

The effect of functional fixation in problem solving among preschool, second grade, and  
ninth grade children.

A DISSERTATION SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL  
OF THE UNIVERSITY OF MINNESOTA

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

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December 2014



## ACKNOWLEDGEMENTS

I would like to first thank my committee members: Dr. Twohig and Dr. Park, thank you for your assistance and for welcoming me into your insightful lunchroom conversations, Dr. LeBlanc, thank you for your assistance with the statistical analysis, and my co-advisors, Dr. Stertz and Dr. Brown, thank you for all of your assistance in helping me complete my dissertation. I would like to thank my many professors and the University of Minnesota; it truly was a world-class education.

I would like to thank all of the members of the National Center for Engineering and Technology Education (NCETE), for sharing your wisdom, guidance, friendship, and of course the fellowship, without which I may have never achieved this doctoral degree. I would like to especially thank my three NCETE fellows at the University of Minnesota: Dr. Chandra Austin, who I could always count on for support and practical advice; Dr. David Stricker, my officemate, friend, and philosophical debater; and Dr. Leah Roue who's friendship and hours of racquetball partnership helped me maintain my sanity throughout the whole process.

I would like to thank Dr. Brian McAlister and Dr. Ken Welty at the University of Wisconsin-Stout for their mentorship, guidance, support, and friendship from the moment I changed my bachelor degree to technology education. Thank you for believing in me, offering me opportunities like participation in NCETE, and for helping me see the vision of technological literacy.

I would like thank my participants, their parents, the schools, teachers and administrators, who graciously provided the data used in this study.

Finally, I would like to thank my family who gave me a great foundation to build on, a belief that education is key to life, and unconditional love and support.

## DEDICATION

To my grandparents, Dolores and John *Blackie* O'Brien,  
who always emphasized the importance of education through the example of earning their  
own advanced degrees, through their belief that we can accomplish anything that we set our  
minds to, and a philosophy of living life to its fullest.

To my family, especially my parents, Ken and Peggy,  
for always supporting me and  
my brother, Patrick, who always set a high academic bar.

To Jessica Hofschulte, it has been a long time coming.

And finally, to my daughters, Olivia and Payton,

I hope this inspires you to achieve great heights!

## ABSTRACT

Functional fixedness is a cognitive function whereby an individual becomes fixated on a given function of an object, which prevents the individual from using the object in an alternative fashion to solve a problem (Duncker, 1935/1945). The current study analyzed the effect of functional fixedness on 36 children from three different age groups, preschool, second grade, and ninth grade. The children were presented with a problem solving activity based on a problem used by German and Defeyter (2000), in which they concluded that young children are immune to the effects of functional fixedness. Research conducted by Chrysikou (2006) indicated using an alternative categorization task could reduce the effects of fixation. The current research sought to answer three research questions: are children susceptible to the effects of functional fixedness; are there differences in the effect of functional fixedness based on age; and does participating in an alternative categorization task reduce the effect of functional fixedness. The results indicated that children are susceptible to the effects of functional fixedness, when the children use the target object in a typical preutilization function, regardless of age. The results also did not demonstrate a reduction in the effect of functional fixedness after participating in an alternative categorization task.

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## CHAPTER ONE

Technology as defined by the International Technology Education Association (2000, p2) is "...[a] diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants." According to the American Heritage College Dictionary (1993), the word technology is derived from the Greek word tekhnologia meaning systematic treatment of an art or craft: teché meaning skill and ology defined as science, theory or study. Throughout history, people have used their problem solving ability to develop new technology to meet their wants and needs. Despite the dependence on creating solutions to society's problems, little formal research has been conducted on the development of the cognitive thought involved in technological problem solving or the most effective means of teaching children how to improve their problem solving ability.

### *Problem Solving in Education*

Problem solving, the process of developing a plausible solution to an encountered obstruction, is an important cognitive ability used throughout a person's life. The importance of problem-solving is recognized by teachers of English, Mathematics, Science, Social Studies, and Technology, as evidenced by its inclusion in their professional association standards (International Reading Association and the National Council of Teachers of English, 1996; International Technology Education Association, 2000; National Council for the Social Studies, 1994; National Council of Teachers of Mathematics, 2000; National Research Council, 1996). Despite the apparent importance

of the development of problem solving abilities, research on problem solving within the educational community is limited (Petrina, Feng, & Kim, 2007).

The lack of research on problem solving within technology education requires the study of research in other disciplines, particularly cognitive development. One area of problem solving that has received some attention from the cognitive development community is the impact of functional fixation on an individual's ability to generate solutions. According to Duncker (1935/1945), functional fixedness is a condition where an individual's problem solving ability is impaired due to a fixation on the common or intended function of an object. Brown (1989) concluded some forms of learning during analogous problems can create situation of functional fixedness or negative transfer in children as young as two. While other forms of learning within the same, analogous problems can create flexible thinking. In contrast, German and Defeyter (2000) conducted a study using a different methodology and concluded children younger than the age of six demonstrated immunity to functional fixedness. Chrysikou (2006) in a study on insight problems concluded the use of an alternative categorization task could reduce the effect of functional fixedness.

### *Purpose of the Study*

The purpose of the study is to understand the differences in children's thought processes as they develop solutions to technological problems. The specific aspects of problem solving the study will focus on are: the existence of functional fixedness in technological problem-solving, understanding how functional fixedness affects children's

development of solutions, and the differences of functional fixedness in children pre-kindergarten to ninth grade.

### *Statement of the Problem*

In general, little is understood concerning the cognitive and developmental dimensions of technological problem solving and more specifically, there is a debate within the literature on the role of functional fixedness in problem solving.

### *Research Questions*

1. Are children impacted by functional fixedness when solving technological problems?

Hypothesis I: There is no difference in the use of the target object in participant's solutions to the problem, based on the target object being presented to the participant in a fixated condition or a nonfixated condition.

Hypothesis II: There is no difference in the amount of time participants spent solving the problem, based on whether or not the participants used the target object.

Hypothesis III: There is no difference in the amount of time participants spent solving the problem based on whether they received the object in the fixated or nonfixated condition.

2. Is there a difference in functional fixedness in children from pre-kindergarten to ninth grade?

Hypothesis IV: There is no difference in the problem solving performance between preschoolers, second graders, and ninth graders.

3. Does completing an alternative categorization task, a form of divergent thinking task, improve problem-solving performance?

Hypothesis V: There is no difference in problem solving performance between participants who were presented with the alternative categorization task prior to attempting to solve the problem.

### *Contributions to Technology Education*

The significance of the study is to improve pedagogy and curriculum development within the field of technology and engineering. By having a deeper understanding of the cognitive development of problem solving, educators will be able to improve instructional strategies for teaching students how to be better problem solvers. Secondly, by having a deeper understanding of the cognitive development of problem solving, educators will be able to improve the development of curriculum used to instruct students on problem solving. Finally, by having a deeper understanding of the cognitive development of problem solving, educators will be better prepared to assist individuals to improve their problem solving strategies.

## CHAPTER TWO

### Literature Review

#### *Cognitive Development Theories*

In order to begin to understand the cognitive development of problem solving, first one needs to have an understanding of the different theories of cognitive development. Some of the most widely referenced theories of cognitive development, Piaget, Vygotsky, Information Processing Theory, as well as the Goswami's theory, which is less known within the educational community.

Jean Piaget, one of the most often cited developmental psychologists, applied his formal education in biology and natural sciences to his desire to understand the human psyche. Much of Piaget's work is focused on the structural changes of intelligence and not the functional aspects. At the core of the Piagetian theory is the mechanism of equilibration. Equilibration, in terms of Piaget, is most notably the balance between assimilation of the new to the old and accommodation, adapting the old to the new. The mechanism of equilibration leads to the development of new knowledge by building on what the individual has already learned (Flavell, 1963; Smith, 2002).

Piaget is most notably known for his theory of developmental stages or periods: sensory-motor, preoperational, concrete operational, and formal operational. The first period, sensory-motor period, in which the infant's cognition develops from simple sensory input from their reflexes to a toddler who is capable of making internal symbolic

representations based on sensory-motor input. There are six stages within the sensory motor period. In the first stage, the infant is a newborn and exhibits little more than primitive reflexes, such as sucking, swallowing, and crying. In the second stage, the infant's reflexes become more coordinated, such as a reflexive precursor to grasping. In the third stage, infants begin to focus their actions toward objects around them. In the fourth stage, infants' actions are now recognizable as intentional. In the fifth stage, infants begin to seek new experiences to explore. In the final stage, infants are able to create internal representations of their experiences (Flavell, 1963).

Following the sensory-motor period is the period of preparation for and organization of concrete operations. The first subperiod is preoperational thought, where a toddler begins to apply their newly developed ability of representation to increasingly more complex problems. As children progress through the preoperational subperiod their thought process becomes less ridged and more flexible. Finally, children in the preoperational subperiod progress from representational thought to simple intuition, and finally to articulated representations. The second subperiod is concrete operations, where children begin developing organized cognitive structures called groupings (Flavell, 1963).

The final period is the period of formal operations. The period of formal operations is marked by children's ability to think abstractly. The restructure that occurs within the formal operations period allows the child, for the first time, to think about all of the possible consequences of their actions or decisions. Children are able to use hypothetical deductive reasoning. Finally, within the formal operations period the

groupings, cognitive organizational structures, are firmly developed and an interconnected lattice is developed (Flavell, 1963).

Although Piaget may have had more impact on developmental psychology than any other person, over the past thirty years many of his theories have been proven to contain flaws (Goswami, 2002b; Lourenco & Machado, 1996; Murphy, 2002; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Thomas & Karmiloff-Smith, 2002). The most cited part of Piaget's theory, developmental stages, is also the most contested. Many of the studies conducted within the last thirty years have demonstrated the basic structures and functions of young children and infants are not unlike those of adults (Murphy, 2002). However, this does not imply an absence of cognitive development. Rather what many modern psychologists will argue is the basic neurological structures and rudimentary functions are present at birth. However, the cognitive differences existing between children and adults are a result of differences in experiences, domain knowledge, and processing capacity.

A second prominent developmental psychologist is Vygotsky. Vygotsky's work is most noted for his inclusion of the social and cultural influence on cognitive development. Much like Piaget, Vygotsky argued cognition was developmental and needed to be studied across the lifespan. Vygotsky argued language among other cultural and social tools mediates the cognitive development process. Vygotsky argued that it is not possible to study a child's cognitive development by studying the child in isolation, but rather one needs to study the child's cognitive development as an interaction between the cognitive tools they use within the cultural society in which the learning occurs.

Finally, Vygotsky is also widely known for his idea of zone of proximal development, in which a comparison is made between the level of learning which occurs by an isolated individual versus the level of learning that occurs with the guidance of an expert. In other words, studying the potential increase in cognitive development as a result of having a teacher or mentor (Rowe, & Wertsch, 2002).

More recently Information-Processing models have been developed to study and understand cognitive development. Information-processing models are a collection of models that seek to understand cognitive development through the use of computer analogies. A major premise behind information-processing models is the brain receives input from our senses, processes the impulses into representations, and uses the representations to produce an output. Information-processing models have introduced a variety of new theories and approaches to studying cognitive development (Goswami, 2002a; Halford, 2002; Morra, Gobbo, Marini, & Sheese, 2008; Siegler, 1997; Siegler, & Alibali, 2004; Sternberg, 2002). Some examples of new areas of research in information-processing models are processing speed, cognitive complexity, and structure mapping (Halford, 2002).

Each of the aforementioned theories of cognitive development offered frameworks for the study of cognitive development, each with their own tradeoffs. Goswami (2002a) offers a twenty-first century framework that combines the time tested positive aspects of each of these theories into a one new framework. To construct this theoretical framework, Goswami suggests taking the idea of knowledge being rooted in action and experience from Piaget's theory. While at the same time discarding the ideas

of content-independent developmental stages for the connectionist's idea that cognitive development is incremental and context-dependent. The new framework would replace Piaget's idea of language and representation as secondary to cognitive development with Vygotsky's emphasis on the importance of language and culture in cognitive development. It would include Vygotsky's idea of the importance of parents, teachers, and other caregivers in the development of knowledge. Finally, the framework would include the information-processing models' hypotheses of higher-order cognitive processing needed to organize individuals' complex and varied experiences.

Goswami (2002a) argues this new framework is based on the empirical evidence that infants are either born with or acquire through simple perceptual experiences a set of core principles that manage the development of future knowledge. The successful implementation of this new framework is dependent on accurately describing the child's cognitive framework, understanding the circumstances that lead to changes in a child's explanatory framework, and determining the role of social and emotional experiences.

### *Problem Solving*

Using Goswami's (2002a) framework for understanding cognitive development in order to interpret the cognitive research on problem solving one would begin by examining problem solving research conducted with infants and toddlers.

Research in problem solving covers a wide range of topics, including inductive reasoning, deductive reasoning, causal reasoning, moral reasoning, and analytical reasoning, among others. Traditionally, problem solving was studied by determining if children could discover and apply logical rules to isolated context-independent novel

situations. Problem solving was considered a separate entity from concept formation. However, more recently researchers have determined problem solving and concept formation are interrelated and often depend on categorization, memory, context, prior experience, and transfer (Goswami, 2002b).

### *Infants' Problem-Solving*

In recent years, there have been a number of researchers studying infants' problem solving abilities. Infants as young as 18-weeks-old have demonstrated an ability to use problem solving strategies when reaching for a moving object. In von Hofsten's (1980) study, infants, 18-weeks-old to 36-weeks-old, were presented with a moving object at three different rates of travel, 3.4cm/sec, 15cm/sec, and 30cm/sec. At the slowest speed, 3.4cm/sec, the infants would reach for the moving object with their ipsilateral arm, meaning the arm located on the same side of their body as the object at its starting point, resulting in a chasing motion, at about the same frequency as their contralateral arm, the arm opposite the object at its starting position, which results in a path of interception. However, when the object was moving faster at 15cm/sec and especially at 30cm/sec, the infants almost always chose to use their contralateral arm, resulting in a path of interception rather than attempting to chase the object. The results of the study indicated that infants as young as 18-weeks-old are able to predict their ability to catch a moving object based on its rate of travel and to choose the strategy that is more likely to result in the successful accomplishment of that goal.

In a later study of infants 5-months-old to 13-months-old, von Hofsten and Ronnqvist (1988) observed that infants, like adults, begin to close their hand to grasp a

moving object 75% of the time before coming in contact with the object, which requires the infant to take into consideration the objects distance and velocity in relationship to the infants own hand. Again indicating an ability to adjust their strategy to accomplish their goal. In order to further understand infants' ability to predict the trajectory of a moving object, von Hofsten, Vishton, Spelke, Feng, and Rosander (1998) modified a drafting plotter to create an experiment that would allow an object to change its linear motion in an non-predictive pattern. The results of the study indicated that infants continued to follow the objects initial linear path for at least 200 ms after the object hand changed direction, which indicates that the infants' were anticipating the trajectory of the object's motion in order to move their hand to intercept the object. The results also indicate that infants as young as 2-months-old are able to apply their visual perception of distance and velocity in order to devise a plan of action to achieve a given goal, also referred to as problem solving.

In a related study, Chen, Keen, Rosander, and von Hofsten (2010) observed when toddlers, 18- to 36-months-old, built towers out of wooden blocks, they demonstrated similar kinetic motions and techniques as adults who performed similar tasks; specifically, planning their movements as a complete set of movements not as individual sequential movements (Rosenbaum, Halloran, & Cohen, 2006). First, the toddlers' movements indicated a planning of the complete sequence of movements to achieve the goal of stacking the blocks upon the initial movement of their hand, instead of planning each individual movement, such as adjusting their movement after picking up the block. Second, the toddlers who were more skilled at constructing the tower would reach their peak speed early in the movement in order to allow for a greater deceleration as they

approached the tower resulting in greater control of placing the block. This use of early acceleration and greater deceleration when precision was needed is consistent with the way adults complete similar tasks, which indicates an anticipation for the need for slower hand movements in precision operations (Chen, Keen, Rosander, & von Hofsten, 2010).

Similarly, Claxton, Keen, and McCarty (2003) observed 10-month-old infants adjusted the speed in which they would reach for an object based on their intended use of the object. Similar to adults, the infants would reach for a ball at a slower rate of speed, when they were going to complete a task, which require precision (placing the ball in a narrow tube). However, the infants would reach for the same ball at a much faster pace if they were going to throw the ball into a large tube located on the floor (a task which does not require precision).

A second area of research into infants' problem solving is the area of hand grasping orientation in relationship to the alignment of tools or objects. In a series of studies in which infants were presented with a rod orientated in a horizontal or vertical position, 7-month-old and 9-month-old infants consistently preoriented the alignment of their hands in relationship to the alignment of the rod. In order to determine if the infants preorientation was determined by visual cues rather than a mental representation of the object, the experimenters conducted the reaching task both in a well lit room and in darkness (McCarty, Clifton, Ashmead, Lee, & Goubet, 2001).

In the first experiment, the infants were presented with the rod in visual light and with a glow-in-the-dark rod with the lights turned off. The result of the experiment indicated that there was no significant difference in the infants' hand orientation based on

the lighting condition. The experiment also indicated that although 5-month-olds did grasp the rod with the appropriate hand orientation, they did not consistently preorientate their grasp before coming in contact with the rod. However, both the 7-month-old and 9-month-old infants consistently preorientated their hand to the appropriate grip before coming into contact with the rod. The results of the first experiment indicated that the infants' visual observation of their hand did not influence the infants' preorientation (McCarty, et al., 2001).

In the second experiment the rod was again display to the infants in a lighted condition, where the rod was illuminated by a light installed inside the rod and in a darkened condition where the rod would be illuminated at the beginning of the trail but as the infants hand reached 10cm from the rod, the infant would trigger an infrared beam that would turn off the rod, leaving the infant in the dark. The result of the second experiment indicated that the 7-month-old and 9-month-old infants again preorientated their grip according to the alignment of the rod when they last saw it, indicating they had constructed a mental orientation of the rod even though they could no longer see it. The results of the experiment also indicate that 7-month-old infants have already developed proprioception, the ability to sense the location and orientation of ones own limb without being able to see it by using the tactile sensation of movement (McCarty, et al., 2001).

In the third experiment, only 9-month-old infants were used and both conditions were presented in a darkened room. In one condition, the rod was illuminated and brought within the reaching space of the infant. In the second condition, the rod was illuminated briefly in order to show the infant the rods orientation before it was turned off

and moved into the infants reaching space. In both conditions, the infants preorientated the appropriate grip based on the orientation of the rod. The results of the third experiment indicates that 9-month-old infants are able to construct a mental image of an object and store that image in the memory in order to complete a task (McCarty, et al., 2001).

Clifton, Rochat, Litovsky, and Perris (1991) conducted a study with 6-month-olds to determine if infants are able to create mental representations of objects, based on differences in grasping motion whether the object they were reaching for was large or small. In a fully lit room, the infants did consistently vary the alignment of their arms based on whether the object they were looking at was large or small. To determine if the infants could create a mental image of the objects, a different sound was associated with the two objects, which provided an auditory clue as to whether the object was large or small. Then the lights in the room were turned off and the infant was presented with the two objects along with their corresponding auditory clues. Using infrared cameras, the infants were observed using the same differentiated arm motions based on whether the object was large or small. Therefore, the researchers concluded that the infants had to have created a mental image of the object in order to determine the appropriate grasp before touching the object.

Berger and Adolph (2003) studied means-end problem solving in 16-month-old infants. The infants were directed to walk across wide and narrow bridges with and without a handrail to determine what strategies they would implement to successfully cross over the bridge. Based on the results of their study, Berger and Adolph determined

infants develop a variety of strategies to adjust to the conditions of the task at hand. They also argue infants are able to apply higher order cognitive skills to determine the appropriate selection and adjustment of problem solving strategies.

Berger, Adolph, and Lobo (2005) continued their research on infants' means-end problem solving to determine if the material the handrail was constructed out of would impact 16-month-olds' strategies. Sixteen-month-old infants were again directed to walk across three bridges varying in width, while using a handrail. However, in this study the infants were presented with a handrail made of wood and another made of foam. The first goal of the study was to determine if infants were able to consider the material properties of the handrail. The second goal of the study was to observe the process infants demonstrated in determining the need for a tool, searching for a tool, and using the tool. The third goal of the study was to determine if walking experience influenced the use of the handrail.

Infants in the handrail study demonstrated their ability to determine differences in materials properties through exploration. Instead of abandoning the softer handrail, as the researches predicted, the infants demonstrated novel strategies to achieve a solution to their means-end problem. Berger, Adolph, and Lobo (2005) argue infants are able to determine when it is necessary to employ the use of a tool. Once an infant has determined the need for a tool, they will begin exploring their surroundings for a viable solution. Finally, within their exploration infants will evaluate the structural and material properties of potential tools.

McCarty, Clifton, and Collard (1999) conducted a study with infants and toddlers, 9-months-old, 14-months-old, and 19-months-old to examine their goal directed problem solving strategies. In order to study if the children's grasp selection was determined by a specific goal, the children were presented with a spoon that contained food or a spoon with a toy attached to it. As a result, the children consistently inserted the spoon containing the food in their mouth. However, the children did not consistently insert the spoon with the toy in their mouth, indicating that the children's movements related to the spoon with the food was based on the specific goal of feeding.

The children were presented with the spoon aligned so that the handle was near one hand and the bowl end was near the other hand. The orientation of the spoon was alternated so the handle end would be near their preferred hand on alternating trials. This variation presented the problem to the children to either alter their grip, alter the path of the spoon to their mouth, or to grasp the food end of the spoon. The results of the study indicated that the 9-month-old infants did not always plan their actions relative to the alignment of their grip and the path to their mouth, resulting in inserting the handle end of the spoon first before readjusting the spoon to get the food in their mouth. The others referred to this strategy as the feedback-based strategy, meaning that the infants would only adjust their strategy when they received feedback that their plan was not working.

Fourteen-month-olds on the other hand, were more likely to demonstrate a partial planned strategy, in which they would alter their path to their mouth when they determined their grip would result in a misalignment of the food-end of the spoon with their mouth. When the 14-month-olds gripped the spoon with the wrong hand, they

always made corrections before reaching their mouth, preventing them from inserting the handle end of the spoon. The third strategy demonstrated by the children was the fully planned strategy, where the selection of the grip and the path to the child's mouth was planned before reaching for the spoon. Finally, the researchers observed that the 19-month-olds were more likely than the younger children to suppress their initial tendency to use their preferred hand, resulting in a strategy of altering their hand selection based on the alignment of the spoon.

McCarty, Clifton, and Collard (2001) conducted a study of infants' problem solving strategies with infants, 9-, 14-, 19-, and 24-months-old. The infants were presented with four different tools, a spoon, a hairbrush, a toy hammer, and a magnet. After being orientated to the use and purpose of the tools, the infants were asked to complete six tasks: spoon-to-self, spoon-to-other, brush-to-self, brush-to-other, hammer-to-object, and magnet-to-object. McCarty, Clifton, and Collard observed, the 9-month-olds generally used oral exploration of the tools instead of their demonstrated function. The one exception was the use of the spoon; the 9-month-olds appropriately used the spoon 76 out of 107 trials. The older infants appropriately used each of the tools the majority of the time. The researchers concluded appropriate tool use probably occurs between 9 and 14 months. Additionally, as infants become more familiar with a tool their actions indicate an anticipation of selecting the appropriate solution.

In a similar study, Claxton, McCarty, and Keen (2009) observed 19-month-old toddlers were more likely to apply the more efficient radial hand grip to tools when the task affected themselves (feeding oneself) than when the task was affected another object

(pouring water into a waterwheel to cause it to rotate). The results indicate that human's problem solving ability first develops in the context of how a solution will benefit the individual to later ability to develop solutions that will benefit others.

In addition to studying infants' problem solving as it relates to tool use. Researchers have examined the problem solving strategies preschoolers use in order to accomplish mathematical problems. The results of Cohen's (1996) research supports previous research that preschoolers use a repertoire of strategies to solve mathematical problems and therefore do not solely rely on one strategy. The results also indicated that despite not being encouraged to do so, the preschoolers continued to adjust their problem solving strategies in an attempt to increase their problem solving efficiency, as measured by the number of moves and solution strategy. The children demonstrated a progression towards a more sophisticated organizational strategy of the problem-solving task, resulting in the increase in efficiency. As the preschoolers became more familiar with the problem-solving task, they moved from undefined to defined strategies.

In recent years, habituation experiments have indicated that young infants possess the ability to understand core concepts of physics, such as solidity and continuity of objects (Spelke, Breinlinger, Macomber, & Jacobson, 1992). However, there is also recent research that indicates that toddlers no longer possess the same ability to understand physical concepts. Although the data from these studies may indicate that toddlers somehow lose their understanding of basic concepts of physics, Keen (2003) explains that the differences are more likely a result of differences in methodology. In the infant research, experimenters use habituation to determine if infants recognize

inconsistencies in the laws of physics, based on the theory that infants will look at a situation longer if it is unfamiliar to them. In contrast, research involving toddlers, requires the participants to actively search for an object.

Baillargeon (1994) provides an additional explanation as to how the changes in infants physiological development, not necessarily cognitive develop and changes in research methodology could be the contributing factor in discrepancies in research results between infants and toddlers. Many studies report infants develop a greater understanding of concepts of physics around six months of age. As Baillargeon points out, around six months of age, infants begin to sit upright providing them with a better vantage point in which to observe and interact with their surroundings. Therefore, six-month-old infants' physiological development, sitting upright, leads to a greater understanding of their surroundings, not necessarily a simple increase in cognitive function or neurological development.

### *Preschoolers' Problem-Solving*

According to Want and Harris (2001), little research has been conducted on young children's ability to use tools to accomplish a problem-solving task. Much of the early literature with in the field of psychology has focused on non-human primates' ability to use tools in problem solving. Want and Harris' conducted two studies with 2- and 3-year-old children to understand the relationship between young children's understanding of adults' demonstrated tool use and the children's understanding of the causal relationships of tool use and the successful solution to a problem-solving task. In the study, children were presented with two different problem-solving apparatus, which

contained a toy that needed to be retrieved. In the first study, the children were presented with an elongated H-shaped tubular structure, with one leg of the H containing a vertical tube, which would trap the toy if it were to fall in it. The problem required the children to insert an L-shaped stick into the horizontal tube and push the toy away from the “trap” to the other end of the horizontal tube, in order to retrieve it. If the toy was pushed from the wrong side, it would fall down into the vertical tube, becoming trapped.

The children were assigned to one of four groups, two experimental groups and two control groups. In one experimental group, the children were given a demonstration on how to correctly use the tool to retrieve the toy from the horizontal tube. In the second group, the children were first given a demonstration on how to incorrectly use the tool to retrieve the toy, resulting in the toy falling into the vertical “trap” and the experimenter exclaiming oops. The experimenter would replace the toy and demonstrate how to correctly use the tool to push the toy away from the vertical trap and out the other side. In the two control groups, the experimenter demonstrated the same tool use motion, however, the tool was never inserted into the tube, but rather was moved along the top of the horizontal tube. The children had 90 seconds to complete the task and the apparatus was rotated 180° (switching the side of the trap) after each attempt (Want & Harris, 2001).

Only 2 out of the 20 children who were in the control group successfully used the tool to retrieve the toy from the tube. In other words, the children were unable to learn how to retrieve the toy from the apparatus by simply watching an adult perform the motions of the tool path in seemingly abstractness, without the tool actually traveling

inside the tube and contacting the toy. Conversely, all of the children in the experimental groups used the stick to either push the toy into the trap or successfully retrieve the toy. Although the 2-year-olds in the experimental groups use the tool to move the toy, there was no significant difference in successful retrieval of the toy based on which experimental condition they received. However, the 3-year-olds did demonstrate a significant increase in successful retrieval rates within the experimental group, which received the demonstration of the incorrect direction to push the toy, leading to it falling into the vertical trap, and the demonstration of the correct direction to push the toy resulting in the retrieval of the toy. This difference could indicate that the 3-year-olds in the incorrect plus correct demonstration had a greater understanding of the causal relationship between the direction of travel and the successful retrieval of the toy (Want & Harris, 2001).

Want and Harris' (2001) second study used a vertical Y-shaped channel made out of wood and covered with acrylic, to allow for clear visibility. Near the bottom of the Y was a toy that was secured to the side of the channel by a magnet, which could be knocked free by dropping a marble into one of the two openings at the top of the Y. One side of the Y allowed the marble to freely travel down the Y to the location of the toy and then out the bottom. The other side of the Y had a wooden block, which prevented the marble from passing through.

In this second study, the 2-year-olds and 3-year-olds were divided into five demonstration groups. The first group watched a demonstration where the marble was placed in the correct side of the Y, resulting in the toy being retrieved from the bottom of

the apparatus. In the second group, the children watched a demonstration of the experimenter placing the marble first in the incorrect side of the Y, resulting in the marble becoming visibly blocked and the experimenter exclaiming oops. Then they watched as the experimenter placed a second marble into the correct side of the Y, resulting in the toy being retrieved. In the third group, the children watched as the experimenter lowered the marble partway into the incorrect side of the Y and exclaimed oops, before withdrawing the marble and dropping it into the correct side of the Y, resulting in the toy being retrieved. In the fourth group, the children watched the experimenter drop the marble into the incorrect side of the Y, where it was visibly stuck, resulting in the experimenter exclaiming oops. The fifth group was considered the control group, where the children watched the experimenter trace the correct marble path on the outside of the acrylic (Want & Harris, 2001).

Consistent with the first study, 17 of the 20 children in the control group did not insert the marble into either side of the apparatus, indicating that seeing the tool path did not provide enough information for the children to successfully attempt to solve the problem. Overall, the children across age groups were more successful at using the tool to solve the problem than the children in the control group. However, there was no significant difference among the 2-year-olds when compared across the four experimental conditions. Therefore, the researchers argue that the 2-year-olds were able to learn the causal relationship between the tool use and the successful retrieval of the toy on a global scale, meaning they understood the marble could be used to dislodge the toy. However, the 2-year-olds did not understand the detailed causal relationship between the path the

marble traveled, the block included in one of the paths, and the retrieval of the toy (Want & Harris, 2001).

The 3-year-olds on the other hand, demonstrated a significant improvement in performance when they watched either the full or the partial insertion of the marble into the incorrect side of the Y and saw the marble travel through the correct side of the Y, resulting in the toy being dislodged. The results indicate that 3-year-olds are able to better understand the specific causal relationship between the tool use and its relationship to a specific problem, through the observation of others' mistakes (Want & Harris, 2001). As the researchers indicated in their discussion, it is unclear if the study's results indicate a developmental change in tool use problem solving ability between 2 and 3 years of age or if the specific problems presented in this study were more familiar to 3-year-olds. However, what does appear to be clear is that young children do not simply mimic others' use of tools, but rather are capable of understanding the causal relationship between a tool's function and its use in problem solving.

Fleer (2000) conducted a study with 16 children ranging in age from three years old to five years old, in which the children were presented with a story about a fictional character, who needs a companion. The children were instructed to create a drawing of their companion character from which they could construct a three-dimensional model using the given materials. Over a two-week process, the children's planning, decision-making, and construction were observed. The children all choose to use familiar animals as the companion character, despite not being instructed to do so.

The children were observed using familiar construction techniques and demonstrated a concurrent assessment process resulting in alterations to their design concurrently with the construction of that design. Many of the alteration to the child's original design were a result of difficulties with the materials or construction technique, the influence of observing their peer's character construction, and their limited ability to represent a three-dimensional object through two-dimensional drawings. The majority of children chose to only use a front view of their character, thereby leaving out important three-dimensional information needed for the construction of the character (Fleer, 2000).

Fleer (2000) concluded children, as young as three years old, are able to develop a plan of action, in general terms, to construct a solution to a problem. However, they also demonstrated a limitation in their ability to develop detailed plans from which they could use for the construction of there idea. In other words, there is a knowledge gap between their idea for a solution and the technical knowledge necessary to translate that idea into a physical model. Therefore, Fleer suggests teachers need to instruct children how to represent their ideas on paper in the form of multiview or isometric drawings, increase the children's understanding of joining materials, and increase the children's experiences with observing adults progressing from an idea, to a two-dimensional representation, to a three-dimensional model of the idea.

#### *Differences in Problem Solving Performance*

In studying the differences in problem solving performance, Flesher (1993) determined that the familiarity of the problem's context influenced the participants' performance. In other words, individuals were more successful at solving the problem

when they were problem solving within their contextual area. For instance, maintenance technicians would search for the fault in the system that was previously working, while the design engineer considered theoretical constructions and basic conceptual operations of faulty systems.

Participants in Flesher's (1993) study were able to successfully solve the problems within their self-identified area of expertise. Only the design engineers correctly framed the problem and considered a design flaw.

### *Expert versus Novice*

A popular form of research in engineering and problem solving research is to compare the performance of experts with the performance of novices. Experts tend to have a large bank of problem solving strategies, tend to sort problems by their solution procedure (Christiaans & Venselaar, 2005) and possess a greater volume of domain specific knowledge (Johnson, & Satchwell, 1993). Novices tend to spend a large amount of time trying to define the problem, whereas experts tend to take a preliminary assessment of the problem definition and then quickly move to early solution suppositions, which are used as a means to further define and solve the problem in a codependent process. Novices tend to focus on a depth-first approach, whereas experts tend to use a breadth-first approach, which allows for the consideration of a greater number of possible solutions (Cross, 2004).

Experts and novices tend to demonstrate clear differences in their solution strategies, with novice problem solvers using more of a trial-and-error or exhaustive search strategy and experts demonstrating a more structured, systematic, and methodical

approach to solution development. Experts demonstrate faster cognitive speeds, an ability to use and store larger chunks of problem relevant information, and recognize the underlying principles within the problem. They tend to focus on solution development rather than problem analysis, by determining the appropriate scope of the problem and then executing a systematic approach to information gathering based on prioritized set of criteria (Cross, 2004).

Additionally, both experts and novices use analogies in order to construct a cognitive map of their understanding of the available information as compared to their prior knowledge in order to make predictions about the plausibility of their solutions (Collins, & Gentner, 1987). Experts tend to use more schema-driven analogies, whereas, novices tend to use more case-driven analogies, indicating that experts are less dependent on applying a solution from a specific prior experience, but rather are able to recognize familiar categories of problems and solutions, in order to determine the most appropriate problem-solving strategy (Ball, Ormerod, Morley, 2004). In other words, experts are able to use their greater domain specific knowledge to recognize the problem from a more abstract and holistic perspective, allowing them to see the relationship of information involved in the problem. Whereas, novices, who possess less domain knowledge and tend to use surface level cues, are unable to see the complete picture and therefore are unable to recognize the nuances and complexities that would prevent the direct application of a prior solution to the existing problem.

## *Developing Expertise*

Experts do not usually develop their expertise on their own, but rather, they typically have a coach, mentor, or teacher that helps them develop their skills through deliberate practice and focused concentration over a minimum of ten years (Ericsson, 2002).

Cary and Carlson (2001) conducted three experiments with college students to test the use and benefits of external memory aids during problem solving. They observed that over time participants took fewer notes indicating they were becoming more efficient at using their internal working memory and less dependent on the external memory aid. Cary and Carlson concluded external memory aids are used in coordination with the participant's internal working memory, providing secondary storage and categorization for information that could not be retained internally. They also concluded the coordination of internal and external memory is conducted on a cost-benefit assessment.

In an effort to have novice designers replicate the thought process of experts, Yilmaz, Seirfert, and Gonzalez (2010) conducted a study to determine if the heuristics used by an expert industrial designer could be taught to novice designers, psychology students, in an effort to improve their performance in redesigning a set of salt and pepper shakers. The participants who were assigned to one of three experimental groups were taught six heuristics, "merging, rescaling, substituting, changing configuration, repeating, and nesting" (p340). The participants in the experimental groups were more likely to develop salt and pepper shakers that were more creative and that had more variation, than participants in the control group, who did not received any instructions on design

heuristics. However, although the participants in the heuristics groups developed more creative designs, the designs that were generated by the control group were rated to be significantly more practical.

### *Insight and Functional Fixedness*

“Einstellung is the set which immediately predisposes an organism to one type of motor or conscious act” (Warren, 1934 as cited in Luchins, 1942, p3). According to Bilalic, McLeod, and Gobet (2010), the Einstellung effect is a function of cognitive efficiency. When an individual is able to recognize similarities in a given problem, it allows the person to solve the problem relatively efficiently by applying a previous solution to the problem. However, when an individual mistakenly identifies similarities in a given problem, where the use of a previous solution will not solve the problem, a cognitive conflict can be created, in which the individual is convinced the previous solution should work to solve the problem, leaving the individual unable to determine why the solution will not function.

One theory into the inability to achieve a solution to an insight problem is the idea of functional fixedness widely accredited to Karl Duncker, a Gestalt psychologist, who in 1935 wrote a book entitled *Zur Psychologie des produktiven Denkens* (Duncker, 1935/1945; Goswami, 2002b). Duncker describes functional fixedness as a condition in which an individual becomes fixated on the common or intended function of an object and is unable to envision an alternative use for the object (Duncker, 1935/1945). According to the researchers who support the idea of functional fixedness (e.g. German

& Defeyter, 2000; Jansson & Smith, 1991), this impairment can result in individuals being unable to solve seemingly simple problems.

To study the idea of functional fixedness Duncker (1935/1945) developed five experiments the “gimlet problem,” the “box problem,” the “pliers problem,” the “weight problem,” and the “paperclip problem.” The gimlet problem required participants to hang three cords from a wooden ledge using two screw-hooks and a gimlet, the fixated item. In addition to the three objects to be used in the solution, the participants were provided with a number of distracter items (e.g. paperclip, pencils, string, etc). The participants in the control and experimental groups were provided with the same materials and instruction on how to complete the task. Additionally, the wood ledge for the control group already contained the holes for the screws.

The box problem required participants to support three candles side by side on a door using tacks and three pasteboard boxes, the fixated objects. Once again, the participants received the same instructions and materials to complete the task. In the control group, the three boxes were randomly placed on the table among the distracter items, but were left empty. In the experimental group, the three boxes were filled with some of the distracter items, fixating their function as a container (Duncker, 1935/1945).

The pliers problem, required participants to create a flower stand using a board as the platform, a wooden bar on one end of the board for support, and a pair pliers as the support on the other end of the board. In both the control and experimental groups, the wooden bar was attached to the platform board. However, in the control group the wooden bar was tied to the platform board and in the experimental group, the wooden bar

was nailed to the platform board requiring the use of the pliers to free it. The use of the pliers by the participants in the experimental group was intended to fixate the pliers' function in its traditional tool use (Duncker, 1935/1945).

The weight problem required the participants to create a pendulum and secure it to the wall using a nail and a weight (fixated item). In the control group a joint is attached to the string to provide a pendulum-weight and the weight (the critical item) is lying on the table among the distracters. In the experimental group, the weight (critical item) is attached to the string fixating its function as a pendulum-weight (Duncker, 1935/1945).

The paperclip problem required the participants to assemble four black squares onto a piece of white cardboard and suspend the cardboard from an eyelet screwed to the ceiling using a paperclip (fixated item). The control group was provided glue to fasten the four black squares to the white cardboard. The experimental group was provided additional paperclips to fasten the four black squares to the white cardboard. The use of the paperclips as a fastener in the experimental group was intended to fixate the function of a paperclip as a simple fastener used with paper products (Duncker, 1935/1945).

For each of the experiments described above, the participants' performance was measured on their successful completion of the predetermined solution and on their alternative attempted solutions. In all five experiments, the control group outperformed the functional fixated group with 97.1% of the problems solved in the control group versus 58.2% of the problems solved in the functional fixed group. Secondly, the alternative attempted solutions measurement indicated on average participants in the

experimental group, who successfully solved the problems, were more likely to explore the use of distracter objects before determining the correct solution (Duncker, 1935/1945).

In Duncker's (1935/1945) original study, participants pre-utilized an object according to its typical function and then the participants were expected to use the object in an atypical function in order to solve the experimental problem. Birch and Rabinowitz (1951), modified Maier's (1930; 1931) two-string problem to evaluate if participants were given a choice of two objects to use as a weight, is there a bias toward one object's plausible use as a pendulum over the other. In Birch and Rabinowitz (1951), participants were divided into one control group and two experimental groups, where the participants pre-utilized one of two objects in a typical function. All three groups of participants were then presented with the Maier (1930; 1931) two-string problem, in which the participants had to use one of the two objects that the experimental groups pre-utilized. The results indicated that the control group did not demonstrate a preference for either object and within each experimental group, the participants were more likely to select the object that they did not pre-utilize. Therefore, the results of the experiment support Duncker's claims that pre-utilization can lead to functional fixation (Birch & Rabinowitz, 1951).

The success of the Duncker (1935/1945) experiments has led to a continuous and varied debate within the field of cognitive psychology over the existence of functional fixedness and its role in creativity and problem solving. Replications of Duncker's experiments, by researchers such as Adamson (1952), have continued to produce similar results; pre-utilization results in functional fixedness. However, researchers such as

Weisberg and Alba (1981) question the conclusions and methodological approaches used by many researchers studying functional fixedness and insight problem solving.

According to Weisberg and Alba (1981), fixation and insight are descriptive terms used to describe the researchers' observations of their participants' inability to solve certain types of problems and not empirically supported explanations of neurological function.

Additionally, Weisberg and Alba (1981) describe the conclusion of fixedness as a circular argument. According to the argument of fixation, the only way to measure if a person has become fixated is if they are unable to solve the assigned problem. While at the same time, the reason the person was unable to solve the problem was that they were fixated. This type of argument creates an unprovable set of interdependent conditions. Weisberg and Alba (1981) on the other hand theorize the difficulty observed in the insight and fixated problems is a result of the process people progress through when encountering any type of problem; mainly the application of prior experiences.

When individuals approach a problem, they call on their prior experiences and knowledge within a specific domain they perceive relevant to the given problem (Weisberg & Alba, 1981). For example, in Duncker's (1935/1945) weight problem a person calls on their prior experiences with securing objects to a wall, such as using a hammer. As the person begins to apply their prior knowledge, they are continuously monitoring how well their prior knowledge is working in the current situation. If the individual determines the application of their prior knowledge is not quite working they begin to adjust their solution to adapt to the new situation. If the individual determines their chosen solution will not work for the new problem, the individual will begin

searching for alternative solutions within their predetermined domain of knowledge. If the individual has exhausted all of their prior knowledge within the domain, they will then switch to a different domain of prior knowledge to determine a solution (Weisberg & Alba, 1981).

Weisberg and Alba (1981) conducted seven experiments to test their theories on why insight and fixated problems prove to be difficult for participants. In their first experiment, participants were presented with Maier's (1930) nine-dot problem, which Gestalt theorists argue is difficult to solve because participants incorrectly assume they have to stay within the boundary of the square. To test if participants would be freed of their fixation on staying within the square, participants in the three experimental groups were informed (after attempting 10 solutions) they had to go outside the boundary of the square in order to solve the problem. In addition, one of the experimental groups (1 line) was provided with the first diagonal line of the solution. A second experimental group (1+2 line) was provided with the first two lines of the solution.

According to the insight theory, once the participants have been freed from their fixated thought they should immediately realize the solution. As reported in other studies using the nine-dot problem, participants in the control group were unable to solve the problem. However, contrary to insight theory participants who received the hint they needed to go outside the boundaries of the square did not demonstrate a significant improvement on their problem solving performance. Only three of the participants were able to solve the problem and they took an average of five additional attempts to reach the solution. Finally, the only group to have 100% of their participants solve the nine-dot

problem was the experimental group who received 2 of the 4 solution lines (Weisberg & Alba, 1981).

Based on the results of their nine-dot experiments, Weisberg and Alba (1981) concluded the reported fixedness in the nine-dot experiment conducted by other researchers is not a result of fixation. Rather the observed fixation is a result of participants lacking the necessary prior knowledge to conceive of a solution to the nine-dot problem and the requirement to continue to attempt to solve the problem.

Additionally, Weisberg and Alba (1981) concluded the way insight problems are designed, they intentionally instruct participants to search for a solution in an incorrect knowledge domain. However, based on the limited information participants are provided, it is not clear to the participants they are using an incorrect knowledge domain. Finally, when participants are informed they are searching the wrong domain, participants often lack the necessary knowledge to determine the correct domain. The combination of these factors leads to the perception of fixation.

In the additional six experiments, Weisberg and Alba (1981) attempted to determine what is necessary to create a condition of truly insightful solution development. Based on the results from these six experiments Weisberg and Alba concluded, people approach new problems by drawing on their prior knowledge related to the information they are provided. In the process of attempting to solve the problem, individuals continually evaluate the appropriateness of their application of the selected prior knowledge and make the necessary adjustments needed for a valid solution. Weisberg and Alba did not observe any evidence of a phenomenon similar to insight.

Finally, Weisberg and Alba concluded experiences specific to a given problem are needed to solve similar problems in the future.

Another approach to studying insight problems was conducted by Metcalfe and Wiebe (1987), to determine if there is a difference in the role of metacognition in problems, which are typically referred to as insight problems and those that are not. In the first experiment, participants were presented with five insight problems and five noninsight problems. As the participants worked on developing a solution to each of the problems, they recorded (every 15 seconds) how close they perceived they were to achieving the solution. In the second experiment, participants were provided with five insight and five noninsight problems written on index cards. The participants were told to rank the problems according to how easy they perceived each problem's solution. Next, the participants indicated their perceived ability to solve each of the problems. Finally, while the participants worked on solving each of the problems, they were asked to indicate how close they perceived they were to solving the problem.

Participants in the two experiments indicated a perception of incremental progress toward the solution in the noninsight problems but not in the insight problems. According to Metcalfe and Weibe (1987), these findings support the idea that solutions to insight problems arrive all of a sudden, were as noninsight problems occur as a result of a progression of thought. Finally, the results from the second experiment indicate participants are less accurate at predicting their ability to solve insight problems than algebra (noninsight) problems.

Weisberg (1992) directly questions the validity of the claims made by Metcalfe and Weibe (1987) based on empirical and logical errors. First, Weisberg makes the argument that the problems Metcalfe and Weibe selected for their study were initially created specifically for their unfamiliarity to most people, whereas most people are familiar with their ability to solve algebraic problems. Next, Weisberg questioned the accuracy and validity of Metcalfe and Weibe's statistics and graphic representation of participants' warmth rating. Finally, Weisberg (1992) calls into question the circular nature of Metcalfe and Weibe's suggestion that warmth rates be used to determine which problems are insight problems. However, the assertion that participants' warmth rating for insight problems differs from noninsight problems is based on problems that are not proven to be insight problems.

Goswami (2002b) describes insight problem solving as a form of inductive reasoning in his chapter on inductive and deductive reasoning. Inductive reasoning is transferring what one knows about the particular and inferring its generalizing. Goswami once again sights the original work of Gestalt psychologists Duncker (1935/1945) and Maier (1931) as the psychologist who introduced the theories of functional fixedness and insight problem solving. Additionally, Goswami discusses the debate within the literature of whether or not young children are affected by functional fixedness. To illustrate the debate, Goswami cites the work of Brown (1989; Brown, Kane, & Long, 1989) and German and Defeyter (2000), as discussed below.

### *Knowledge Transfer in Problem-Solving*

Brown (1989) conducted inductive reasoning research with children ages 5 and 9 using analogies to provide a context for the problems the children were given. The children were to create a tunnel with the given materials to transport various objects for the characters in each of the stories. The tube was to be constructed out of a piece of paper. In the experimental group, the researchers instructed the children to draw pictures on their paper prior to receiving the inductive reasoning problem.

Brown, Kane, and Long (1989) conducted four experiments with children 3 to 10 years of age to examine the reason for children's difficulty with transfer studies traditionally reported in the literature. In developing the rationale for their study, Brown, Kane, and Long drew attention to the assumption of traditional transfer studies, where the researcher presents a series of problems seemingly related to each other in consciousness of the his or her mind. However, Brown et al. theorize the participants, especially children, may not see the connection between the problems, based on their different life experiences. Unlike the artificial conditions of a clinical study, the connection between the original topic and the analogy is explicitly communicated.

A second concern Brown, Kane, and Long (1989) have with traditional transfer studies is the nature of the knowledge participants are expected to learn and transfer to a new problem. According to Brown et al., the initial knowledge and expected transfer knowledge is usually unfamiliar to the participants. The nature of solving a novel problem with novel knowledge is considerably different than what most participants are

used to doing. Generally, people attempt to solve novel problems by applying their existing knowledge.

To test their concerns with traditional transfer studies Brown, Kane, and Long (1989) conducted the first experiment the children were assigned one of three groups: control group, instructional analogy group, and reminder group. The three groups received the same problems and instructions in an ABAC format.

In the control group, when the children were unable to solve the first problem they were informed that they should move on to the second problem. When the children were unable to solve the second problem, they were shown an illustrated book, which included the protagonist solving the second problem. After seeing how the second problem (B) was solved, the participants were reintroduced to the original problem (A). If the participants were unable to solve the first problem (A) after their second attempt, they were shown an illustrated book with the protagonist solving the problem. Finally, the children were presented with the third problem (C) (Brown, Kane, & Long, 1989).

In addition to receiving the same instruction and procedure as the control group, individuals in the reminder group were consoled after their first failed attempt at problem A. They were told to continue to think about how they could solve the first problem while they attempted the second problem. In the instructional group, the participants were again consoled about the difficulty of the first problem and were told explicitly the solution to the second problem (B) would help them solve the first problem (A) (Brown, Kane, & Long, 1989).

The results from the first experiment indicated the advantage of receiving the explicit instructions as to the relevant similarity between the first and second solutions. The results also indicated the first problem was more difficult for the younger children with only 46% of participants successfully applying the solution from the second problem to the first. Finally, most of the children were able to solve the third problem with the exception of the younger children in the control group (Brown, Kane, & Long, 1989).

Due to concerns that the use of paper as an analogous solution is too far removed from the materials presented in the stories, Brown, Kane, and Long (1989) conducted a second study using a carpet, a rug, and a heavy blanket instead of paper. However, the results of their second study replicated the results of the first study; indicating the materials had little effect. Based on the results to the first two experiments, Brown et al. developed a third experiment to determine if younger children would improve their transfer if the problem was more familiar.

Experiment three was conducted with 3-year-olds utilizing the same procedures as the first two experiments. The problems for this experiment were completely different from those used in experiments one and two. The key solution in the three problems for this experiment required the use of the concept of stacking and pulling. Stacking and pulling was selected based on prior research that indicates children under the age of two, routinely use stacking and pulling to retrieve desired objects. The results from experiment three were similar to the results from the first two experiments, indicating that children as young as three are able to transfer across analogous problems (Brown, Kane, & Long, 1989).

The fourth study conducted by Brown, Kane, and Long (1989) was intended to test children's ability to transfer abstract rules from one problem to another. Experiment four, again used 3-year-olds, with each of the children assigned to either the control, instructional, or reminder groups. However, the procedure for experiment four was setup differently than the first three experiments. During the first day of the experiment, the children were presented with three stories of animals that used mimicry as a form of defense. Again, the stories were presented in an ABAC procedure. On the second day, the children were presented with two new stories of animals whose environments had changed. In the first problem, the children were asked how the animals could adapt to their new environment to protect themselves. In the second problem, the children were asked what happened to the mice that moved to a new environment (where their fur did not match the surroundings).

The results from day one of experiment four, once again suggests that providing instructional examples significantly increases student ability to transfer analogous solutions. When the data from experiment four was analyzed against the data from experiment three, there was a statistical difference in the 3-year-olds performance when using animals then tools. This difference suggests children will perform better when they are tested on a content area they are more familiar with and interested in (Brown, Kane, & Long, 1989).

Despite the statistical improvements in performance demonstrated in day one's data, the first problem on day two (Manchester moths) was determined to be very difficult. Many children were unable to understand the concept of natural selection, even

when it was explicitly explained to them. However, 62% of children who solved the pocket mice problem on day two spontaneously mention the similarity between the mimicry and the pocket mice problems. Additionally, 72% of the children who solved the problem mentioned the similarity between the moths and pocket mice problem (Brown, Kane, & Long, 1989).

Based on the results from the four studies, Brown, Kane, and Long (1989) concluded the use of analogies at any age is an important tool for teaching new information. Second, contrary to previous studies, children as young as 3 are able to demonstrate their ability to transfer analogous solutions to new problems. Although Brown, Kane, and Long do not dispute that there are developmental differences between children of different ages, they take aim at previous researchers who make the claim young children are rigid thinkers unable to transfer knowledge.

Brown et al. argue the reason traditional studies of transfer, insight, and fixedness led to these results is the inappropriate use of problems designed for adults and primates. According to Brown, Kane, and Long, many of the problems continuously used by these researchers originate from Köhler's (1927) research on apes. Finally, Brown et al. argue the reason researchers report young children tend to rely on surface perceptions rather than on richer relational properties is a result of their limited knowledge of the selected problems they are presented.

### *Immunity to Functional Fixedness*

As previously stated, Goswami (2002b) highlighted the research debate on the effect of fixation on children's problem solving ability through the juxtaposition of

Brown's (1989) and German and Defeyter's (2000) research. In contrast, German and Defeyter (2000), using a modification of Duncker's (1935/1945) box problem (originally designed for adults), conducted a series of studies to determine whether or not young children are immune to the effects of functional fixedness.

German and Defeyter (2000) conducted a study, based on a modification of Duncker's (1935/1945) box problem, to test their hypothesis that younger children have a more fluid idea of the function of objects than older children. The modified box problem is an analogy problem requiring children to assist a 10-centimeters tall bear in retrieving a toy from his shelf. The children were presented with a model of a room made from a wooden box (38cm wide x 25cm deep x 58cm high) with the top and sides removed. A toy lion sitting on top of a shelf hanging on the back wall of the box were the only objects described as being in the model. The shelf was 18 centimeters long and 30 centimeters off the floor.

Children were presented with the scenario that the bear needs help retrieving the toy lion from the shelf, because he is too short to reach it and cannot jump. The children were presented with a pencil, a ball, a small flat magnet, an eraser, a small toy car, a coin, four building blocks (4 cm high), and a wooden box 12 centimeters high. Half of the children ages 5, 6, and 7 were assigned to a preutilization group, which started the experiment with all of the items in the 12 centimeter wooden box and placed inside the model. The other half of the children were assigned to the control group, where all of the items (including the 12 cm box) were placed next to the model (German & Defeyter, 2000).

The children were given credit for solving the problem when they combined the four building blocks and the 12 centimeter wooden box within 180 seconds. The same number of five-year-olds and six-year-olds, 6 out of 10, in the preutilization group met the criteria for solving the problem. Two fewer seven-year-olds in the preutilization group, 4 out of 10 were credited with solving the problem. Were as 8 out of 10 five year olds, 9 out of 10 six-year-olds, and 8 out of 9 seven-year-olds in the control group were credited with solving the problem (German & Defeyter, 2000).

German and Defeyter (2000) also reported the average time it took the children to reach the required solution. On average children in the five-year-old preutilization group (6 subjects), took 44.5 seconds to develop the excepted solution. Whereas on average the six-year-olds (6 subjects) and seven-year-olds (4 subjects) took 113.8 seconds and 115.3 seconds respectively. In the control group, on average the five-year-olds (8 subjects) took 55.8 seconds, the six-year-olds (9 subjects) took 50.7 seconds, and the seven-year-olds (8 subjects) took 28.9 seconds. Despite the small number of subjects in each age group (e.g. 4 seven-year-olds) and relatively small difference in times, German and Defeyter conducted a test of significance for the overall trend and between control and experimental groups.

Based on their results, German and Defeyter (2000) argue their study is consistent with Duncker's (1935/1945) idea of functional fixedness. German and Defeyter also make the argument that five-year-olds are immune to functional fixedness based on the time results of their study. On average, the six five-year-olds were 70.8 seconds faster than the four seven-year-olds. To defend their claim German and Defeyter vaguely cite

the findings from a replication of their study citing a large number of participants. However, the details of the replication or the findings are not presented. Instead, a poster presentation is referenced and percentages supporting their claims are discussed.

Finally, German and Defeyter (2000) hypothesize why five-year-olds appear to have performed better. One of their ideas is the five-year-olds have an underdeveloped understanding of the function of a box as a container. Their second idea, which they believe is the correct idea, is that five-year-olds have a more fluid idea of an objects function. They believe five-year-olds believe the function of an object is whatever the user intends the object to be.

German and Defeyter (2000) do not directly address the issues raised by Weisberg and Alba (1981), about the validity of functional fixedness studies, with the exception of a mention of its existence in a footnote. Secondly, with much of their claims based on differences in time, German and Defeyter do not address the difference in experimental conditions. In the control group, all of the items are displayed separately, allowing the participant to take a quick visual inventory of the items. However, in the experimental group all of the items are contained within the 12 centimeter box, requiring their removal. Finally, the time it takes to remove the items and the removal process used by the children is not addressed in their study.

More recently, Defeyter and German (2003) conducted two experiments, the first to replicate their finding of immunity to functional fixedness in young children and the second to test their hypothesis that older children become fixated as a result of an emergence of understanding design intent. In the first experiment children ages five, six,

and seven were assigned to a function demonstration group and a control group.

Children in the function demonstration group were assigned either the long pencil or the straw as their target solution object.

The children were initially introduced to a doll and told he was going on a voyage through space. The function of the target objects, a long pencil and a straw, were demonstrated to the children in the function demonstration group. After the functional demonstration, the distracter objects were presented to the children without a demonstration of their function. Before being presented with the problem, the children were asked to state the function of the two demonstrated items. To be scored as being correct, the children had to explain the function of the object that had been demonstrated to them. The children were then shown the clear plastic tube and asked to help the doll get the stuffed animal out of the tube. If the children were able to retrieve the stuffed animal from the tube, they were to explain the demonstrated function of the two objects again (Defeyter & German, 2003).

In the control group, the half of the children received the straw and cup first followed by the pencil and paper and the other half received the pencil and paper first. For both control groups, the straw and cup were placed on the table with one distracter item in between them. The pencil and paper were placed on the other side of the table with one distracter item separating them. After the items were presented, the children were told the same story as the function demonstration group and asked to help the doll retrieve the stuffed animal from the tube (Defeyter & German, 2003).

Children were scored on whether or not they selected the target object first and on the duration to solve the problem. In the function demonstration groups 8 out of 20 six and seven-year-olds selected the target object first, whereas 12 out of 20 five-year-olds selected the target object first. In the control groups, 16 out of 20 five and six-year-olds selected the target object first, whereas 19 out of 20 seven-year-olds selected the target object first. The post-hoc analysis of the difference in duration between age groups indicated no significant difference between the five-year-olds and the seven-year-olds. Although, the post-hoc analysis did determine five-year-olds were faster than six-year-olds. Unfortunately, the specific times were not presented outside a graph, which indicates on average five-year-olds took approximately five seconds and six-year-olds took between 20 and 25 seconds (Defeyter & German, 2003).

The procedures and problem for the second experiment were identical to the first experiment. Children ages five, six, and seven were assigned to a function demonstration group and a control group. Instead of presenting familiar objects to the children, the researchers created novel objects similar in size and shape as the objects used in the first experiment. Finally, as in the first experiment, the functional demonstration group was presented with the function of two pairs of novel objects (Defeyter & German, 2003).

Defeyter and German (2003) argue the results from the two experiments replicate their earlier study (German & Defeyter, 2000), which found five-year-olds have an immunity to functional fixedness. Defeyter and German argue the results from the second experiment supports their theory that functional fixedness is a result of knowing

an objects functional design. This is in contrast to prior literature, which suggests functional fixedness is a result of negative transfer from prior knowledge.

In summarizing, the arguments put forth by German and Defeyter (2000), “close attention will have to be paid to the nature of the function to be learned, the existing state of the child’s conceptual system, and the context in which the new function is first encountered if German and Defeyter’s hypothesis about immunity to fixedness in younger children is to be tested adequately” (Goswami, 2002b, p288).

### *Negative Transfer on Problem-Solving*

Chrysikou and Weisberg (2005) conducted two experiments to study the negative transfer effect of using negative examples of design in the presentation of a problem-solving task. Undergraduate students were assigned to either the control group, fixation group, or defixation group. Individuals in the fixation group were presented with an example of a negative design solution and an explanation of why it was a poor design. Individuals in the defixation group were also presented with an example of a negative design, but were also specifically instructed to avoid making the same error. Chrysikou and Weisberg concluded the inclusion of a negative example did lead to negative transfer to individual’s solutions, often referred to as fixation. However, if instructions to avoid using the design error in their solutions were provided, individuals did not negatively transfer the error.

### *Mitigating Fixedness*

Chrysikou and Weisberg (2006) conducted a study to determine the effect of alternative categorization tasks on seven traditional insight problems. Undergraduate students were assigned to one of four groups, two treatment groups and two control groups. Prior to the insight problem solving tasks, participants in the first control group completed the Embedded Figures Test (EFT), which has been shown to improve performance on insight problems. The second control group completed the Word Association test, which has not been shown to improve insight problem solving performance. The first treatment group completed the Alternative Categorization Task (ACT), where the participants list alternative categories for 12 common items. The second treatment group completed the Alternative Categorization Task with critical items task (ACT-C). The critical items are the critical items used for the solutions of the insight problems. At the beginning and end of instruction for the insight problem-solving phase, the individuals in the ACT, EFT, and ACT-C groups were instructed to remember the thought process they utilized during the pre-problem solving phase because it may help them with the insight problems.

Individuals in the two alternative categorization groups performed significantly better than individuals in the two control groups. There was no significant difference between the two alternative categorization groups suggesting the improvement in performance was not affected by the inclusion of problem specific items (Chrysikou, 2006). The results were consistent with their pilot study, in which Chrysikou and Weisberg (2004) concluded problem solving is a goal-derived categorization process.

Additionally, when confronted with ill-defined problems, such as an insight problem, ad-hoc categorization is employed in the absence of a familiar context. Finally, receiving training in developing ad-hoc categorization (ACT & ACT-C) can improve problem-solving performance when presented with an insight problem (Chrysikou & Weisberg, 2004; Chrysikou, 2006).

Similar to Chrysikou's (2006) alternative categorization task, Flavel, Cooper, and Loiselle (1958) conducted an experiment to determine whether an increase in atypical pre-utilization of an object would mitigate the effects of functional fixedness. Participants were divided into one control group and five experimental groups. In each of the experimental groups, the participants pre-utilized the target object in a typical function; in addition, the participants in four of the experimental groups also pre-utilized the object in one, two, three, or four atypical functions. The results of the experiment indicated the more a participant pre-utilized the function of the object in an atypical way, the less likely an effect of functional fixedness would be observed. In other words, as with Chrysikou's (2006) alternative categorization task, Flavel, Cooper, and Loiselle's (1958) experiment indicates that divergent thinking can mitigate functional fixedness.

Flavel, Cooper, and Loiselle (1958) and Chrysikou (2006), provide a possible solution for reducing the effects of fixation, by requiring participants to complete a divergent thinking exercise prior to receiving the fixation problem. However, if fixation has already occurred, Storm and Angello (2010) suggest that participants need to forget the idea that they have become fixated on, which Smith and Blankenship (1991) suggest may be a function of time between when the fixation occurs and when the problem is

solved. In their experiments, participants performed significantly better on the word association task if they were allowed time away from the problem, than if they attempted the problem immediately after becoming fixated. Smith and Blankenship's results support earlier research conducted by Adamson and Taylor (1954), in which the reduction of functional fixedness was a result of retroactive inhibition, which increased as the time between the pre-utilization and the problem solving task increased. Adamson and Taylor concluded that the mitigation of functional fixedness was not merely a result of time, but that the distractions of other activities during the time delay, causes the participant to forget about the fixation.

Another possible means for mitigating functional fixedness was examined by Glucksberg and Weisberg (1966), to determine if functional fixedness is a result of participants' perceptual observations. Glucksberg and Weisberg conducted three experiments that included labeling all of the objects, partially labeling the objects, or not labeling the objects. In the first experiment, the participants were provided one of three illustrations of the objects (all objects labeled, no objects labeled, and only the word tacks printed on the side of the box) that could be used to solve Duncker's (1935/1945) candle problem. Participants who were given the illustration with all of the objects labeled were significantly more likely to include the word box in their first answer. However, the differences between the groups were no longer significant when considering all of the participants' solutions (Glucksberg & Weisberg, 1966).

The second experiment assigned participants into three groups in which they saw one of the three illustrations from experiment one (all objects labeled, no objects labeled,

and the word tacks printed on the side of the box), while they received recorded instructions. While the illustration was displayed for ten seconds to the participants, an experimenter removed the cover, revealing the objects. Manipulating the objects to solve the candle problem, the time participants took to use the box in their solution was recorded. If the participants failed to use the box within 15 minutes, they were assigned a time of 15 minutes (Glucksberg & Weisberg, 1966).

Coinciding with results from the first experiment, participants who received an illustration with all of the objects labeled performed significantly faster, which indicated that providing the cue of labeling the box reduced the effect of functional fixedness. The third experiment was identical to the second experiment, except the instruction to not allow the wax to drip on the floor was removed from the recording. The results of the third experiment were consistent with the results from the second experiment, which indicated that participants, who saw an illustration with all of the objects, took significantly less time to use the box in their solution than the other participants (Glucksberg & Weisberg, 1966).

### *Categorization*

In recent years, researchers have indicated that categorization, memory, context, prior experience, and knowledge transfer all influence the relative success or failure of an individual's attempt to solve a problem.

Categorization is the process individuals use to organize their memories of encountered stimuli based on discriminate differences. Categorical representation is a term used to describe the structure, which contains the information about a particular

category. The importance of categorization includes the efficient and accurate retrieval of information, the ability to reduce the need to store every stimulus into separate memories, and it simplifies novel stimuli allowing for an instant familiarization (Quinn, 2002).

One area of research within categorization analyzes whether or not children and adults differ in their application or flexibility of different types of categorization. Some research suggests that children are more flexible in their application of categorization, which could lead to greater flexibility in problem-solving. Other research suggests that there is no difference in children's flexibility in applying categorization modes. According to Kalish (2007), very little is understood about how children apply their selection of categorization modes, whether it be flexible or rigid, to different categorization tasks.

Kalish (2007), conducted an experiment in which two groups of children, four- to five-year-olds and seven- to eight-year-olds, were presented with two sets of pictures, one of animals and the other of tools. For each animal picture, participants were presented with some additional perceptual information as to the animals' disposition and physical ability, such as an ability to climb. For each tool picture, participants were presented with some additional perceptual information as to the tools functional affordance and material composition. The participants were then presented with a brief scenario and a forced choice question that required the participants to choose between two animals or two tools. The forced choice questions were developed to examine children's flexibility

in assigning membership to objects in different categorization tasks, such as species identification, animal disposition, functional affordance, etc.

The Rosch framework on categorization argues the world is naturally ordered into distinguishable categories, such as the characteristics of birds versus animals. This natural order enables young infants to develop categories prior to their demonstrated understanding of language. Infants as young as three months, have demonstrated their ability to categorize stimuli through familiarization / novelty-preference experiments. Although many modern researchers agree on the early existence of categorization, there is not yet agreement on the developmental differences between infants and adults. One explanation for the increased sophistication of adult's categorization is the increase in overall knowledge through experiences (Quinn, 2002).

Infants younger than two years of age, demonstrate the ability to distinguish causal and noncausal relationships and demonstrate a preference for causal properties in categorization (Booth, 2008). Iachini, Borghi, and Senese (2008), as a result of their three experiments, concluded individuals place more importance on properties of function and interaction. Ahn (1998) concluded the central criteria for categorization remains the same for natural and artificial causal properties.

### *Functional Affordance*

According to Hernik and Csibra (2009), adults, as well as young children, naturally categorize objects according to the object's function. Therefore, in order to understand how children categorize objects, researchers, such as Asher and Kemler Nelson (2008), German and Johnson (2002), Wohlegelernter, Diesendruck, and Markson

(2010), etc. have conducted studies on functional affordance, how children determine the function of an object. Being able to better understand how children determine the function of an object, will lead to a better understanding of how children categorize objects, which will lead to a better understanding how children select objects to use during a problem solving task, which could provide an explanation for why certain problem solving tasks lead to an observed condition of functional fixedness.

Much like problem solving and categorization research, functional affordance research is dependant on the quality of the methodology used by the researcher in order to ensure that the results truly reflect the young child's thought process. Therefore, a large variety of methodologies have been used in an attempt to determine young children's functional affordance, which leads to conflicting results.

One topic of debate within functional affordance research is whether children and adults demonstrate a preference for the labeling of an objects function based on its current use or its intended (designed) use. Kelemen (1999) conducted a series of studies to examine whether young children demonstrate a preference toward the designed or intended function of an object versus the objects use.

The discussion within the literature of functional intent takes on a debate as to whether the results are due to children's understanding of design intent or functional intent or are the results related to children's linguistic understanding. Matan (1995) concluded that preschoolers interpret the word 'does' to mean the same as the phrase 'what is it for'. Matan's conclusion suggests that the results of functional intent have more to do with children's linguistic intent rather than their beliefs or cognitive

understanding of functional intent. Kelemen (1999) also raised the question of whether her results, that preschoolers tended to assign functional purpose to natural whole objects more indiscriminately than adults, could be interpreted as a difference in children and adults' linguistic understanding of function. Kelemen's third study presented an experiment to analyze if there was any significant difference in preschoolers and adults' biases towards the original function of an object or the alternative function of an object or a body part. Kelemen's results indicated that there was no significant difference between adults and preschoolers' understanding of the linguistic question 'what is it for?' Kelemen's study also indicates that children and adults do not have a significant difference in their conceptual understanding of functionality. In other words, preschoolers and adults have a similar understanding that if an object has an original intended function, then that intended function does not change simply because it is used in an alternative way.

Kelemen's (1999) first two studies also indicated that preschoolers were significantly more likely to assign functionality to all categories of living, non-living, naturally occurring, and human made objects. However, preschoolers were also more likely to assign functionality to parts of living things, such as a tiger paw, over whole living things, such as the tiger. So the question becomes why, if children and adults seem to have a similar understanding of the concept of function as indicated in Kelemen's third experiment, then why are children more likely to assign a function to naturally occurring whole objects like mountains than adults?

One explanation that Kelemen (1999) presents is that young children lack the understanding of the origin of naturally occurring objects, such as mountain ranges. In the absence of understanding the origin of naturally occurring objects, children may possess the belief that someone or something had to have created it for a particular purpose. In a related study, Gelman and Kramer (1991) determined young children accurately distinguish between naturally occurring objects, such as the sun, and human constructed objects, such as a chair. However, their research also suggested that young children often lack the understanding of how natural occurring objects are created, resulting in an inability to articulate the natural cause beyond the fact people were not involved.

A second explanation for Kelemen's (1999) results could be related to the linguistic use of the phrase 'what is it for' as discussed previously. Kemler Nelson, Egan, and Holt's (2004) determined that when young children, two-, three-, and four-years-old, ask the somewhat ambiguous question 'what is it?' they are more likely to be seeking an explanation of the objects intended function rather than the name of the object. Based on the results from Kemler Nelson and O'Neil's (2005) research, parents are acutely aware that if their child knows the name of an object, then they are also likely to know the function of the object. Their research also indicated that a child may know the function of an object, but not necessarily the name of the object. However, it is very unlikely that the child will know the name of the object without knowing the function of the object, indicating that the function of an object is more important to the child's conceptual understanding of the object than the name of the object.

Additionally, parents appear to be intuitively aware of their child's understanding of objects, to the point that if a child asks the question 'what is it?' and the parent believes the child is familiar with the function of the object or the functional category of the object, the parent will only provide the name of the object. By providing the name of the object, the parent is making the assumption that the name will provide sufficient information for the child to recognize the function of the object. However, if the parent believes the child is not familiar with the function of the object, then the parent will provide the function of the object or the functional category of the object, in addition to the name. It is very unlikely that the parent would only provide the name of the object, if they believed the child did not already know the function of the object. Consequently, if the parent's response to the child's question 'what is it?' did not provide the necessary information for the child to understand the function of the object, the child asked a follow-up question that explicitly requested more information about the object's function. Twelve of the thirteen follow-up questions that the children asked explicitly requested information on the object's function (Kemler Nelson & O'Neil, 2005).

Given the results of Kemler Nelson and O'Neil (2005) that young children possess an affinity for the function of objects, it seems plausible to draw a connection between a child's understanding of an object's function and the manner in which the child categorizes objects. Kemler Nelson, Frankenfield, Morris, and Blair (2000) concluded that young children, like adults, will use the function as a means of categorizing objects, especially when the object's function appears plausible. Given time to explore the function of an object and given the object's appearance provides clear clues to the objects function, even two-year-olds are more likely to use functional

affordance in categorizing novel objects, than simply using perceivable similarities (Kemler Nelson, 1999; Kemler Nelson, Russell, & Jones, 2000). By age two, children have learned to generalize that objects with the same name tend to have the same function (Kemler Nelson, Russel, & Jones, 2000).

Wohlegelernter, Diesendruck, and Markson (2010) conducted a study with two- and three-year-olds in which they concluded the children were more likely to consider the demonstrated function of an object to be the conventional function of that object, when the experimenter intentionally used the object, rather than when the experimenter accidentally used the object. Thereby indicating that young children understand that the designed intent is what determines the correct function of an object. The young children were also more likely to expect the demonstrated function of an object to be the conventional function of that object when the experimenter consistently used the object in the demonstrated manner. Wohlegelernter, Diesendruck, and Markson's research indicated that there was no significant difference in the children's assumption of conventional function based on the child's age.

In a second experiment, Wohlegelernter, Diesendruck, and Markson (2010) sought to determine if two- and three-year-olds would indicate that others' should also take into consideration the intentional or accidental function of an object. In the second experiment, the children observed a video of someone using the object in a manner in which they indicated satisfaction (intentional use) and someone using the object in a manner in which they indicated unsatisfaction, by shaking their head and saying oops (accidental use). Following the video, the experimenter, using one of two puppets, had

one of the puppets replicate the intentional function of the object and one of the puppets replicate the accidental use of the object. The experimenter then asked the children three questions, which puppet used the object correctly, how would the child use the object, and which puppet would the child like to play with.

The results indicated the three-year-olds were more likely than the two-year-olds to indicate that the puppet, who used the object according to the intentional use, was correct. Three-year-olds were also more likely to indicate that they would want to play with the puppet who used the object according to the intended function, thus supporting earlier research on social behavior (Birch, Vauthier, & Bloom, 2008), which indicates children want to associate with others who they perceive are following social norms. Despite three-year-olds' greater tendency to apply their functional reasoning to others, the experiment did not find a significant difference between the two- and three-year-olds' personal preference for using the object according to the intentional or accidental use (Wohlegelernter, Diesendruck, & Markson, 2010).

Both age groups did not perform at a level greater than chance, indicating no preference for whether or not they should use the object according to the accidental or intentional function. One possible explanation of why the children in the second experiment did not indicate a preference for the intended function, could be do to the change in methodology. Following the video in which the actors indicated that they accidentally or intentionally used the object in a specific manner, the children then watched the two puppets intentionally replicate the accidental and intentional function of the object, without indicating expressing that one of them made a mistake. The researchers

stated that this may have created some confusion within the children as to which function they should replicate (Wohlegelernter, Diesendruck, and Markson, 2010).

German and Johnson's (2002) approach to studying children's understanding of an object's functional affordance focused on whether or not children possessed the concept of design stance, in other words regardless of what the object is currently being used for, what was the object designed to do. In German and Johnson's study, participants were presented with four stories about a novel object. For each story, the participants were presented a picture of the novel object and informed that "a long time ago an inventor..." (German & Johnson, 2002, p284) made the object to perform a specific function. After the child recited the original function back to the researcher, the participant was read a second story in which the current owner either intentionally uses the object for a different function, on an ongoing basis, or while in the possession of the new owner was accidentally used for a different function. After the alternative function was presented to the children, they were asked to repeat the function to the researcher. The researcher then summarized the two functions of the object and the condition in which they were used, which the participant again repeated.

After repeating the two functions of the object, the participants were asked to choose which function the object was really for. The adult participants were given the same four stories, however, the method in which they received the stories was different. The adult participants were given the stories in a written format, without the picture cues, in a booklet in which they wrote their answers to the prepared questions. Based on their

results, German and Johnson (2002) concluded that young children, five-year-olds, lack the competence to understand the design stance.

Defeyter, Hearing, and German (2009) conducted two additional experiments, in the first experiment which was designed to replicate the German and Johnson (2002) study, in which participants shown line drawings of novel objects and told that the object was designed for one purpose but used by everyone for a second purpose. The participants were then asked to determine what the object “really” was for. The second experiment, also replicated the procedures of German and Johnson’s experiment, except instead of asking the participants what the object was really ‘for’, the participants were asked to indicate what the correct name of the object was (e.g. “What is it really? Is it a bottle carrier or a fish catcher?” (Defeyter, Hearing, & German, 2009, p263)). According to the researchers, by asking the participants to state the correct name of the object, the participants had to determine the correct categorization of the object not the functional use of the object.

The results of Defeyter, Hearing, and German’s (2009) first experiment, similar to German and Johnson (2002), indicated that adults based their decision on the true function of an object according to the designer’s intended function. Where as children did not indicate a preference for, either the designer’s intended function or the current use of the object, greater than chance. In other words, the children selected the designer’s intended use and the current use at a statistically equal level. However, in Defeyter, Hearing, and German’s (2009) second experiment, children in the idiosyncratic condition were more likely to select the true name of an object, as the name reflecting the

designer's intended function, rather than the name reflecting the current use of the object. The researchers believe their results indicated that children are unable to privilege the designer when making judgments about function or categorization, when they believe the majority of people use an object for an intended function. However, children are able to privilege the designer when making judgments about categorization when told one individual uses the object in an alternative function.

Despite German and Johnson's (2002) conclusion, Asher and Kemler Nelson (2008), based on their research with three- and four-year-olds, concluded that young children understand that the true function of an artifact is the function that the object was designed for. In other words, in contradiction to German and Johnson's research, Asher and Kemler Nelson's study indicates that young children do possess the competence to understand the design stance.

As stated earlier, one possible explanation for the conflicting results could be the differences in methodology between the two studies. In the German and Johnson (2002) and Defeyter, Hearing, and German (2009) studies, the participants were shown pictures of objects and asked to answer a specific question "what is it really used for?", which requires the participant to interpret the question to mean what was the object originally designed to do. However, in the Asher and Kemler Nelson (2008) study, the participants selected physical objects from around the room and when the participant asked a function related question or a more general question of what is it, the experimenter would provide a corresponding answer relating to the objects plausible or implausible function. In

addition, the experimenter would demonstrate the corresponding plausible or implausible function.

The participants in both the plausible and implausible condition were allowed to ask follow-up questions, for which correct information was provided regardless if the participant was in the plausible or implausible condition. In the implausible condition, if the participant's question was not able to be answered with truthful information, such as the question "what else can it be used for?", then the experimenter would tell the participant that "the person who made [the object] made it to [do the plausible function]" (Asher & Kemler Nelson, 2008, p478). The participant's questions and follow-up questions were then analyzed; compared across the two age groups and between conditions (plausible and implausible). According to Asher and Kemler Nelson's results, participants were significantly more likely to ask additional questions regarding the function of the object, when the demonstrated function and the participant's questions were answered with an implausible function. Therefore, as stated earlier, Asher and Kemler Nelson concluded that young children do have a conceptualization of design stance.

A study conducted by Kemler Nelson, Holt, and Egan (2004), provides additional support for the possibility that the research methodology and young children's command of language could play a role in the debate as to whether or not young children possess the ability to conceptualize design intent as it relates to functionality. The study presented two- and three-year-olds with familiar objects, such as a cup, where the objects were either broken in a manner in which the object would no longer perform its intended

function or the object appeared to be intentionally altered, rendering the usual function inoperable.

Unlike other studies, such as German and Johnson (2002), and Wohlegelernter, Diesendruck, and Markson (2010), participants in Kemler Nelson, Holt, and Egan (2004) were not presented with a story that explained one alteration was done accidentally and the other was done intentionally. Nor were the participants asked to identify which object represented the true function of the object. Instead, the participants were handed the objects and asked to state what he / she would call the objects. Two- and three-year-olds were more likely to give a name to the accidentally altered objects (broken items) than the intentionally altered objects that were similar to the category of the original object, such as a cup. Kemler Nelson, Holt, and Egan concluded children as young as two-years-old, not only take into consideration the function of an object when determining its categorization, but also in the absence of a narrative, which explicitly stated the objects' intentional or accidental alteration, are able to use their observational reasoning skills to consider the intended function of an object.

A second possible explanation for why researchers, such as German and Johnson (2002), who concluded young children lack the ability to understand the design stance, and other researchers, such as Kemler Nelson, Holt, and Egan (2004), who concluded young children are able to understand the design stance, find conflicting results may have to do with the complexity of determining whether to use inductive reasoning based on their own observations or whether to use social norms to determine categorization (Kalish, 2007).

In Casler and Kelemen's (2005) study, both preschoolers and adults demonstrated a learned preference for choosing a novel tool to complete a specific task, after being taught the tool's function by an adult. The results of their second experiment also indicated that children as young as two-years-old recognize that the learned intentional function of a novel object should also be used by others in the same fashion even though they were not taught the intended functions.

### Summary

According to the research presented in this chapter, an emerging theory within cognitive development, over the past few decades, indicates that the physical structure and basic cognitive functions of the brain are present from birth and that the demonstrated differences across developmental age groups can be attributed to the individual's diverse life experiences (Murphy, 2002). The current study is focused specifically on cognitive development within the context of problem solving involving the manipulation of physical objects. Therefore, the literature review analyzed a variety of factors that potentially impacts the development of one's problem solving ability, over a large age range.

Research into the exhibited differences in individual problem solving success, indicates that a person's experience within the specific context of the problem space has a positive correlation with the individual's success (Fletcher, 1993). In research focused specifically on the differences between novices and experts, experts are able to use their superior understanding of the problem space, proven solution strategies, and greater context specific prior knowledge, to out perform novice problem solvers, who are often

doing little more than using an educated guess (Ball, Ormerod, & Morley, 2004; Collins, & Gentner, 1987; Cross, 2004). Therefore if experience plays an important role in problem solving, then it is important to understand the degree to which infants and young children are able to successfully solve problems, given their limited life experiences.

Despite their seemingly little life experiences, young children (Want & Harris, 2001) and even infants as young as 5-months-old (von Hofsten, Vishton, Spelke, Feng, & Rosander, 1998; McCarty, Clifton, Ashmead, Lee, & Goubet, 2001) are able to demonstrate an ability to successfully analyze a problem and utilize an effective problem solving strategy to accomplish their goals. When a problem is presented in a familiar context, with a familiar goal, such as feeding oneself, infants and young children are able to use their prior knowledge to effectively solve a problem, much the same as older children and adults.

Therefore, based on the notion that infants and young children are capable of successfully completing problem solving tasks, the literature review narrowed in focus to insight problem solving. The term, insight problem, refers to a type of problem where the solution seems to just appear in the participant's mind without using a known problem solving strategy, as if by insight (Goswami, 2002b; Metcalfe & Weibe, 1987). Insight problems have been used for decades to study a phenomenon in problem solving called functional fixation, in which a participant's prior use of an object in one function will create a mental block to using that object in a different function, even when it is the seemingly obvious component to the solution for a person who has not been preconditioned to its function (Duncker, 1935/1945; Maier, 1931).

One possible explanation for the fixation on an object's function maybe the result of cognitive efficiency, in both why people categorize objects (Quinn, 2002), and why people negatively transfer a problem solving strategy from one context to another (Chrysikou, & Weisberg, 2005). The categorization of an object allows an individual to create a generalizable memory of an object's characteristics, thereby eliminating the need to store a separate memory for each similar object (Quinn, 2002).

Finally, research by German and Defeyter (2000) indicated that young children exhibit immunity to the effects of functional fixation in problem solving. Therefore, the current study was set up to examine whether or not children demonstrate the functional fixation phenomenon when they are presented with a problem that requires them to pre-utilize an object in a familiar function.

## CHAPTER THREE

### Introduction

The purpose of the study is to understand the differences in children's thought processes as they develop solutions to technological problems. The specific aspects of problem solving the study will focus on are: the existence of functional fixedness in technological problem-solving, understanding how functional fixedness affects children's development of solutions, and the differences of functional fixedness in children pre-kindergarten to ninth grade. Previous research involving problem-solving and functional fixedness used various forms of verbal protocol analysis.

### Design of the Study

#### *Population*

Data was collected in three small communities located in Upstate New York, near Syracuse. The preschool was located on a university campus, although it is run independently from the university. The second grade and ninth grade students attend the same small school district nearby, although the schools are located in two different rural communities. According to the 2000 U.S. Census, the city where the preschool is located has a population of approximately 18,000 people, where as the two townships that make up the school district where the second grade and ninth grade students attend consists of approximately 9,600 people.

The preschool is a non-profit National Association for the Education of Young Children certified program, serving children from age 18 months to 5-years-old. The

curriculum is developed by teachers who possess a Masters degree in early childhood education. The children are grouped according to three age categories: 18 months to 2-years-old (toddlers), 2-years-old to 3-years-old (toddlers), and 3-years-old to 5-years-old (preschoolers), with the preschoolers divided between two classrooms. For the purpose of this study, only 4- and 5-year-olds were asked to participate in the study. Twelve children agreed to participate in the study, 8 girls and 4 boys.

The school district in which the second and ninth grade students attend consists of about 2,700 students in a rural community located in central New York. Twelve second grade students agreed to participate in the study, 8 girls and 4 boys. Twelve ninth grade students agreed to participate in the study, 5 girls and 7 boys.

### *Problem Description*

The problem solving activity was based on the problem used in German and Defeyter's (2000) study, where the participants were asked to assist a character in the retrieval of an object within a model of a room. The model room, constructed out of  $\frac{3}{8}$ " plywood, was 12- $\frac{11}{16}$ " W x 10- $\frac{3}{4}$ " L x 11- $\frac{7}{16}$ " H with three walls, a floor, and an open ceiling. A  $\frac{3}{8}$ " x  $\frac{1}{8}$ " shelf was located in the upper left corner 11" inches above the floor. Located on the shelf was a small plastic dog. The participants were presented with the scenario that the  $4\frac{1}{4}$ " tall character, named Kennedy, needed help getting her dog down from the shelf.

The participants were told Kennedy could not jump very high but that they could use any of the items they were given by the researcher to help Kennedy get her dog down from the shelf. The objects that the participants were given to assist Kennedy were: a 4"

x 4" x 3-13/16" box, three wooden blocks 1-1/4" cubed, two rubberbands, two paper clips, a 4" piece of twine, a 4" broken pencil, a toy jeep, a pencil top eraser, and a 4" diameter plastic ball. The shelf was placed at a height that would only allow the character to reach it using the box and three blocks. The participants were encouraged to continue to work on solving the problem until he/she declared that they had solved the problem.

#### *Fixated and Nonfixated Condition*

Participants were given the objects that they could use to solve the problem in either a fixated condition or a nonfixated condition. The targeted object, in other words the fixated object, was a 4" x 4" x 3-13/16" box that when it was presented in the fixated condition, meant that the participants used the box in its typical function, a container. In both the fixated and nonfixated condition, the objects were always presented in the same order, with the 4" x 4" x 3-13/16" box being the first object given to the participants. After asking the participants to explain what the object was, a box, and its typical function, to hold things, in the fixated condition the participants were asked to place all of the remaining objects inside the box after they explain what it was and its typical function. In the nonfixated condition, the participants did not place the objects inside the box, instead they set the box off to the side along with all of the remaining objects.

#### *Alternative Categorization Task*

Half of the participants in each age group were asked to complete an alternative categorization task, based on Chrysikou and Weisberg's (2006) study in which they studied the effect of an alternative categorization task on undergraduate students'

performance on seven traditional insight problems. For the alternative categorization task, participants were presented a list of 12 common items and asked to generate a list of alternative uses for the objects.

The alternative categorization task used in this research presented participants with a list of eight objects that children ages 4 to 15 years of age would be familiar with and would have had experience using the items in unintended ways. Before the participants were asked to generate their list of alternative uses for the eight objects, the researcher gave them an example of how a newspaper could be used for a variety of uses, such as a paper hat, a boat, to line a drawer, to roll up and smash a bug, etc.

Following the example of the newspaper, the participants were asked to state all of the uses they could think of for each of the eight objects: shoe, paper, paper/Styrofoam plate, ball, hat, marker, broom, and hammer. The list of objects were presented to each participant in the same order; following each of the participant's responses the researcher stated "okay, what else could you use the object for." The researcher would continue the request for additional uses until the participant stated they could not think of any additional ideas, then the participants were given the next item on the list until the list was exhausted.

#### *Four Participation Groups*

The participants were assigned to one of four groups (AF, AN, F, and N), based on whether or not they received the alternative categorization task and whether or not they received the problem solving objects in a fixated condition or in a nonfixated condition. Participants in the first group, AF, received the alternative categorization task

prior to receiving the objects to be used to solve the problem. Participants in the AF group also received the problem solving objects in the fixated condition. Participants in the second group, AN, also received the alternative categorization task, prior to receiving the objects, but in this group the participants received the objects in the nonfixated condition. Participants in the third group, F, did not receive the alternative categorization task, and received the objects in the fixated condition. Participants in the fourth group, N, also did not receive the alternative categorization task, and received the objects in the nonfixated condition.

### *Data Collection*

Participants were audio and video recorded in order to record their verbal expression of their thought process and in order to record their actions during the problem solving activity.

### *Procedural Description*

The participants were assigned to one of four groups: Alternative categorization task and Fixated (AF), Alternative categorization and Nonfixated (AN), Fixated (F), and Nonfixated (N). After providing each participant with a brief explanation of what the study was about and what they would be asked to do, the participants were given an explanation of why they were going to be audio recorded and video recorded. Once the participants agreed to participate in the study, the participants were given an explanation of a think-aloud method, where they would be asked to verbalize their thought process throughout their participation. To practice thinking out-loud, the preschoolers were asked to count the number of windows that they saw in the room. To practice thinking

out-loud, the participants in second and ninth grade were asked to think about the first floor of their house and count the number of windows on the first floor. After the participants had finished, they were reminded that what they just did was verbalize what they were thinking and that they would be asked to continue to verbalize their thought process throughout the remainder of their participation.

After completing the practice think aloud, the participants in the alternative categorization task were given an explanation of how objects can be used for different functions other than their intended function. They were then given an example of how a newspaper is typically used for reading information, but it could also be used for a variety of other uses, such as folding it into a hat, or a boat, or it could be rolled up to squish a bug, etc. Following this example the participants were told that it was their turn to come up with a list of ways you could use different objects. The participants were verbally presented with a list of objects: a shoe, paper, a paper/Styrofoam plate, a ball, a hat, markers, a broom, and a hammer. Object by object, the participants were asked to explain what each of the objects could be used for. After each of the participant's responses, they were told okay what else could it be used for, this continued until the participant indicated that they could not think of any other uses for the object.

Following the alternative categorization task or following the think aloud practice activity for the participants who were not asked to do the alternative categorization task, the participants were presented with the objects that they would eventually use to solve the problem, although they were not informed of the problem at that time. All of the participants were presented with the objects in the same order and in the same manner.

The participants were not informed what the objects would be used for until after they had received all of the objects. For each of the objects, the participants were asked to explain what the object was, for instance a box, and what it was typically used for, in the case of the box, for putting things inside it. If the participants did not know what the name of the object was, such as the paperclips, the researcher explained what it was. Likewise, if the participant did not know what the typical use the object was, the researcher provided an explanation.

The first object that the participants received was the target object, a 4" x 4" x 3-13/16" paperboard box. The participants were handed the object and asked to explain what the object was and how it was typically used. Following the participants explanation of the box's function, the participants that were in the fixated groups were told that they would put everything else they were given inside the box, thereby creating a condition of functional fixedness. After setting the box to the side, the participants were given the second set of objects, 1-1/4" cubed wooden letter blocks. Following the participants' explanation of the function of the wooden blocks, the participants in the fixated groups were instructed to place the blocks inside the box they were previously given. The participants in the nonfixated groups were instructed to set the blocks aside, next to the box. This procedure continued until the participants had received all of the objects.

After the participants received the final object, the plastic ball, they were told that they would be able to use any of the things they were just given to solve the following problem. The participants were then presented the 4-1/4" tall doll and told that her name

was Kennedy and that she had a problem that they needed to help her solve. The participants were then presented with the model room and told that Kennedy had a problem, her dog was stuck on the shelf and that she needed their help to get the dog down. They were told that Kennedy could not jump very high but that they could use anything that they were given to help her get her dog down. The participants were also reminded to verbally explain what they were thinking as they attempted to solve the problem. The participants were encouraged to continue working until they had developed their best solution or until they could not come up with any other solutions.

### *Data Analysis*

The first variable that was analyzed was whether or not the participants used the targeted object, the box, as a part of a viable solution that resulted in the character being able to retrieve her dog from the shelf. A second data variable that was examined was the amount of time it took participants to develop a viable solution to the problem, using the target object. If the participant was not able to develop a viable solution using the target object, then the total time they spent working on the problem was used for this variable. The third variable that was examined was analyzing the differences between the four different groups, AF, AN, F, and N. The fourth variable that was examined was an analysis of differences between the three age groups.

Chi-Square was used to analyze the differences in whether or not participants used the target object, the box, in their solution. An independent samples T-tests was used to analyze the differences in the time participants took to solve the problem based on the group they were assigned. An analysis of variance (ANOVA) was

used to analyze the differences in time to solution between age groups. Finally, a nonparametric analysis, the Mann-Whitney U-test, was used to analyze the rank sum differences in the time to solution between the participants in the fixated and nonfixated conditions.

### *Summary*

In summary, a total of 36 children from three different age groups participated in the study. The children were divided into two groups, a fixated group and a non-fixated group. Within each main group, the participants were subdivided into two additional groups, an alternative categorization group and a non-alternative categorization group.

## CHAPTER IV

### Data Analysis

#### Research Question One

Are children impacted by functional fixedness when solving technological problems?

#### Hypothesis I

The first hypothesis states there is no difference in the use of the target object in participants' solutions to the problem, based on the target object being presented to the participants in a fixated condition or a nonfixated condition. Pearson's Chi-Square was used to test the relationship between whether or not participants used the target object and whether or not the target object was presented in a fixated or nonfixated condition.

As indicated in Table 4.1 and Table 4.2, the chi-square analysis of hypothesis I indicates the relationship between the target object presented in a fixated or nonfixated condition and the participants' use of the target object in their solution to the problem was significant,  $\chi^2 = 13.49, p < 0.001$ .

Table 4.1 Fixated vs. Nonfixated in use of target object

Condition	No box in solution	Used box in solution	Total
Nonfixated	4	<b>14</b>	18
Fixated	15	<b>3</b>	18
Total	19	17	36

Table 4.2 Chi-Square Fixated vs. Nonfixated use of target object in solution

	Value	<i>df</i>	Asymp. Sig. (2-sided)
$\chi^2$	13.486	1	.000

## Hypothesis II

The second hypothesis states there is no difference in the amount of time participants spent solving the problem, based on whether or not the participants used the target object. As indicated in Table 4.3, the participants who did not use the target object averaged 260.48 seconds to solve the problem, whereas the participant who used the target object in their solution averaged 90.21 seconds to solve the problem. To test the significance of the time difference, an independent sample test was used. According to the Levene's test for equality of variances,  $F = 11.852, p = 0.002$ , equal variances not assumed was used to determine the significant difference in the participants' total time spent developing a solution to the problem (Table 4.4). Therefore, the *t*-test,  $t(23.82) = 3.296, p = 0.003$ , indicated that the amount of variance in the total time to solution was significantly different (Table 4.4).

Table 4.3 Total Time to Solution: Did Not Use vs. Used Target Object

Box	<i>n</i>	<i>Mean</i>	<i>SD</i>	<i>SEM</i>
Did not use	19	260.48	208.32	47.79
Used	17	90.21	80.93	19.63

Table 4.4 Independent Sample T-Test: Used Target Object vs. Did Not Use Target Object

	<i>F</i>	<i>Sig.</i>	<i>t</i>	<i>df</i>	<i>Sig.</i> (2- tailed)	<i>M Dif</i>	Std. Error Difference	95% CI
Equal variances assumed	11.85	.002	3.160	34	.003	170.27	53.89	[60.75, 279.79]
Equal variances not assumed			3.296	23.82	.003	170.27	51.67	[63.60, 276.95]

### Hypothesis III

The third hypothesis states there is no difference in the amount of time participants spent solving the problem based on whether they received the objects in the

fixated or nonfixated condition. In analyzing the difference the total time participants worked at developing their final solution, the first noticeable difference was the range of times. In the fixated group, participants' time ranged from 57.10 seconds to 553.50 seconds, with a mean of 211.12, a standard deviation of 157.60, and a median time of 178.85 seconds (Table 4.5 and Table A1).

Table 4.5 Total Time to Solution

	<i>n</i>	<i>M</i>	<i>Mdn</i>	<i>SD</i>	<i>Min</i>	<i>Max</i>
Fixated	18	211.12	178.85	157.60	57.10	553.50
Nonfixated	18	149.02	69.50	201.34	16.70	819.40
Nonfixated & Used Box	14	86.70	53.65	83.17	16.70	333.00

In contrast, participants' times in the nonfixated group ranged from 16.70 seconds to 819.40 seconds, with a mean of 149.02, a standard deviation of 201.34, and a median time of 69.50 seconds (Table 4.5 and Table A2).

Although the minimum, mean, and median times of the nonfixated group all indicate participants who received the target object in a nonfixated state solved the problem quicker than participants in the fixated group, the range also illustrates how the tendency to solve the problem faster was also depended on the participants' use of the target object. As illustrated in Table 4.5, when the four participants who did not use the box were removed from the descriptive statistics, the range became 16.70 to 333.00, the mean became 86.69, the standard deviation became 83.17, and the median time became 53.65 seconds.

To test the significance of the difference in the amount of time it took participants to develop their solution, based on whether or not they received the target object in a fixated or nonfixated condition, an independent samples test was initially used to compare the groups' average times. As indicated by Table 4.6, the difference between the average total time participants in the fixated group, 211.12 seconds, spent solving the problem was not statistically significant,  $t(34) = 1.030$ ,  $p = 0.310$ , as compared to the average total time participants in the nonfixated group spent, 149.02 seconds.

Table 4.6 Independent Sample F-Test: Fixated vs. Nonfixated

	<i>F</i>	<i>Sig.</i>	<i>t</i>	<i>df</i>	Sig. (2- tailed)	<i>MDif</i>	Std. Error Difference	95% CI
Equal variances assumed	.135	.716	1.030	34	.310	62.10	60.27	[-60.37, 184.57]
Equal variances not assumed			1.030	32.15	.310	62.10	60.27	[-60.64, 184.84]

However, the statistical significance of hypothesis I, indicated there was a significant difference in whether or not participants used the target object as part of their solution, based on whether or not the object is presented in a fixated or nonfixated condition. Additionally, hypothesis II indicated there was a significant difference in the average total time participants spent on solving the problem based on whether or not they used the target object in their solution. Based on the statistical significance of both hypothesis I and hypothesis II, it was necessary to run a second analysis on the significance of hypothesis III; was there a significant difference in the total amount of time participants used to solve the problem based on whether the target object was presented in a fixated or nonfixated condition.

Therefore, a nonparametric test, the Mann-Whitney  $U$ -test, was used to examine the significance in the distribution of times between the fixated and nonfixated groups. The Mann-Whitney  $U$ -test is not based on the assumption of a normal distribution of the total solution time, rather, it assigns a rank order to the participants total time to solution. The use of a rank order system of analysis reduces the effect of participants who took approximately 400 seconds longer than any other participants. Based on the Mann-Whitney  $U$ -test,  $U = 84.00$ ,  $p = 0.014$ , indicates there was a significant difference in participants' total time to solution development, based on whether or not they received the target object in the fixated or nonfixated condition (Table 4.7 & Table 4.8).

Table 4.7 Mann-Whitney  $U$ -test: Fixated vs. Nonfixated Time to Solution

	<i>n</i>	<i>Mean Rank</i>	<i>Sum of Ranks</i>
Nonfixated	18	14.17	255.00
Fixated	18	22.83	411.00

Table 4.8 Mann-Whitney U-test: Fixated vs. Nonfixated Time to Solution

	Total time to solution
Mann-Whitney U	84.00
Wilcoxon W	255.00
Z	-2.468
Asymp.Sig (2-tailed)	.014
Exact Sig. [2*(1-tailed Sig.)]	.013 <sup>a</sup>

#### Research Question Two

Is there a difference in functional fixedness in children from pre-kindergarten to ninth grade?

#### Hypothesis IV

The fourth hypothesis states there is no difference in the problem solving performance between preschoolers, second graders, and ninth graders. In order to analyze this hypothesis, participants' use of the target object and participants' total time to solution was compared across the three age groups.

The first level of comparison across the three age groups was an analysis of the number of participants who used the target object in their solution. As indicated in Table 4.9, five out of twelve preschoolers used the target object in their solution, five out of twelve second graders used the target object in their solution, and seven out of twelve ninth graders used the target object in their solution.

Table 4.9 Participants' Use of Target Object based on Grade Level

	No Box	Used Box	Total
Preschool	7	5	12
Grade 2	7	5	12
Grade 9	5	7	12
Total	19	17	36

As indicated in Table 4.9, there is no difference in the number of participants who used the target object among the preschoolers and second graders. Additionally, as indicated in Table 4.10, based on Pearson's Chi-Square,  $\chi^2 = 0.892$ ,  $p = 0.640$ , the difference between the number of ninth graders who used the target object was not statistically different than the number of preschoolers and second graders who used the target object.

Table 4.10 Chi-Square: Participants' Use of Target Object based on Grade Level

	Value	<i>df</i>	Asymp. Sig. (2-sided)
$\chi^2$	.892 <sup>a</sup>	2	.640

A comparison across the three age groups as to whether or not participants used the target object based on the condition the target object was presented to the participants, indicates there was no statistical difference,  $\chi^2 = 2.571$ ,  $p = 0.276$  among participants in the Nonfixated group and  $\chi^2 = 0.000$ ,  $p = 1.00$  among participants in the Fixated group (Table 4.11 & 4.12).

Table 4.11 Use of Target Object Across Age Groups and Condition

		Preschool	Grade 2	Grade 9	Total
Nonfixated	No Box	2	2	0	4
	Used Box	4	4	6	14
Total		6	6	6	18
Fixated	No Box	5	5	5	15
	Used Box	1	1	1	3
Total		6	6	6	18

Table 4.12 Chi-Square: Across Age Group & Condition

		Value	<i>df</i>	Asymp. Sig. (2-sided)
Nonfixated	$\chi^2$	2.571 <sup>a</sup>	2	.276
Fixated	$\chi^2$	.000 <sup>b</sup>	2	1.000

Similar to the analysis of whether or not participants used the target object across the three age groups, a layered approach was used to analyze the total amount of time participants spend developing their solutions to the problem. The first layer of analysis examined whether or not there was an overall difference in the average amount of time participants spent developing their solutions. As indicated by Table 4.13 & 4.14, there was no statistical difference in the average amount of time participants in each of the age groups spent solving the problem,  $F = 0.023$ ,  $p = 0.977$ .

Table 4.13 Participants' average time to solution development within age groups

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>95% CI</i>	<i>Min</i>	<i>Max</i>
Preschool	12	182.93	127.47	36.80	[101.94, 263.91]	16.70	446.80
Grade 2	12	186.49	239.12	69.03	[34.56, 338.42]	50.50	819.40
Grade 9	12	170.80	174.97	50.91	[59.63, 281.97]	16.90	553.50
Total	36	180.07	180.96	30.16	[118.85, 241.30]	16.70	819.40

Table 4.14 ANOVA

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Between Groups	1623.86	2	811.93	.023	.977
Within Groups	1.144E6	33	34680.53		
Total	1.144E6	35			

A second layer of time analysis was used to examine if there was a difference in the amount of time participants in the three age groups, based on whether or not they used the target object in their solution. As indicated in Table 4.15 & 4.16, there was no significant difference between the three age groups in average amount of time participants spent on solution development based on their use of the target object,  $F = 0.709, p = 0.509$ .

Table 4.15 ANOVA: Time to solution based on use of target object between age groups

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>95% CI</i>	<i>Min</i>	<i>Max</i>
Preschool	5	126.88	131.24	58.69	[-36.08, 289.84]	16.70	333.00
Grade 2	5	71.40	23.77	10.63	[41.88, 100.92]	50.50	103.30
Grade 9	7	77.44	63.25	23.91	[18.95, 135.94]	16.90	202.80
Total	17	90.21	80.93	19.63	[48.60, 131.82]	16.70	333.00

Table 4.16 ANOVA: Time to solution based on use of target object

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Between Groups	9633.52	2	4816.76	.709	.509
Within Groups	95156.56	14	6796.90		
Total	104790.11	16			

As indicated by Table 4.17 and Table 4.18, there was no significant difference in the amount of time participants spent developing their solution across the three age groups, based on those that did not use the target object,  $F = 0.197, p = 0.823$ .

Table 4.17 Participants who did not use the target object

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>95% CI</i>	<i>Min</i>	<i>Max</i>
Preschool	7	222.96	117.55	44.43	[114.24, 331.67]	132.30	446.80
Grade 2	7	268.70	292.46	110.54	[-1.78, 539.18]	61.40	819.40
Grade 9	5	301.50	203.92	91.20	[48.30, 554.70]	107.50	553.50
Total	19	260.48	208.32	47.79	[160.07, 360.89]	61.40	819.40

Table 4.18 ANOVA: Participants who did not use the target object

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Between Groups	18741.93	2	9370.97	.197	.823
Within Groups	762418.52	16	47651.16		
Total	781160.45	18			

As indicated by Table 4.19 and Table 4.20, there was no significant difference in the amount of time participants in each of the three age groups spent on developing their solution based on the condition the target object was presented to them,  $F = 0.989, p = 0.395$ .

Table 4.19 Participants in the fixated condition across age groups

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>95% CI</i>	<i>Min</i>	<i>Max</i>
Preschool	6	172.82	86.40	35.27	[82.14, 263.49]	57.10	309.00
Grade 2	6	175.50	179.59	73.32	[-12.97, 363.97]	59.90	523.00
Grade 9	6	285.05	186.79	76.26	[89.03, 481.07]	107.50	553.50
Total	18	211.12	157.60	37.15	[132.75, 289.50]	57.10	553.50

Table 4.20 ANOVA: Participants in the fixated condition across age groups

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Between Groups	49209.45	2	24604.72	.989	.395
Within Groups	373048.98	15	24869.93		
Total	422258.43	17			

As indicated in Table 4.21 and Table 4.22, there was no difference in the amount of time participants in each of the three age groups spent developing their solution within those who received the target object in the nonfixated condition,  $F = 0.944$ ,  $p = 0.411$ .

Table 4.21 Participants in the nonfixated condition across age groups

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>95% CI</i>	<i>Min</i>	<i>Max</i>
Preschool	6	193.03	167.43	68.35	[17.32, 368.74]	16.70	446.80
Grade 2	6	197.48	305.37	124.67	[-124.67, 517.95]	50.50	819.40
Grade 9	6	56.55	33.67	13.75	[21.22, 91.88]	16.90	114.00
Total	18	149.02	201.34	47.46	[48.90, 249.14]	16.70	819.40

Table 4.22 ANOVA: Participants in the nonfixated condition across age groups

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Between Groups	77019.41	2	38509.71	.944	.411
Within Groups	612095.92	15	40806.40		
Total	689115.33	17			

### Research Question Three

Did participants' completion of an alternative categorization task prior to receiving the problem solving task improve their performance, as measured by use of the target object and the time to solution?

### Hypothesis V

The fifth hypothesis states there is no difference in problem solving performance between participants who were presented with the alternative categorization task and the participants who did not receive the alternative categorization task prior to attempting to solve the problem. Pearson's Chi-Squared was used to test the relationship between participants that completed the alternative categorization task before attempting to solve the problem and the participants who did not receive the alternative categorization task.

Table 4.23 Alternative Categorization Task vs. Fixated

	No Box	Used Box	Total
ACT Fixated	8	1	9
Fixated	7	2	9
Total	15	3	18

Table 4.24 Chi-Square Alternative Categorization vs. Fixated

	Value	<i>df</i>	Asymp. Sig. (2-sided)
$\chi^2$	.400 <sup>a</sup>	1	.527

In comparing the two groups that received the objects in a fixated condition, the Chi-Square  $\chi^2 = 0.400$ ,  $p = 0.527$  indicates that there was no significant difference in participants' use of the target object based on whether or not they received the alternative categorization task, as displayed in Table 4.23 and 4.24. In comparing the two groups that received the objects in a nonfixated condition, the Chi-Square  $\chi^2 = 1.286$ ,  $p = 0.257$  indicates that there was no significant difference in participants' use of the target object based on whether or not they received the alternative categorization task, as displayed in Table 4.25 and Table 4.26. Finally, an independent sample T-Test was used to determine if the participation in the alternative categorization task reduced the effect of fixation on the amount of time a participant spent to solve the problem. As indicated in Table 4.27 and Table 4.28, there was no significant difference in the amount of time a participant spent working on a solution to the problem,  $t(16) = -0.235$ ,  $p = 0.817$ .

Table 4.25 Alternative Categorization Task vs. Nonfixated

	No Box	Used Box	Total
ACT Nonfixated	1	8	9
Nonfixated	3	6	9
Total	4	14	18

Table 4.26 Chi-Square Alternative Categorization vs. Nonfixated

	Value	<i>df</i>	Asymp. Sig. (2-sided)
$\chi^2$	1.286 <sup>a</sup>	1	.257

Table 4.27 Time to Solution for Alternative Categorization Task Fixated vs. Fixated

	<i>n</i>	<i>Mean</i>	<i>SD</i>	<i>SEM</i>
ACT Fixated	9	202.12	175.80	58.60
Fixated	9	220.12	147.29	49.10

Table 4.28 Total Time to Solution: Alternative Categorization Task Fixated vs. Fixated

	<i>F</i>	<i>Sig.</i>	<i>t</i>	<i>df</i>	Sig. (2- tailed)	<i>M Dif</i>	Std. Error Difference	95% CI
Equal variances assumed	.688	.419	-.235	16	.817	-18.00	76.45	[-180.06, 144.06]
Equal variances not assumed			-.235	15.52	.817	-18.00	76.45	[-180.47, 144.47]

## Summary

### *Research Question One*

The first research question, are children impacted by functional fixedness when solving technological problems, was examined by analyzing if the way the object was presented, in a functional fixated state or a nonfunctional fixated state, would impact the likelihood that the participant would use the target object in their solution. The answer to this question was yes, participants were more likely to use the target object in their solution if the target object was presented in a functionally nonfixated state ( $\chi^2 = 13.49, p < 0.001$ ). The data analysis also indicated that the converse effect also was significant: if participants were presented with the target object in a functionally fixated state, then they were less likely to use the target object in their solution.

A second dimension of the effect of functional fixedness was its impact on the total amount of time it took participants to develop their solution to the problem. In analyzing the effect on time, the data analysis indicated that participants took significantly less time to develop their solution when the target object was presented in a nonfunctional fixated state, in particular when the participants used the target object in their solution ( $U = 84.00, p = 0.014$ ).

### *Research Question Two*

The second research question: was there a difference in the effect of functional fixedness on participants based on their age. Based on the data analysis, there was not a significant difference in the participants' likelihood of using the target object ( $\chi^2 = 0.892,$

$p = 0.640$ ) or in the amount of time it took participants to develop their solution ( $F = 0.023, p = 0.977$ ).

### *Research Question Three*

The third research question: did participants' completion of an alternative categorization task prior to receiving the problem solving task improve their performance, as measured by use of the target object and the time to solution. The data analysis of the participants' likelihood to use the target object (ACT-Fixated vs. Fixated Condition  $\chi^2 = 0.400, p = 0.527$  & ACT-Nonfixated vs. Nonfixated Condition  $\chi^2 = 1.286, p = 0.257$ ) indicated no significant difference. The data analysis of the time participants spent working on their solution to the problem indicated that the alternative categorization task was unable to significantly improve the effect of fixation on the participants time to solution ( $t(16) = -0.235, p = 0.817$ ).

## CHAPTER FIVE

### Discussion

The purpose of this study was to examine the effect of functional fixedness on problem solving with children of varying age levels. A total of 32 students from three age groups, preschool, second grade, and ninth grade participated in the experiment in Upstate New York. The students in each of the three age groups were randomly assigned to one of four conditions: alternative categorization task-fixated, alternative categorization task-nonfixated, fixated, and nonfixated.

Chapter I established a framework for the study by describing the problem that little is understood concerning the cognitive and developmental dimensions of technological problem solving, specifically when a person becomes fixated on the intended use of an object. Three main research questions were purposed: (1) is there measureable evidence that children are impacted by functional fixedness when trying to solve a technological problem; (2) is there a measureable difference in the effects of functional fixedness in children of different age groups; (3) does the participation in an alternative categorization task prior to the problem reduce the effects of functional fixedness.

Chapter II provided a review of the literature on problems solving, functional fixedness, immunity to functional fixedness, object affordance, cognitive development theories, insight problem solving, tool use, knowledge transfer in problem solving, and categorization. Chapter III described the design of the research and the methods, including the materials used in the problem solving activity, and the procedure for

presenting the objects and the problem to the participants. Chapter IV reported the data analysis of how many participants were able to solve the problem using the target object, how long the participants spent developing their solution, and whether there was any significant difference in the results, based on the experimental condition. Finally, Chapter V will summarize the findings of the current study, provide a discussion of the results in comparison to the prior literature, followed by a conclusion and implications, and finishing with recommendations for further research.

### Summary of Finding

The analysis of the data relating to the first research question, are children impacted by functional fixedness when solving technological problems, indicated that children were in fact impacted by the condition in which the materials were presented to them. When the target object was presented to the participants in the functional fixated condition, the children were significantly less likely to use the target object in their solution (3 out of 18 versus 14 out of 18;  $\chi^2 = 13.49, p < 0.001$ ). Participants who used the target object in their solution took significantly less time to develop a solution to the problem ( $M = 90.21s$  vs.  $M = 260.48s$ ;  $t(23.82) = 3.296, p = 0.003$ ). Therefore, given the effect of whether or not a participant used the target object on time-to-solution, a nonparametric test, the Mann-Whitney U-test, was used to determine if participants in the fixated group took significantly longer to develop their final solution to the problem. Based on the mean ranking of the Mann-Whitney U-test, participants in the fixated group took significantly longer ( $U = 84.00, p = 0.014$ ) than participants in the nonfixated group.

The analysis of the data relating to the second research question, was there a difference in effect of functional fixedness on participants based on their age, indicated there was no significant difference in performance as measured by target object use ( $\chi^2 = 0.892, p = 0.640$ ) and time-to-solution ( $F = 0.023, p = 0.977$ ). Finally, the analysis of the data relating to the third research question, would participation in an alternative categorization task prior to receiving the problem solving task improve the effects of functional fixedness on participants performance, indicated there was no significant difference in participants performance, as measured by target object use ( $\chi^2 = 0.400, p = 0.527$ ) and time-to-solution ( $t(16) = -0.235, p = 0.817$ ).

#### Discussion of Findings

What does the literature tell us about why functional fixedness occurs or can be measured? According to Bilalic, McLeod, and Gobet (2010), the Einstellung effect is a function of efficiency, if a solution has already been determined to be plausible then searching for a new solution would be an inefficient use of cognitive function. Therefore, in the current study, participants in the functional fixated condition had already assigned a function to the box, through the process of placing all of the other items available to the participant inside the box. Assigning the function of 'container' to the box appeared plausible, since they had stated earlier that the typical function of a box is a container and they were currently utilizing the box as a container. Based on Bilalic, McLeod, and Gobet's (2010) conclusion of the Einstellung effect, once the participants had determined that the appropriate function of the box was a container for holding the other objects, it

allowed the participants to ignore other possible uses for the box as part of the solution to the problem.

Additionally, based on observing the participants' approach to solving the particular problem presented in this study, in which the goal was to assist the character to retrieve an item from a high shelf, all of the participants focused on using a familiar strategy, the construction of a ladder / stair. This singular focus of a familiar and plausible solution to retrieve an item that cannot be reached could be considered an additional example of the Einstellung effect.

What does the literature tell us about why there was no significant difference in performance based on age? Over the past few decades, there has been a tremendous growth in the understanding within developmental and cognitive psychology. One of the emerging theories of cognitive development is that the basic neurological structures and core neurological functions of an adult are present at infancy (Murphy, 2002). Therefore, cognitive development is a function of differences in experiences, domain knowledge, and processing capacity. In other words, a child's cognitive development occurs as a result of experiencing new interactions with the world, which leads to a greater understanding within a domain of knowledge, which in turn leads to greater understanding across domains of knowledge.

The concept of functional fixedness is based on two related theories of cognition, the first area of research is related to the functional affordance of an object and the second on the fixation on an idea, sometimes referred to as the Einstellung effect. Research on functional affordance has indicated that children as young as two-years-old

are able to determine the function of an object based on perceived similarities to known objects (Kemler Nelson, Russell, & Jones, 2000), based on observing others demonstration of the function of an object (Wohlegelernter, Diesendruck, and Markson, 2010), and based on the child's experimentation with the object (Kemler Nelson, Russell, Duke, and Jones, 2000). Therefore, given the participants' familiarity with the objects available to use in the problem solving activity, participants, no matter their age, effectively assigned the function of the target object (a box) as a container and therefore often ignored its existence when trying to solve the problem. Some participants verbalized the need for their makeshift ladder to be taller and proceeded to search for additional objects inside the box, but never considered using the box as one of the items.

Why then is there conflicting results between in the research conducted by German and Defeyter (2000), which concluded young children were immune to functional fixedness, and the current study which indicates young children are just as likely to experience functional fixedness? First, it should be noted that in both studies, the sample size was relatively small and therefore the differences in participants could have been enough of a factor to change the results.

However, it is important to consider the slight, but significant modification to the methodology. In German and Defeyter's study, the participants were presented with the objects either in a wooden box (pre-utilization condition) or with all of the objects placed next to the model (control condition). In contrast, in the current study, the participants in both conditions received the objects one at a time and were asked to state the name of the object and its typical use. Additionally, in the functional fixedness condition (pre-

utilization) the participants utilized the typical function of the box (a container) by physically placing each item in the box. The significance of this change required the participant to actively use the target object as a container, instead of observing how someone else has used the object.

What does the literature tell us about overcoming fixation? As described in Chapter II, there is some research evidence (e.g. Chrysikou, 2006; Flavel, Cooper, & Loiselle, 1958) that indicates it is possible to reduce the effect of fixation within problem solving through divergent thinking exercises. In the current study, participants were presented with an alternative categorization task, similar to the one developed by Chrysikou (2006), in which the participants were asked to verbally list alternative uses for common items, such as a shoe, paper plate, ball, hat, etc., prior to receiving the problem solving task. However, unlike Chrysikou's (2006) research, the current study did not demonstrate measurable improvement in participants' performance.

One possible explanation for why there is some discrepancy between the results of Chrysikou (2006) and the current study is that although the alternative categorization tasks were similar, the problem solving tasks were significantly different. In the Chrysikou (2006) study, participants both generated their alternative categorization task on paper and wrote out their solution to the various insight problem-solving tasks. In other words, the way in which the participants conducted the alternative categorization task and the way in which they conducted the problem-solving task were closely associated with each other. Whereas in the current study, the participants generated their ideas for the alternative categorization task verbally and then physically manipulated

objects to generate a solution to the problem-solving task. In this case, the two activities had little in common and therefore the participants may not have associated the divergent thinking activity with the problem-solving task.

## Conclusion

In summary, the current study demonstrated children are susceptible to the effects of functional fixedness in problem solving, when the participant pre-utilized the target object in its typical function, resulting in children ignoring the availability of the object, which would allow them to solve the problem. Second, the current study found no significant difference in the effect of functional fixedness on children across the three age groups (preschool, second grade, and ninth grade), which indicates given the right circumstances anyone can be susceptible to functional fixedness, resulting in impaired problem solving ability. Finally, although there is some research evidence to suggest functional fixedness can be overcome with divergent thinking, the current study was unable to demonstrate improved performance based on an alternative categorization task.

Based on the finding of this study the conclusions are as follows...

- Children, as young as preschool (four & five-years-old), demonstrate effects of functional fixedness in problem solving, when the object is pre-utilized in its typical function.
- There appears to be no significant difference in the effects of functional fixedness across three age groups (preschoolers, second graders, and ninth graders).

- The performance of an alternative categorization task prior to problem solving did not reduce the effects of functional fixedness.

### Implications and Recommendations

The current research, which demonstrated that participants will ignore the most viable solution to a problem, when they have become fixated on the pre-utilization function of the object, is concerning for the fields of engineering and technology, which are based on an individual's ability to develop solutions to problems. To illustrate the need for engineers to overcome the effects of functional fixedness, one can look at the challenges the engineers and crew had to overcome during the Apollo 13 mission, made famous by the movie of the same name. During the launch of Apollo 13, the number two oxygen tank in the service module exploded. As a result, the crew was forced to move to the lunar module, which was not designed to handle the carbon dioxide of three crew members for the length of time needed. Therefore, the engineers and crew had to develop a solution to the problem of how to attach the command module's lithium hydroxide canisters to the lunar module air filtration system using only the materials they had in the two crafts (cardboard, plastic bags, and tape) (NASA, 2009). Had the engineers not been able to overcome the effects of functional fixation and use the items in an atypical way, the crew would not have survived the carbon dioxide buildup.

As illustrated by the Apollo 13 mission, the ability to overcome functional fixedness can be critical to problem solving. The current study demonstrated that even young children are susceptible to functional fixedness and therefore, it is recommended that the issue should be studied further.

Given the small number of participants in the study, it is recommended that the current methodology be used in a larger sampling of children to determine if the findings remain consistent with a larger population. In addition to a greater number of participants, future research should also include children from the complete range of student population, from preschool to grade twelve.

A third recommendation would be to include a greater variety of problem-solving tasks. With the research indicating a connection between prior experience and cognitive efficiency, the selection of problems should take into consideration the familiarity of the function of the target object to the participants. For instance, a second problem that was developed by the researcher for a pilot study, involved using a pencil as the target object in the construction of a paper bridge. The selection of the pencil was based on preschool children's familiarity with using a pencil primarily as a writing or drawing utensil. In examining the research originally conducted by German and Defeyter (2000), one hypothesis for their conclusions was that unlike older children, who primarily use a box as a container, whereas, younger children more freely use boxes in all sorts of imaginative ways, such as a house, spaceship, tunnel etc. Therefore, if the familiarity of the target object's function impacts functional fixedness, it was hypothesized that having preschool children use an object, which they too readily use with a predefined function, may have an impact on the effect of functional fixedness.

A fourth recommendation for future study, would be to conduct a mixed method analysis of the participants' thought processes as they work through the problem-solving tasks. As part of the current study, the participants were instructed to use a "think-aloud"

protocol, verbally expressing their thought process, while they worked on their problem solutions. The participants were audio and video recorded, which will be used in a follow up study to analyze the thought process and strategies used by the participants to attempt to solve the problem. Additionally, it is recommended that the participants be interviewed after they had declared they have finished solving the problem in order to achieve a greater insight into their thought process. An interview could be especially interesting in the case of the participants who did not use the target object. A mixed method study may be able to provide additional insight into why the participants in the fixated condition ignored the seemingly most obvious solution to the problem.

Given the lack of measurable improvement to the effects of functional fixedness by participants who participated in an alternative categorization task, a fifth recommendation is to develop and analyze different strategies for overcoming functional fixedness. According to the research conducted by Chrysikou (2006), the Einstellung effect can be overcome by using a divergent thinking exercise. One possible idea would be to have the strategy more closely align with the type of object manipulation the participants are asked to do during the problem-solving task, such as using a box for functions other than a container.

Finally, it is recommended to develop and analyze strategies that will take the results of the research on functional fixedness and implement solutions into the school curriculum. Given the results of the current study, children are susceptible to functional fixedness and therefore, one of the strategies that classroom teachers should evaluate is the effectiveness of explicitly pointing out the child's fixation during problem solving as

part of the teachers regular formative assessment of students' problem solving. Using this strategy, the teacher would make the students' fixation conscious to them thereby allowing the students to evaluate and adjust their strategy. For example, given the problem in this study, the teacher could ask the student if they had thought about using the box as part of their solution.

A second strategy a teacher could use would be to teach the students to use divergent thinking strategies. For example, the teacher could have the students practice developing solutions to a problem where the obvious material needed to solve the problem is missing, similar to the problem the engineers, who worked on the Apollo 13 mission, faced. A second example would be to have students practice using objects in atypical ways.

Finally, given the research that indicates fixation in problem solving is a function of cognitive efficiency (Bilalic, McLeod, & Gobet, 2010), teachers could teach student more methodical methods for approaching a problem, thereby increasing their solution efficiency and reducing the need for fixation.

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Appendix

Table A1: Total Time to Solution: Fixated Condition

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	57.10	1	5.6	5.6	5.6
	59.90	1	5.6	5.6	11.1
	61.40	1	5.6	5.6	16.7
	92.30	1	5.6	5.6	22.2
	100.70	1	5.6	5.6	27.8
	107.50	1	5.6	5.6	33.3
	132.30	1	5.6	5.6	38.9
	135.00	1	5.6	5.6	44.4
	175.30	1	5.6	5.6	50.0
	182.40	1	5.6	5.6	55.6
	183.80	1	5.6	5.6	61.1
	202.80	1	5.6	5.6	66.7
	215.70	1	5.6	5.6	72.2
	219.70	1	5.6	5.6	77.8
	309.00	1	5.6	5.6	83.3
	488.80	1	5.6	5.6	88.9
	523.00	1	5.6	5.6	94.4
	553.50	1	5.6	5.6	100.0
Total		18	100.0	100.0	

Table A2: Total Time to Solution: Nonfixated Condition

**TotalTime\_to\_Solution**

	Frequency	Percent	Valid Percent	Cumulative Percent
Valid 16.70	1	5.6	5.6	5.6
16.90	1	5.6	5.6	11.1
32.90	1	5.6	5.6	16.7
46.50	1	5.6	5.6	22.2
50.50	1	5.6	5.6	27.8
50.90	1	5.6	5.6	33.3
53.30	1	5.6	5.6	38.9
54.00	1	5.6	5.6	44.4
68.40	1	5.6	5.6	50.0
70.60	1	5.6	5.6	55.6
90.00	1	5.6	5.6	61.1
103.30	1	5.6	5.6	66.7
114.00	1	5.6	5.6	72.2
134.10	1	5.6	5.6	77.8
181.10	1	5.6	5.6	83.3
333.00	1	5.6	5.6	88.9
446.80	1	5.6	5.6	94.4
819.40	1	5.6	5.6	100.0
Total	18	100.0	100.0	