concepts in the class readings or the lessons. Mr. Lauer also had his teachers videotape a lesson which he used to reinforce the ideas touched on during Dr. Friend's professional development sessions. He also continued to meet with teachers throughout the semester to discuss their progress in this area. Based on the data that Dr. Friend collected before and after this intervention, there was a significant improvement in the frequency and quality of teachers' questions and also a marked increase in the frequency and quality of students' questions—just what Mr. Lauer and Dr. Friend wanted to see happen.

It is vital that students feel as though they can express their honest views—not those that they feel will win teacher approval. Because teachers remain the principal authorities and evaluators in the classroom, it makes sense that students want to gain their approval. If students believe that there is a "true" position or stance that their teacher wants promoted, then many will bend their own views to fit that preferred position. One way to avoid this type of situation is for teachers to avoid entering a discussion in too strong or direct a manner. Facilitating class discussions and controlling them are very different modes of operation. In facilitating a discussion, teachers would prompt student responses, seek clarification, and reflect on a stated opinion. It is a very different situation when teachers interject supporting examples or explanations that constrain the discussion. If teachers want to aid students during discussions, they should be very careful to offer general support that does not reveal their own views in any explicit way.

Discussions should not be thought of as the sole or primary mode of content delivery, despite their strengths in building shared understanding. The effectiveness of discussions rests on a breadth or depth of knowledge and adequate interest in the topic or issue. As such, administrators and teachers are urged to consider discussions to be a useful complement to other forms of social interaction.

Moreover, it is important to remember that discussions require flexibility in scheduling. That is, effective discussions do not always fall within precise time limits. In the elementary grades, it may mean that the discussion might carry over into time set aside for another subject-matter. For middle- or high-school teachers, whose students change classes, it may mean carrying the discussion into the next session. When the discussion is carried over to another day, it may be necessary to take steps to preserve the flow of conversation. In being flexible, it may also be necessary to modify the physical environment of the classroom. A classroom of students sitting in rows of desks, unable to see or engage others easily is unlikely to promote deep, meaningful discussion. Simply put, the physical arrangement in the learning environment can reinforce or undermine the goal of promoting the social exchange of ideas among students. This may mean that teachers will have to try multiple different arrangements to find the one that works best for their students and their goals.

For example, to cope with her large high-school literature classes, a colleague, Tamara Jetton, uses an arrangement she calls "inner-outer circle." The students form two concentric circles with their desks. Those seated in the inner circle begin the discussion, while those on the outer circle observe or make notes. Then, when signaled, the students shift positions. Those seated to the outside move into the inner circle and carry on the discussion, making references to the issues and arguments their classmates already put forward.

Like other forms of social interactions, discussion is most effective when all participants feel they have a role and a voice. In any classroom, there are some students who find it difficult to hold back so that others can share. And, there are some students who find it hard to speak out during discussions. Finding appropriate ways to promote balanced student involvement is part of the learning curve when using discussion as an instructional technique. Whatever actions teachers take, they need to ensure that all students participate in some manner during discussions. These simple ideas will help promote student understanding through shared learning.

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PUBLICATIONS

Murphy, P. K., Edwards, M. N., Buehl, M. M., & Zeruth, J. A. (in press). Using the *Domain-Specific Beliefs Questionnaire* with adolescents enrolled in high-poverty, high-minority schools: Examining psychometric properties. *Journal of Experimental Education*.

Edwards, M. N., Higley, K. H., Zeruth, J. A., & Murphy, P. K. (2007). Pedagogical practices: Examining preservice teachers' perceptions of their abilities. *Instructional Science, 35*, 443-465.

Murphy, P. K., Holleran, T., & Long, J. F., & Zeruth, J. A. (2005). Examining the complex roles of motivation and text medium in the persuasion process. *Contemporary Educational Psychology*, *30*(4), 418-438.

Murphy, P. K., Buehl, M. M., Zeruth, J. A., Edwards, M. N., Monoi, S., & Long, J. F. (in press). Examining the influence of epistemic belief and goal orientations on the academic performance of adolescent students enrolled in high-poverty, high-minority schools. In L. D. Bendixen & F. C. Haerle (Eds.), *Personal epistemology in the classroom: Theory, research and implications for practice*. Cambridge: Cambridge University Press.

SELECTED PRESENTATIONS

Kulikowich, J. M. & Zeruth, J. A. (2007, November). Does the worked example work when reading statistics texts? Paper presented at the annual meeting of the National Reading Conference, Austin, Texas.

Dornish, M., Sperling, R., & Zeruth, J. A. (2007, April). All generation strategies are not equal: Comparing elaborative comprehension strategies. Paper presented at the annual meeting of the American Educational Research Association, Chicago, Illinois.

Zeruth, J. A., Kulikowich, J. M., & Murphy, P. A. (2006, April). Knowledge, efficacy, and beliefs: Studying emergent expertise in probability. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, California.

Higley, K., Edwards, M. N., & Zeruth, J. A. (2005, August). The viability of the persuasion metaphor for educators with varying levels of teacher-efficacy. In H. Fives (Chair) *Teaching as persuasion: Is the metaphor viable?* Symposium presented at the annual meeting of the American Psychological Association, Washington, D.C.

Warcholak, N. D., & Zeruth, J. A., & Kulikowich, J. M. (2005, August). Reading about statistical probability by two groups of experts. In P. A. Alexander & M. N. Edwards (Chairs), *The road to domain expertise: Texts, situations, technology, and methodology.* Symposium presented at the annual meeting of the American Psychological Association, Washington, D.C.

Murphy, P. K., Alexander, P. A., Greene, J., & Edwards, M. E. (2005, April). Epistemological threads in the fabric of conceptual change. In J. A. Gushka (Chair), *Examining the hinge: The influence of epistemological beliefs in conceptual change*. Symposium presented at the annual meeting of the American Educational Research Association, Montreal, Canada.

Sperling, R. A., McCollum, D. L., Gushka, J. A., & Gormley, S. E. (2005, April). The approach is important: Consideration of achievement motivation in learners' general monitoring ability. Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.