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Early Biological Thinking: Teaching Preschoolers About Inheritance

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Early Biological Thinking: Teaching Preschoolers About Inheritance" submitted by Cassandra Carolyn White in partial fulfillment of the requirements for the degree of Master of Science.

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Abstract

Solomon and Johnson (2000) demonstrated that 5 and 6 year-old children could be taught to make more adult-like judgments regarding biological inheritance. Jaakkola (1997) determined that young children develop their first biological theory between the ages of 4 and 6. In this presentation, preliminary data are presented regarding the effectiveness of the Inheritance Unit of the Child As Scientist: Beginning Biology program (Lawson Foundation, 2001) in promoting more adult-like biological inheritance reasoning in children ages 3 through 5. The responses of the children who had already acquired their first biological theory (Life Theorizers) and the children who had not yet acquired their first biological theory (Non-Life Theorizers) in the Experimental and Comparison groups were compared and contrasted to determine if Life Theorizers demonstrated a similar or different trajectory of learning biological information than Non-Life Theorizers. Fifty-one participants, aged 3-5 years, completed the Life Theorizer questionnaire and three biological reasoning tasks at pre-test, followed by alternate forms of the three biological reasoning tasks at post-test. Statistical and contingency table analyses demonstrated differences that provided preliminary support for the hypothesis that preschool aged children can be taught to demonstrate more adult-like biological reasoning, and also the hypothesis that Life Theorizers and Non-Life Theorizers would demonstrate different trajectories of learning biological information. Results also suggested that Non-Life Theorizers who participated in the instructional program made post-test responses that more closely resembled those of Life Theorizers who also participated in the instruction program.

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CHAPTER I

INTRODUCTION

Young children are fascinated by biological phenomena. They will stop abruptly on the sidewalk to watch a caterpillar creep to its destination; they take note of and are fascinated by family resemblances ("Daddy has brown hair and I have brown hair"). They are intrigued by questions of life such as "What will happen if we put the bug in the jar with the lid on it?", of death ("Where is grandpa now?"), and reproduction ("Where do babies come from?"). Parents and pre-school teachers alike are familiar with such experiences, yet preschool curricula often do not address biological science topics such as family resemblance, life, death or inheritance directly. This may be the result of assumptions on the part of curriculum developers that preschool children are incapable of making abstract inferences (e.g., Association for Supervision of Curriculum Development, 1995). These assumptions are based on a pattern of characterizing preschoolers as having no causal scientific theories, particularly specific theories relating to biology (Piaget & Inhelder, 1969). However, more recent research has indicated that children can and do create their own theories to reason about complex phenomena such as psychology, mechanical physics (Carey, 1985a; Carey & Spelke, 1994; Keil, 1994; Wellman & Gelman, 1992), and biology (Gopnik & Wellman, 1994).

The Child As Scientist: Beginning Biology Program

Although a void exists in developmentally appropriate science programs for preschool children, a review of the conceptual development literature suggests that this topic has become an area of interest for many researchers. Carey, in her seminal 1985 publication, Conceptual Change in Childhood, instigated a burst of research in the area of children's conceptual development specifically relating to biology. Following this publication, many researchers set out to investigate further children's understanding of biological processes including growth, living things, death, biological inheritance, and physical illness, to name a few. It is because of the burgeoning of research in children's conceptual development in the area of biological understanding that biology was chosen as the specific topic addressed in the creation of a new pre-school science program initiative entitled the Child As Scientist: Beginning Biology program (Lawson Foundation, 2001).

Based on this current research, four main topics – Growth, Life Properties, Biological Inheritance, and Physical Illness were chosen for inclusion in the Child As Scientist: Beginning Biology program. For the purposes of this thesis, one unit from the Child As Scientist: Beginning Biology program was selected for further investigation due to promising preliminary results for the evaluation of the program.

Biological Inheritance

Past research has found that preschool children are aware, at some level, many of the concepts associated with understanding biological inheritance. For instance, preschoolers know that bodily and mental traits differ – that, for example, a mother cannot will her child's gender or hair colour to change (Inagaki & Hatano, 1993). Preschool children also know that offspring tend to resemble their parents. They know that dogs have puppies and not kittens, people with dark skin tend to have offspring with dark skin (Gelman & Wellman, 1991; Hirschfeld, 1995; Springer & Keil, 1989). Additionally, most preschoolers know that babies come from their mothers' bellies (Berstein & Cowan, 1975; Springer, 1995).

As Solomon & Johnson (2000) pointed out, what tends to be missing from preschooler's understanding of biological inheritance, however, is an organizational system or framework onto which these facts can be mapped and understood. In other words, although preschoolers have been found to demonstrate knowledge regarding biological inheritance, they may confuse inherited traits with environmentally influenced traits. For example, although preschool children know that cats have kittens (biologically inherited physical traits), they may also judge that parents who wear blue shirts will have offspring who also wear blue shirts (environmentally produced trait). This claim has been supported in the research (e.g., Hirschfeld, 1995; Johnson & Solomon, 1997; Solomon, Johnson, Zaitchik & Carey, 1996; Springer, 1996; Weissman & Kalish, 1999). To determine if such an organizing system could be taught, Solomon and Johnson devised a teaching intervention that was found to correspond with increased theoretical understanding of biological inheritance in five- and six-year-old children.

In order to teach young children about biological inheritance, Solomon & Johnson (2000) first assessed what American high school graduates know and understand about biological inheritance. Based on the results of this assessment, they devised their benchmark for an "adult" conceptualization of biological inheritance. Next, Solomon and Johnson found out what most five and six year olds already knew about biological inheritance, and subsequently they determined how the children understood the facts that they knew to be causally linked.

In their teaching intervention, Solomon & Johnson taught preschool children a conceptual peg (a rudimentary notion of genes), which they theorized would help the children organize their reasoning about biological inheritance. Ultimately, Solomon &

Johnson found that children who participated in the teaching condition demonstrated significantly improved understanding of biological inheritance relative to children in the comparison group who did not participate in the instruction intervention.

Life Theorizers and Non-Life Theorizers

In a related vein is the research addressing children's acquisition of their first "biological theory." As mentioned above, Carey (1985) first investigated the topic of when children begin to understand concepts such as life, death, growth, and inheritance. She asserted that children do not acquire their first true biological theory until approximately age ten. According to Carey,

> ...a theory is characterized by the phenomena in its domain, its laws and other explanatory mechanisms, and the concepts that articulate the laws and the representations of the phenomena. Explanation is at the core of theories. It is explanatory mechanisms that distinguish theories from other types of conceptual structures, such as restaurant scripts (Carey, 1985, pp. 201).

Carey later lowered the age at which children acquire their first biological theory to between ages seven to ten (Carey, 1995).

Jaakkola (1997) further investigated children's biological theorizing and suggested that children develop their first biological theory between the ages of four and six, but that this theory must be reconstructed before children reach a more "adult-like" theory of biology. Jaakkola's (1997) research centred around preschoolers having an integrated understanding of life and death. That is, the children demonstrated that they understood life and death as a process and that interruption of the life process resulted in death. Those children who demonstrated that they had mastered this understanding were termed "Life Theorizers" and those who had not yet acquired this integrated understanding were termed "Non-Life Theorizers." Life theorizers, according to Jaakkola, have acquired their first biological theory.

Based on this claim, in a subsequent publication, Jaakkola and colleagues (Slaughter, Jaakkola, & Carey, 1999) questioned whether children termed "Life Theorizers" might learn biological information more quickly than "Non-Life Theorizers." If children have already acquired their first theory of biology (i.e., Life Theorizers), they further sought to understand if they learn new biological information more quickly than children who do not already have this organizing system for biological knowledge in place? The Child As Scientist: Beginning Biology program (Lawson Foundation, 2001) offered an ideal opportunity to address this question.

The present study, based largely on the work of Solomon & Johnson (2000) and Jaakkola (1997), was designed to investigate the effectiveness of the Inheritance Unit of the Child As Scientist Program: Beginning Biology program in instructing children to understand biological inheritance more fully. Secondly, this study aimed to determine whether children's trajectory of learning in the area of biological inheritance is the same or different for Life Theorizers as compared to Non-Life Theorizers.

Organization of Thesis

This thesis is organized as follows. In Chapter II the reader is presented with a review of the literature regarding children's conceptual development in the area of biology in general, children's understanding of biological inheritance specifically, and educational approaches to instruction. In Chapter III the specifics of the research design are reviewed including a description of the methods, subjects, tasks and procedures.

Chapter III will also outline the instruction program (Child As Scientist: Beginning Biology, Biological Inheritance Unit). In Chapter IV, I provide the results of the quantitative analysis of the children's responses to the Species Adoption Task and the Modified Springer-Keil task (as outlined in Solomon & Johnson, 2000) and the Life Theorizer questionnaire (Jaakkola, 1997). The final chapter, Chapter V, integrates the information gathered throughout the study, provides a summary of the results, and relates the findings to the literature. Finally, the study's limitations and implications for research and practice are outlined.

CHAPTER II

LITERATURE REVIEW

In order to provide effective instruction to preschoolers regarding biological inheritance, it is first necessary to understand what the conceptual development research has found regarding children's understanding of biological inheritance (Case, 1993), and secondly to understand what the field of educational research has to offer regarding teaching young children about science. In the present chapter, the conceptual development literature regarding biological inheritance, children's theorizing about scientific concepts (specifically biology), and educational approaches to teaching young children science are reviewed. Finally, the research conducted for this thesis will be situated in the existing research.

Conceptual Development

How do children conceive of the world around them? In what ways do children think about and make sense of their environment? Over the years, researchers have shifted in their conceptualizations of how children think about the world around them. Three main hypotheses offered by investigators interested in answering such questions have been proposed. As outlined by Siegler (1998), these hypotheses include: classical or defining-features theory, probabilistic theory, and theory-based theory.

Defining-features theory suggests that people represent concepts analogous to the way that a dictionary provides simple definitions for words. Only the necessary and sufficient information is used to determine whether something does or does not fit with a concept. An example is the concept of uncle. According to defining-features theory, an "uncle" is a mother or father's brother or an aunt's husband. Piaget & Inhelder (1969) and Vygotsky (1934) are examples of investigators adhering to the defining features theory in which children are thought to represent a particular concept if they know its defining features. Children are said to use these features to differentiate whether a case fits or does not fit a certain concept. An example offered by Piaget (1959) is that of a child who classified a cloud as alive because it moves, which was thought to demonstrate that the child used movement as a defining feature for living things; to this child, living things are classified by their ability to move. The defining-features view has been criticized because although some concepts have defining features, most do not. Therefore, Rosch and Mervis (1975) devised another theory of conceptual representation: probabilistic representation.

From the perspective of probabilistic representation, there are no defining features that guide decisions regarding classification of concepts. Probabilistic theory is more analogous to encyclopedic articles. Concepts may be represented in terms of properties that are typically, but not always present. That is, concepts are classified based on the probability of related features. For example, with respect to the uncle example above, from the probabilistic representation perspective, uncles are usually but not always nice. Individuals rely on cue validities to express the degree to which a feature cues a concept. For example, things that fly tend to have wings and feathers.

More recently, the probabilistic representation has been questioned because some researchers (e.g., Carey, 1985; Keil, 1989, Wellman & Gelman, 1998) have queried how people decide which features of unfamiliar objects should be attended to and which features should be ignored. These researchers have suggested that naïve theories may guide such decisions.

Proponents of the theory theory suggest that concepts are represented in a way that is analogous to the chapters in a science book; they emphasize the causal relationships in the elements of a system (e.g., Carey, 1985; Hatano & Inagaki, 1997; Keil, 1989; Wellman & Gelman, 1992, 1998). Therefore in the example of the way "uncle" is represented, according to the theory theory, the representation includes explanation of why uncles tend to be nice, why they tend to be around the same age as parents, and so on.

In recent years, the theory theory position has received much attention and has been the subject of considerable debate. Although various researchers have offered different renditions of how and when children acquire theories about the world around them, there has been general consensus that children develop domains of knowledge that are organized around causal explanations (e.g., Carey, 1985; Inagaki, 1997; Keil, 1989; Wellman & Gelman, 1992, 1998).

Conceptual Domains

Although stage theorists such as Piaget posited that children's cognitive development in all areas proceeds uniformly and follows certain age-related stages (e.g., Piaget, 1969), more recently other investigators have suggested that different bodies of knowledge may advance at different rates (e.g., Carey, 1985b, 1991; Carey & Spelke, 1994; Gopnik & Wellman, 1994; Inagaki & Hatano, 1993; Keil, 1992, 1994; Springer, 1992; Springer & Keil, 1989, 1991; Vosniadou & Brewer, 1992; Wellman & Gelman, 1992). Bodies of knowledge that formulate into naïve theories about the world have been referred to as "foundational knowledge" by authors such as Wellman and Gelman (1998). Foundational knowledge serves as a theoretical framework from which children form their explanations of phenomena. These explanations are made based on their understandings of causal mechanisms within a certain domain.

Two examples of commonly accepted domains of cognitive development in which naïve theories exist are psychology and mechanical physics. These two domains are thought to constitute intuitive theoretical frameworks for young children. Cognitive development, according to this hypothesis, is a process of theory elaboration and change (Carey, 1985a; Carey & Spelke, 1994; Keil, 1994; Wellman & Gelman, 1992). For example, Carey (1985) suggested that preschool and early elementary aged children explain and interpret much that goes on around them in terms of psychology (e.g., a child may say that one eats because of social expectations rather than recognizing the biological need for food). As children get older, their theories change and become more standard and elaborate (e.g., the child's naïve psychological theorizing would become more elaborate and divide into psychological and biological theories).

Although researchers have generally agreed upon the existence of two domains, psychology and mechanical physics, as being innately present in young children (e.g., Carey & Spelke, 1994; Gopnik & Wellman, 1994; Spelke, 1991), biology as a third domain of foundational knowledge has more recently been a topic of much debate. Within this debate, researchers tend to align themselves with one of three positions.

The first position, posited by Carey (1985, 1995), is that before age seven to ten, children make sense of biological phenomena by way of psychological theorizing. That is, the young child explains biological phenomena such as eating in terms of psychology (e.g., wants, likes, and dislikes – "She eats "X" because she *likes/ wants* it.") rather than with a biological frame of reference (e.g., "She eats "X" because *people need to eat to* *stay alive."*). Psychological reasoning is based on intentional causality, whereas biological reasoning is based on an integrated understanding of life and death as well as the processes that support life and death. The difference between psychological and biological reasoning is that the child who reasons that a person eats because he/she *wants to* does not take into consideration that eating is necessary to sustain life. Carey (1985, 1995) stated that there is nothing wrong with understanding human behaviour based on intuitive psychology, only that by approximately age seven to ten, children develop another, more biologically based framework for understanding the way that the body works. Therefore, Carey suggested that biology cannot be said to be a third foundational domain because it develops out of the domain of psychology.

The second position, endorsed by Inagaki & Hatano (1993) and Hatano & Inagaki (1994) is that by at least six years of age, children have an autonomous domain of biology. Although their understanding of this domain is organized around the causal principles involved, it is different from that present in older children and adults. Inagaki and Hatano (1993) suggested that by the time a child is six years of age, he/she has constructed an autonomous domain of biology, which is vitalisitic in nature. By this, Inagaki and Hatano mean that children tend to explain bodily processes in terms of health and growth. For example, according to Inagaki and Hatano, when asked why we eat, pre-school children often respond that we eat so that we grow or so that we do not die (see Hatano & Inagaki, 1994). Of note, is that Inagaki and Hatano study Japanese children who, because of their culture, are familiar with Japanese vitalism, which emphasizes the concept of vital life force.[1]

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[1] The Japanese concept of *ki* in Western terms is analogous to the idea of being the extra something that a body must have to be alive (Carey, 1995).

Finally, the third position, advocated by Keil (1992, 1994), suggested that even the youngest children may have reasoning "stances" that pertain to different domains of thought. Keil suggested that children possibly as young as one year reason about mechanics, intentionality, and teleological functioning in different ways. These reasoning stances are precursors to the later development of autonomous domains of thought. An example Keil offered with respect to children's reasoning about biology is that of a 2 ½-year-old child questioning why a certain insect had pincers. To Keil, this question demonstrated teleological thinking (i.e., assuming that body parts must serve a function), which he suggested is associated with young children's first biological theory.

Recent research reviewed these three positions and investigated the question of when children develop their first intuitive theory of biology as well as the type of theorizing that the children engaged in (Jaakkola, 1997). Jaakkola, following Carey (1985), stipulated that in order for children to be said to have an autonomous domain of biology, two criteria must be met: first, the child must distinguish between biological and non-biological entities and second, the child must use biologically specific causal principles when explaining biological phenomenon (Jaakkola, 1997; Korpan, 2000).

In one part of Jaakkola's study, she investigated children's understanding of bodily organs and processes and their relationship to maintaining life/ preventing death. This part of the study investigated whether children use teleology as a causal principle in their biological theorizing. She found that children made a dramatic shift in their functional explanations between the ages of four and six and credits their discovery of life as a biological goal with precipitating this change. Children who demonstrated understanding of bodily functions and processes as they related to life and death were said to have developed their first biological theory. Therefore, Jaakkola's research differs from previous research in that Jaakkola concluded that children develop their first biological theory between the ages of four and six – earlier than other researchers previously suggested (Carey 1985,1995; Inagaki & Hatano, 1993; Hatano & Inagaki, 1994).

Jaakkola characterized children as Life Theorizers if they mentioned the goal of maintaining life or avoiding death when asked about a series of bodily organs such as the heart and lungs or substances such as blood. Her rationale for this was that if children use life as an ultimate biological goal, then they must actively use this concept in reasoning about body part functions (although it was not expected that children would use this concept to explain all or even most body parts). Given her results which appear to support the existence of differences between Life Theorizers and Non-Life Theorizers, a question posed by Jaakkola (1997) and later by Slaughter, Jaakkola, and Carey (2000) was whether Life Theorizers may learn biological information in a way that is similar to or different from children who are Non-Life Theorizers. In other words, if preschool children were taught biological information, would Life Theorizers and Non-Life Theorizers differ in their trajectory of learning such information? This question is central to the research addressed in this research, specifically focusing on biological inheritance as a topic of instruction.

Biological Inheritance

What is biological inheritance? Biological inheritance refers to the passing of biological information from parent to child (Solomon & Johnson, 2000). Over the past four decades researchers' views of children's capacity to understand biological inheritance have changed and evolved. Whereas young children were once thought to be incapable of understanding about offspring and resemblance to parents, more recent research does not support this claim.

Progression of Research in the Area of Children's Understanding of Biological Inheritance

Piaget (1929/1951/1960), in his early writings on the topic of animism and artificialism, concluded that children do not use biological reasoning in making sense of the birth of babies. Piaget based this claim on examples of statements made by children between the ages of two and ten. He suggested, instead, that children tend to consider living things to be both "artificially made" and living, indicating that they do not have a biologically-based reasoning system.

> ...in the ideas of children on birth lies the explanation of the basic interdependence of artificialism and animism. A baby being considered as at the same time artificially made and living, the child has the tendency to consider all things as possessing the same characteristics (p. 369).

It is important to note that Piaget's conclusions were drawn based on published statements, or statements and recollections gathered by Piaget and colleagues.

Since Piaget's initial writings on children's (lack of) biological reasoning regarding the topic of birth, subsequent researchers, using more direct investigative techniques, have provided evidence that children have ideas about biological inheritance that evidence biological reasoning and are not based in animism and artificialism (e.g., Kargbo, Hobbs, & Erickson, 1980; Engel Clough & Wood-Robinson, 1985; Springer, 1992, 1995, 1996; Springer & Keil, 1991). These investigators have approached the area of children's understanding of biological inheritance by focussing on several concepts including differentiation between environmentally-produced and inherited traits. Kargbo et al. (1980) studied children ages seven to thirteen to determine the extent to which they predicted the outcome of an offspring's characteristics by simple deduction of the physical characteristics the parents exhibit – inherited versus environmentally-produced (e.g., Both parents have been in an accident that caused them to have a finger cut off. Would their baby also be missing a finger?). Kargbo et al. also investigated the types of explanations used by the children to support their predictions. From their research, they found that younger children tended to take into consideration only one feature to determine an offspring's characteristics, regardless of its heritability (e.g., if the mother is injured, the offspring would be deformed; if the mother dog is black, the puppies would be black). The researchers also found that the younger children tended to explain each situation without regard for what they had said previously. In other words, the children's answers varied from one situation to the next; an explanation given for a previous situation was not consistent with subsequent explanations. From their research, Kargbo et al. concluded that even though children do not generally explain inheritance in a way that concurs with current scientific theory, they had developed a common-sense framework for making sense of phenomena involving inherited characteristics. The fact that these frameworks exist suggests that the topic of inheritance is of interest and importance to children.

Springer & Keil (1989) furthered this line of research by studying preschool children and their understanding of inborn versus acquired traits. To do this, children were presented with brief "stories" about animals who were either born with, or had acquired, an unusual physical trait (e.g., dogs with pink hearts inside instead of red hearts). The children were then asked to state whether the offspring of such animals would also exhibit that trait at birth. Springer and Keil found that young children's judgements differed from adults' in a systematic way; the children's responses indicated that they believed that features were inherited if they had biological, functional consequences and only among animals that were described as biological relatives. Springer and Keil also found that four-year-olds did not differentiate between inherited and acquired characteristics.

In subsequent research, Springer and Keil (1991) asked preschoolers to choose between several mechanisms of colour transmission in living things such as dogs and flowers and also artifacts such as tin cans. In this case, they observed systematic differetiation in the mechanisms chosen relative to the target. Preschoolers were found to be more likely to see transmission of properties between animals as being due to something considered to be inherent in the mother.

Another line of research in the area of biological inheritance has centered around children's predictions of family resemblance, particularly in the cases of genetically-related families as opposed to adopted families. Research by Gelman & Wellman (1992) found that preschool children expect baby animals grow up to be like other members of their species even if they are raised with members of a different species. Springer (1992) investigated whether four and seven-year-olds distinguish between biologically-related and non-related animals within the same species. He found no difference between the age groups and concluded that children's knowledge of inheritance within families was due to knowledge of intrauterine development. Preschoolers have also been shown to expect that adopted human babies will physically resemble their biological rather than their adoptive parents (Hirschfeld, 1994).

How is it that children understand biological inheritance? Similar to Kargbo et al. (1980), Springer (1995) suggested that young children have what he refers to as a "naïve theory of kinship" (NTK). By this, Springer meant that young children make inferences regarding kinship from the knowledge that they already possess. Springer emphasized that this process does not involve structural change, use of analogy, or acquiring new knowledge. According to Springer, the factual knowledge that is required as a pre-requisite in order for these inferences to be possible includes three premises. The first premise is that babies grow inside their mothers. The second is that fetal growth is not typically affected by extra-uterine development. The third premise is that physical proximity between two objects facilitates (but does not guarantee) transmission of properties between them. Based on these three premises, Springer suggested that three beliefs can be inductively inferred. These beliefs are: 1.) Babies share more traits with their mothers than unrelated animals (Springer, 1992); 2.) Good and bad functional properties are equally heritable (Springer & Keil, 1989); and 3.) Inheritance occurs by means of material transfer (Springer & Keil, 1989).

Based on this theoretical foundation, Springer hypothesized that children's understanding of biological inheritance could be enhanced if gaps in their knowledge of the three premises were rectified, thereby providing a framework for the subsequent inferences outlined above. Springer investigated this hypothesis (Springer, 1995) and discovered that when children ages three and four years who did not possess the three premises were taught them, they subsequently demonstrated better biological reasoning about inheritance. His results suggested that children who knew where babies grew were more able to differentiate between features inherited from biological parents versus adoptive parents. Based on these findings, he concluded that preschool children have a "partially biological construal of kinship" (Springer, 1995, p.2848), meaning that although they do not yet know about genetics, they do know where babies grow and they use this knowledge to guide their understanding of parent-offspring resemblance.

Following this line of investigation, Solomon, Zaitchik & Carey (1996) examined biological and social aspects of family resemblances with four- and seven-year-olds. Using cross-family adoption stories, they found that children younger than seven years tended not to distinguish between biologically-based and socially-based resemblance to parents. This led them to conclude that it is not until around age seven that children appreciate birth as part of a causal process of the inheritance of unchangeable traits.

Although at first glance it would appear that Springer (1995) and Solomon et al (1996) demonstrate conflicting results, the actual results of the studies are not conflicting. Rather, it is the interpretation of the meaning of each study's results which makes the results appear to conflict. Whereas Springer concluded from his study that preschool children have a partially developed biological construal of kinship based on their demonstrated knowledge of certain biological facts, Solomon et al (1996) concluded from their results that children under the age of seven do not have an explicitly biological theory because they cannot reliably differentiate between features that are the result of biological inheritance and features that are socially acquired. These results are not mutually exclusive -- Springer may be correct in suggesting that preschool aged children know certain facts which help them to draw biologically based inferences, but do not yet have a complete biological theory. In other words, Springer suggested that preschoolers who know some basic facts such as where babies grow make inferences which are biologically-based, but they do not yet reason about biology in an entirely distinct way (i.e., they do not yet have a complete biological theory). The preschool-aged children in Solomon et al.'s study were not able to differentiate between biological and social features (which would require more elaborate biological reasoning). Therefore, both studies found that preschool children demonstrate a degree of biological reasoning regarding biological inheritance, but they do not yet have a distinct, complete, ontological domain of knowledge.

Solomon and Johnson (1997) further investigated the question of when children can be said to use distinctly biological reasoning to explain biological inheritance. They found that although children are able to predict what species a baby animal will be on the basis of who gave birth to it, analysis of the children's explanations suggested that only a minority of preschoolers and six-year-olds used birth as a causal explanatory framework to make biological inferences, whereas the majority of seven-year-old children did. This study bridges the results of Springer (1995) and Solomon et al (1996) in that it demonstrates that younger children are able to make basic judgments about biological inheritance (i.e., they demonstrate a partial biological theory), but it is not until they are older (around age seven) that they demonstrate a cohesive and complete theory which includes birth as a causal explanatory framework.

Teaching Children to Understand Biological Inheritance Better

In order to understand children's thinking around biological inheritance and the causal explanatory frameworks they use in making determinations about biological inheritance better several investigators have attempted to advance children's understanding of biological inheritance by teaching them the information that is hypothesized as being necessary to improve understanding. As mentioned above, Springer (1992, 1995, 1996) suggested that knowledge of where babies grow is necessary to make correct, biologically-based inferences about family resemblance. When Springer (1995) taught preschoolers facts about where babies grow, he found that the children make significantly more correct judgments about biological inheritance.

Solomon et al. (1996), Johnson and Solomon (1997), and Solomon and Johnson (2000) suggested, however, that knowledge of this fact is necessary but not sufficient for improving children's understanding of biological inheritance. To investigate this assertion, when Solomon and Johnson (2000) endeavored to teach preschool children to understand biological inheritance better, they sought to teach a system of knowledge that included the content relevant to biological inheritance. This content included: a.) physical and mental traits are ontologically different kinds of traits, b.) offspring tend to look like their parents, and c.) birth is one mechanism in the chain of events that lead to the origin of the body. To teach the children the information within a system of knowledge, Solomon and Johnson first made the children aware that they lacked an adequate explanation for a phenomenon through asking a series of questions. One of the questions referred to a picture of a bunny with a big belly and asked what kind of babies would come out of her belly. Then, the children were asked how they knew that baby bunnies would come out and not dogs or cats or people. Second, Solomon and Johnson (2000) supplied the children with the relevant facts (in this case, the fact that babies come from their mother's bellies). Third, they presented the children with a placeholder mechanism that was suggested to "organize the facts in service of causal inference" (p.84). The placeholder mechanism was an elementary version of gene theory. That is, they gave the children the following explanation.

> We all have these tiny things called genes inside us that make us what we are … people have people genes and rabbits have rabbit genes. When a baby is being made inside its mother's belly it gets … genes from her (p. 88).

To evaluate the effectiveness of their teaching intervention, Solomon and Johnson chose to use two well-known tasks from the biological inheritance literature: the Species Adoption task (based on Johnson and Solomon, 1997) and a modified version of the Springer-Keil task (Springer and Kiel, 1989). The Species Adoption task focused on the understanding that resemblance in physical traits is mediated by a different causal mechanism than is resemblance in beliefs or activities. It contrasts the biological and social aspects of offspring's features, thereby underscoring the centrality of the notion of birth as a causal mechanism in biological inheritance. The children were told a story about an animal that gave birth to a baby and then subsequently died. The children were then told that the baby was raised by an animal of a different species. Following the story, the children were asked a series of forced-choice questions about what the baby would be like when it grew up (physical features and beliefs or activities). For example, in one story, a horse gives birth to a baby and then dies. The baby is then raised by a cow. The questions that follow the story involve the child making judgments about which physical features and beliefs the baby will have when it is grown such as: "The horse has a black nose and the cow has a brown nose. When the baby grows up, do you think it will have a black nose like the horse or a brown nose like the cow?" In addition, Solomon and Johnson also evaluated the children's understanding of inheritance by analyzing the explanations of their judgments. At post-test four of the 32 children in the experimental group and no children in the comparison group mentioned genes when giving explanations for their judgments in the Species Adoption task. In their discussion, Solomon and Johnson were not able to conclude whether the gene instruction was actually responsible for the children demonstrating improved understanding of biological inheritance following their teaching intervention or whether their responses may have relied upon what Wellman and Gelman (1991) called an "essentialist bias." Wellman and Gelman (1991) found that young children were likely to judge that offspring of a particular species would have the features typical of their species regardless of learning or environment.

The modified Springer-Keil task (Springer & Keil, 1989) also emphasized the role of birth in determining resemblance to parents, but did not require children to differentiate between physical and psychological traits. Instead, it required them to differentiate between inherited (innate) traits and those that are acquired due to life experience. "In effect, the task requires children to link the birth of the offspring to the birth of the parent, thereby implying the concept of life cycles so central to biological reasoning" (Springer & Keil, 1989, p. 87). The following is an example of the questions posed to the children on the modified Springer-Keil task:

> This is Mr. and Mrs. Bear. They had an accident and now have only four fingers instead of the normal number, so they are better at sticking their hands into holes to get honey. Later, Mr. and Mrs. Bear have a son named Bernie Bear. When Bernie is born, do you think he'll have four fingers, just like his parents, or will he

have the normal number like the other bears? (Solomon and Johnson, 2000, p.88).

Solomon and Johnson (2000) found that when they taught five- and six-year-old children a twenty-minute lesson that included the three-step procedure, the children demonstrated significantly better understanding of biological inheritance as compared to comparison children who did not receive instruction. The authors suggested that these results indicate conceptual reorganization regarding understanding of biological inheritance. Solomon & Johnson proposed that this conceptual reorganization was accomplished by changing what the children considered to be a 'central fact' upon which they made their judgments regarding biological inheritance. This study was intended to be a first step in the marriage of cognitive science and science education. It was an attempt to better understand the explanatory frameworks used by young children to understand and explain biological inheritance so that future curricula could be appropriately designed to build on them.

Interestingly, other researchers have also endeavored to teach children about biological inheritance but did not find that the children demonstrated significantly improved biological knowledge following instruction. Williams and Affleck (1999) used an intervention technique adopted from Springer (1995) in which four- and seven-year-old children were taught the basic facts of intrauterine development and birth in story form during a ten-minute, individual teaching session in order to improve children's conceptual understanding of inheritance. Although pre-test results indicated a significant difference in the level of biological sophistication evidenced in the judgments and explanations given by the four- versus seven-year-old, post-test and delayed post-test results did not demonstrate significant improvements in the judgments or explanations offered by children of either age level. Why do these results not fit with those found by Springer (1996) or Solomon and Johnson (2000)?

Although Williams and Affleck used many of the same procedures as Springer (1995, 1996) they chose to make some changes. First, Williams and Affleck used stories involving animals rather than humans. They also chose to represent the animals in their stories in cartoon-like pictures as compared to Springer's use of realistic pictures of his teaching intervention. Finally, Williams and Affleck did not allow the children to interact with the information they were to have learned from the stories. In fact, the children were actively prevented from attempting to link the stories to other knowledge or clarifying the stories: "No additional information concerning intrauterine development, birth processes or inheritance was provided to the children, even when they asked for clarification or further details" (p. 263).

A later study by one of the same authors (Williams & Tolmie, 2000) also investigated improvements in biological inheritance reasoning, but with older children. Williams and Tolmie (2000) found that eight- and twelve-year-old children who encompassed differing initial concepts of biological inheritance, after being required to do a group project on biological inheritance and discuss their differing concepts to come to consensus, demonstrated the greatest advance in their reasoning about inheritance compared to other groups whose initial concepts of biological inheritance were more similar. The students who were in groups whose initial concepts of biological inheritance differed widely likely engaged in more discussion and idea-sharing than those students whose initial concepts were more similar. This may have resulted in the groups whose initial concepts were more varied demonstrating greater advance in their reasoning. These results help to further explain why Williams and Affleck's study was not able to affect change: they did not allow the children to interact with the new information. This conclusion was supported by the work of Solomon and Johnson (2000) in which a small-group format, discussion, and related activities were used in the teaching intervention with pre-school children and produced significant changes in the children's reasoning about biological inheritance.

Approaches to Instruction

What can theories of development and theories of learning offer to support an instructional preschool science program? Classical developmental theory as outlined by Piaget served as a foundation to theories of learning. One of the most important suggestions made by Piaget was that "at several times in their growth, children acquire new systems of cognitive operations (structures) that radically alter the form of learning of which they are capable" (Case, 1993, p. 219). Based on this assertion, it can be assumed that one should not begin any instruction without first considering and assessing the cognitive structures that the child has acquired already and instruction should incorporate and build on these existing structures (Case, 1993).

According to Case (1993), a second major contribution of Piaget was his hypothesis concerning how new structures are created. Piaget saw children as highly involved in the process of constructing new structures. As a result of Piaget's insights regarding developmental theory and in conjunction with the advent of information science, learning theory was revolutionized. Learning theorists began to assess the structures and processes of children who were at the beginning stages of developing a new domain of knowledge and they also began to assess the types of misconceptions that resulted. Because of this, curricula began to take naïve structures into consideration and challenged children to become active (as opposed to passive) in their learning experience.

This is evidenced in three general developmental principles reviewed by McKeough and Sanderson (1996). The first principle states that children are active constructers of knowledge (e.g., Piaget, 1950). The second principle states that instructional planning should be guided by knowledge of children's domain-specific concepts and the typical pattern of their development (e.g., Case, 1985). Finally, the third principle states that maximum learning occurs when we build onto children's existing knowledge, offering material that is just slightly in advance of it (e.g., Brown & Campione, 1990).

These three general developmental principles are consistent with constructivism as an approach to learning. As outlined by Driver (1994), and later in Banet & Ayuso (2000), the constructivist approach to teaching science is an approach that encompasses the following components: students learn science based on their previous knowledge, learners are actively involved in restructuring their ideas about the subject matter, and learning is viewed as being the process of reorganizing prior knowledge and building on it so as to create new meaning or understanding in the learner's mind.

This means that unlike traditional approaches to teaching in which the teacher is viewed as being the possessor of knowledge and the student as the recipient of knowledge, from a constructivist perspective, the student is also considered to be an active partner in the learning process. What the student knows prior to teaching is taken into consideration by the teacher and is built upon (scaffolded and restructured) by the student (with teacher support) yielding new understanding and meaning for the student (see Watts & Jofili, 1998 for further discussion of constructivist approaches to teaching science). This is the case regardless of the correctness of the students' conception from a scientific point of view.

According to Banet & Ayuso (2000), who employed a constructivist approach to teach secondary students about biological inheritance, the planning and teaching process must, therefore, also include teaching activities that: (a) arouse students' interest (so that they are involved in the learning process); (b) provide opportunities to elicit students' conceptions; (c) question these ideas (cognitive conflict) and promote situations in which new meaning can be constructed or restructured; (d) consolidate new knowledge; (e) apply the knowledge to different contexts; and (f) encourage reflection on what has been learned from the teaching process (p.333).

Banet and Ayuso's suggestions are helpful guidelines by which teachers can design their science instruction. However, particularly in the case of instructing preschool aged children, McKeough and Sanderson (1996) following Case (1993) also offer important, developmentally-appropriate suggestions for effecting developmental bridging between children's current structures of knowledge and the next level. Like Banet and Ayuso, McKeough and Sanderson suggested it is important to first make children aware of their current representation. In the case of biological inheritance, this involves determining with the children how they currently understand the relationship between offspring and parents (e.g., social relationship, biological relationship) and the basis on which they make such determinations. Next, it is important to provide a graphic cue or mnemonic to help bridge between the current conceptual structure and the next level in the developmental hierarchy. Pictorial mnemonics have been used to assist with conceptual bridging between 'old' and 'new' structures in the instruction of biological inheritance to preschoolers by Springer (1996), Solomon and Johnson (2000), and Williams and Affleck (1999). For example, Solomon and Johnson (2000) used schematic pictures of animals such as a rabbit that was pregnant and had a protruding belly to discuss the concept of "genes." Finally, McKeough and Sanderson state that after children have successfully integrated the content of the graphic mnemonics into their cognitive structure, the final step was to gradually remove them. McKeough and Sanderson found conceptually appropriate scaffolding was associated with learning and acquiring the next level of sophistication in narrative development.

In a related vein, McKeough, Davis, Forgeron, Marini, & Fung (under review) recently investigated whether a technique they called "multi-modal scaffolding" may be helpful to assist children to advance to a next stage in conceptual development in narrative story-telling. Because Case (1993) suggested that working memory limitations may impede children from being able to advance to the next level of conceptual development, McKeough et al (under review) provided conceptual mnemonics in the form of icons to serve as a bridge between a child's level of spontaneous achievement and the next level of development. The authors suggested that "as cognitive scaffolds, these graphic depictions circumvented children's processing capacity limitations and thus, helped them to construct a more advanced understanding" (p.14). McKeough et al. (under review) also used other materials and techniques including graphic instructional supports included story frames, icons, story starter picture cards, and picture storybooks to assist with circumventing working memory demands. Results suggested that properly sequenced, multi-modal scaffolding is an effective approach for teaching and advancing children's conceptual development in story-telling. Could this same approach also be effective for teaching science to young children?

Although Solomon and Johnson did not set out to follow McKeough and Sanderson's steps for conceptual bridging, explicitly mention multi-modal scaffolding, nor did they mention constructivism as an instructional approach, their methods were somewhat consistent with these. Solomon and Johnson sought to understand the children's conceptions of biological inheritance to some extent through their pre-test measures using the Species Adoption task and a modified version of the Springer-Keil task. They then sought to expand and restructure the children's knowledge of biological inheritance through the use of graphic mnemonics to assist the children with bridging previous conceptions with new conceptions. The present study sought to further the work of Solomon and Johnson (2000) by expanding their approach to teaching even younger preschool children about biological inheritance.

Overview of the Present Study

Preschool aged children were chosen for the current study for several reasons. First, they were chosen in order to address the question of whether Life Theorizers and Non-Life Theorizers differ with respect to their learning of biological information. Secondly, preschool children were chosen in order to determine whether findings by Solomon and Johnson (2000) could be replicated with a younger group of children. Finally, this age group was chosen because of the relative paucity of science curriculum for preschool aged children, particularly in the area of biology. Research in this area may prompt preschool educators to address this gap. Biological Inheritance as a topic of study was chosen because it is developmentally relevant – it is a process that impacts children's everyday lives – they are told that they look "just like" their mother or father or "have grandma's eyes," and preschool aged children are also often presented with the facts and subsequent questions surrounding biological inheritance with the birth of siblings.

Hypotheses

Hypothesis 1

It was predicted that there would be a significant difference between the biological inheritance knowledge expressed by children who participated in the experimental instructional program as compared to a comparison group composed of children who did not participate in the instructional program. The differences would be indicated by increased biological theorizing, marked by increased biologically-based categorical responses that are more closely resemble canonical adult responses.
The comparison group was expected to evidence gains in biologically-based categorical responses that are typically found in normal child development following a second exposure to a task.

Hypothesis 2

It was predicted that there would be a significant difference between the biological inheritance knowledge gained by children categorized as "Life Theorizers" as compared to those categorized as "Non-Life Theorizers." The differences would be indicated by increased biologically-based categorical responses that more closely resemble canonical adult responses, with the Life Theorizers outperforming Non-Life Theorizers.

CHAPTER III

RESEARCH DESIGN AND METHODOLOGY

A developmentally based instructional module (Inheritance Unit) from the Child As Scientist: Beginning Biology program (Lawson Foundation, 2001) was utilized and quantitative methods were employed to examine children's responses to instruction. The module's design drew on findings from the conceptual development literature as well as the educational/ instructional literature. The goal of the research was twofold: first, to determine whether children who participated in the biological inheritance instruction demonstrated significant improvements to their understanding of biological inheritance in relation to a comparison group who did not receive such instruction, and second, to determine whether children who were identified as "Life Theorizers" followed similar or different trajectories of learning when learning biological information – in this case, information related to biological inheritance, as compared to "Non-Life Theorizers."

Participants

Participants were enrolled in two preschool programs that served primarily lower-middle to middle-class families in a small farming community in Western Canada. These two preschool programs comprised all of the preschool programs available in the small farming community. Ten three-year-olds (5 boys and 5 girls), 40 four-year-olds (14 boys and 26 girls), and 11 five-year-olds (8 boys and 3 girls) participated in the study. This age range was selected for two reasons: First, conceptual development literature suggests that children develop their first biological theory ("Life Theory") roughly in this age span and second, the Child As Scientist: Beginning Biology program (Lawson Foundation,

2001) was written as a developmentally-appropriate instruction program for preschool aged children.

Nineteen children who were invited to participate in the study did not participate due to lack of signed consent form from parents, children being absent on days of pre- and/ or post-testing, and children unable or unwilling to participate in the pre- and/ or post-testing. These cases were omitted from the study. The final study sample consisted of 13 boys and 20 girls in the Experimental group and 6 boys and 12 girls in the Comparison group.

Assessment Tasks

The Life Theorizer Task

Based on the work of Jaakkola (1997), the Life Theorizer task served to categorize the children into "Life Theorizers" and "Non-Life Theorizers," which according to Jaakkola (1997), is indicative of whether the children had or had not developed their first biological theory. The Life Theorizer task included questions pertaining to the purpose of 14 different body parts and organs in addition to two questions about why we eat food and why we breathe air. For each body part the children were asked "What is/are X (e.g., brain, muscles, heart) for?" followed by the question "What would happen if someone didn't have a/an X ?" (see Appendix A for the entire task).

Following Jaakkola's scoring protocol, children's responses were scored according to whether they cited maintaining of life or avoidance of death as relating to the purpose of the body organs or processes. Children who mentioned the goal of maintaining life or avoiding death for at least two organs or processes were categorized as "Life Theorizers." The children who did not meet this criteria were categorized as "Non-Life Theorizers."

Biological Reasoning Task #1 (The Species Adoption Task)

The Species Adoption task (Solomon & Johnson, 2000) focused on the understanding that physical resemblance to parents is mediated by birth as a causal mechanism, while similarity in family beliefs and knowledge are mediated by the environment as a causal mechanism. Offspring should be more likely to resemble their birth parents in physical traits and their adoptive parents with respect to their beliefs or knowledge (learned traits).

The children were seen individually and told a story in which one animal gives birth to a baby that is then raised by another animal. There were two versions of the task, one used as the pre-test and another used as the post-test. In the pre-test version, the mother who gives birth to the baby is a horse and the mother who adopts the baby is a cow. In the post-test story, the birth mother is a duck and the adoptive mother is a chicken (see Appendix B for copies of the stories). Although the pre- and post-tests differ in terms of forms of birth, (i.e., mammalian direct birth and avian laying of eggs), Solomon and Johnson determined that the different forms of birth were not found to be a factor in children's performance (Solomon & Johnson, 1997, 2000).

Following Solomon and Johnson, in the present study, the experimenter told each child the story while pointing to schematic pictures of the adult animals to make the story clear to the children and to maintain interest. As in Solomon and Johnson's study, the offspring in the story was always referred to as "baby" and never "baby horse" or "baby duck" so as to avoid leading the child to make simple category inferences. In addition, no pictures of the babies were shown. Before proceeding with testing, the experimenter asked the following questions: "Who gave birth to the baby?" and "Who raised the baby?" Children who failed one or both of the probe questions were told the story a second time. If the children did not accurately answer the probe questions following the second telling of the story, the remainder of the task was not completed. The children who correctly answered the probe questions were asked a series of twelve two-alternative, forced-choice format questions. The birth parent was described as having one set of features, the adoptive parent as having another, and the children were asked what they thought the baby would be like when it grew up (e.g., "The horse has a black nose [experimenter points to the picture of the horse] and the cow has a brown nose [experimenter points to the picture of the cow]. When the baby grows up, do you think it will have a black nose like the horse or a brown nose like the cow?" Of the twelve features described, four were physical features (e.g., thin fur/ thick fur), four were beliefs (e.g., believed pigs eat corn/ believed pigs eat straw), and four were behaviours (e.g., chased butterflies/ chased crickets). The feature pairs were presented in blocks to make the task easier. For each trait type, the children were also asked to provide explanations for their judgments.

Scoring of the task involved categorizing the children's responses into the following four categories following Solomon and Johnson (2000): Birth-Parent Bias, Adoptive Parent Bias, Mixed, and Canonical. Birth Parent Bias was defined as having a response pattern in which the child selected characteristics that were consistent with the birth parent on at least 9 out of 12 responses (75% of responses). Adoptive Parent Bias was defined as the child selecting characteristics that were consistent with the adoptive parent on at least 9 out of 12 responses (75% of responses). The Canonical Adult response pattern was defined as the child differentiating between the inheritance of physical characteristics and the acquisition of beliefs and practices. This pattern was defined by a response pattern in which the child indicated that at least 3 out of 4 (75%) of the baby's physical characteristics would be like the birth parent and at least 6 out of 8 beliefs and practices (75%) would be like the adoptive parent. The Mixed pattern was defined as any response pattern that did not fit any of the other three categories.

Biological Reasoning Task #2 (Explanation of Judgment)

In addition, as in Solomon and Johnson's (2000) study, the children were asked to explain their response to a question regarding offspring's inherited physical features (i.e., "Tell me why the baby would have a brown/ black nose" (pre-test)/"Tell me why the baby would have black/brown eyes " (post-test)) and also a belief/learned experience feature question (i.e., "Tell me why the baby would know/ not know where special food was kept" (pre-test)/"Tell me why the baby would know/ not know where to hide in bad weather" (post-test)). Following Solomon & Johnson, the responses were categorized into the following categories: Nature (i.e., the explanation referred to the trait being passed from one generation to the next or to the trait being inborn), Nurture (i.e., the explanation referred to learning or experience to explain the existence of the trait), or Other (i.e., explanations that did not fit into either of the other two categories).

Biological Reasoning Task #3 (The Modified Springer-Keil Task)

Following Solomon and Johnson (2000), Biological Reasoning Task #3 (Modified Springer-Keil task) was a modification of the work of Springer and Keil (1989). Like Biological Reasoning Task #1 (Species Adoption Task), Biological Reasoning Task #3

(Modified Springer-Keil Task) was also meant to assess children's understanding of birth as a causal mechanism in determining resemblance to parents. All traits described were physical traits. This task required the children to make judgments to distinguish between innate traits and traits that were acquired through life experience. "In effect, the task requires children to link the birth of the offspring to the birth of the parent, thereby implying the concept of life cycles so central to biological reasoning" (p. 87, Solomon & Johnson, 2000).

The children were presented with schematic pictures of eight pairs of animals (e.g., Mr. and Mrs. Pig) and were told that the animals had an atypical feature (e.g., big eyelashes). They were told that the animals later had a son or daughter and were asked if they thought that he (she) would have the same feature as the parents or the normal feature. For example,

> This is Mr. and Mrs. Pig. Mr. Pig was born with big eyelashes. Mrs. Pig was also born with big eyelashes. Their big eyelashes kept things like dirt from getting in their eyes. Later, they decided to have a baby and named her Elsa Pig. When Elsa is born, do you think that she would have big eyelashes like her parents, or will she have regular sized eyelashes like the other pigs?

Two versions of the task were used, each describing different sets of six animals. One was used as a pre-test, the other was used as a post-test (See Appendix C).

Following Solomon and Johnson (2000), scoring of the task consisted of determining which of four judgment patterns the child's responses fit: Generational, Parent Bias, Acquired Bias, or Mixed. A Generational judgment pattern was defined as offspring being judged to resemble their biological parents on 4 out of 4 inborn traits and none of the 4 acquired traits. A Species Bias judgment pattern was defined as judging offspring to resemble others in the species on at least 7 out of the 8 features. A Parent Bias judgment pattern was defined as judging offspring to resemble their parents on at least 7 out of the 8 features. The Mixed judgment pattern group was defined as those participants whose judgment patterns did not fit in any of the other three categories.

Procedure

All preschool teachers (two teachers) in the small farming community were contacted asked to participate in the study. Both teachers agreed to participate and to have their respective preschool classes participate. Both teachers taught multiple classes with each group of children attending preschool two times per week. Although the two teachers did not teach the same curriculum, both used their respective lesson plans for their morning and afternoon classes. It was decided that the morning classes would participate in the Child As Scientist: Beginning Biology (Lawson Foundation, 2001) instruction program during a scheduled story-time and the children in the afternoon classes would participate in story-time activities as usual.

The experimenter conducted all instruction sessions with the children in the experimental group, and the teacher observed. In the comparison group, the regular teacher conducted her class as usual and the experimenter observed. Participants were pre-tested using the Life Theorizer questionnaire developed by Jaakkola (1997), and Biological Reasoning Task #1 (Species-Adoption PRE), Biological Reasoning Task #2 (Explanation of Judgment on Species Adoption Task) and Biological Reasoning Task #3 (Modified Springer-Keil PRE) tests used by Solomon & Johnson (2000). Following the pre-testing, the children in the experimental groups participated in six instructional sessions of 20 minute duration, which were held two times per week for three weeks, whereas the children in the comparison groups participated in their regular preschool curriculum. Three weeks after the pre-testing was completed, post-testing was initiated with all participants using Biological Reasoning Task #1 (Species-Adoption POST), Biological Reasoning Task #2 (Explanation of Judgment on Species Adoption Task) and Biological Reasoning Task #3 (Modified Springer-Keil POST).

Instruction

A developmentally- based instructional module was developed and used. The module's design drew on findings from Solomon and Johnson's (2000) work in addition to Jaakkola (1997). Grounded in developmental and learning theory as outlined by Case (1993) and McKeough and Sanderson (1996), the framework of the current study emphasized the coordination of prior knowledge with understanding gained in the instructional context. At a global level, the purpose of the program was to support children's cognitive growth by providing multi-modal cognitive scaffolding through opportunities to link the information presented with prior knowledge and experience through the use of children's literature. Previous research in the area of biological inheritance has established a precedent for using stories as a vehicle to assessing and teaching biological inheritance concepts to young children (see Johnson & Solomon, 1997; Springer, 1995, 1996; Solomon & Johnson, 2000; Williams & Affleck, 1999). Because of this precedent, and because children learn best when the information to be learned is interesting and presented in a developmentally appropriate context, children's picture-books and visuals such as felt-board stories were used as instructional aides.

The Child As Scientist: Beginning Biology program (Lawson Foundation, 2001) Inheritance Unit format resembled the children's typical story-time routine with some background knowledge discussion around a topic (in this case, biological inheritance), followed by a story, followed by guided questions and answers regarding the story as it pertained to biological inheritance.

The format and themes of instruction follow those of Solomon and Johnson (2000) but elaborated on them in the following ways. The current investigation involved six- 20-minute instruction sessions while Solomon and Johnson only conducted one 20-minute session. Solomon and Johnson (2000) did not use stories as an instructional medium, whereas the current program did. Solomon and Johnson's instruction did not include game-like "hands-on" activities (i.e., body graphing, picture books) whereas the current study did in order to enhance and engage the younger learners' interests. These changes were made with the intention of creating a developmentally appropriate program for the younger children in the current study (the current study's participants ranged in age from three to five years while Solomon and Johnson's (2000) study involved children ages five and six years old).

Solomon and Johnson designed their study around three factors which they suggested must be taken into consideration when working to effect conceptual change: first, children must be motivated to seek change to their understanding (i.e., they must be aware that they lack an explanation for why offspring tend to resemble their parents); second, they must be supplied with the relevant information; and third, they must be presented with a "conceptual peg" (in this case a rudimentary notion of genes) around which they can organize the relevant facts. These factors were also taken into consideration in the current study. The children were presented with information and questions (following Solomon and Johnson's procedures), which encouraged them to think about the answer to questions such as "Where do babies come from?" and "How do we know that a mommy bunny will have baby bunnies in her tummy and not puppies or people?"

Outline of Lessons

In the first lesson, the children were invited to consider why they look the way they look, to think about the features that they have, and which features they share with their parents. These questions were intended to increase the children's motivation to seek change in their understanding. Due to the current study involving younger participants than Solomon and Johnson's (2000) study, the first lessons were devoted to the idea of "like begets like." For this, the story Are You My Mother? (Eastman, 1960) was used (see Appendix D for a complete outline of the lesson plans).

In the second lesson, the children were led to consider the features of ducks and then contrast these with the features of swans. Following this discussion, the children listened to the story of The Ugly Duckling (Anderson, & Watts, 2000). Discussion during and after the story revolved around what type of bird the "ugly ducking" really was.

In the next lesson, following Solomon and Johnson (2000), the children were further encouraged to consider their explanations for why they looked the way they did. Additionally, they discussed why and how animal offspring tend to resemble their parents. This was done by showing the children felt cut-outs of animals with a range of different properties (e.g., a horse with a black mane; a horse with tusks). They were led to consider why they would believe that the animals might have some features (e.g., a horse with a black mane) but not others (e.g., a horse with tusks). Next, the children were presented with a felt cut-out of a rabbit with a big belly and asked what kind of babies would be in her belly. The children generally responded that "bunnies or rabbits" would come out. They were then asked why bunnies would come out and not dogs or people. The children were provided with the same explanation given in Solomon and Johnson's (2000) study which was:

> We all have tiny things called genes inside us that make us what we are and people have people genes and rabbits have rabbit genes. When a baby is being made in the mother's belly it gets rabbit genes from her and so becomes a rabbit. Not only do rabbits have rabbit genes, but they have long ear genes and bushy tail genes, rabbits with brown fur have brown fur genes and rabbits with white fur have white fur genes. (adapted from p. 88)

In the fourth lesson, the experimenter reviewed the idea of genes by presenting the felt-board examples of animals from the previous day and asking the children why the animals might have some features and not others. The experimenter re-stated the same explanation about genes. Following the explanation, the experimenter read the story Alligator Baby (Munsch, 1997). In the story, the human parents continuously bring home different kinds of babies from the zoo. Discussion centred around what types of genes the different babies had and what types of genes the parents would have. For example, the "people parents" bring home a baby alligator. The children in the study were asked what kind of genes the alligator would have (e.g., alligator genes, green genes, sharp teeth genes).

For the fifth lesson, the idea of adoption was introduced through the story David's Father (Munsch, 1983). In this story, the children discussed why David did not look like his father (related to the idea of genes) and also reviewed how the genes explanation fit with the story of The Ugly Duckling by Hans Christian Anderson. The children were invited to discuss the types of genes that David would have (e.g., "normal size" genes versus "giant" genes like his father) and also discussed how genes related to the Ugly Duckling; the Ugly Duckling had swan genes because its biological mother was a swan.

Finally, the sixth lesson touched on the idea of inborn versus acquired traits with the story Franklin Goes to the Hospital (Jennings, 2000). In this story, a young character named Franklin has an accident and has to go to the hospital to have an operation. This story was used as a vehicle to discuss how accidents and other events happen and whether such events would lead to similar features being displayed by future offspring (e.g., if Mr. and Mrs. Cat stayed outside in the cold one night and their ears got frost-bitten, if they had a baby someday would the baby also have frost-bitten ears?"). Discussion centered around the idea that typically accidents do not affect genes and therefore, future offspring would not inherit acquired traits.

Plan of Analysis

Analysis of the data involved following procedures outlined by Jaakkola (1997) for the scoring of the Life Theorizer questionnaire and conducting chi-square analyses for categorical data as outlined by Solomon and Johnson (2000) for the Species Adoption task and the Springer-Keil task. In addition, contingency table analyses were conducted to compare pre- and post-test results when small sample sizes did not allow for chi-square analysis. The children's biological reasoning was also evaluated by reviewing their responses on the Species Adoption task to questions regarding why they answered as they did (e.g., "Tell me why the baby would have long/short feathers."). Finally, t-test analysis was employed to determine whether the experimental and comparison groups and/or the Life Theorizer and Non Life Theorizer divisions of the groups could be said to differ according to age.

Summary

The current study involved preschool children from two preschools in a small, rural town in Western Canada. The children in the experimental group participated in story-reading and discussion regarding biological inheritance in a series of six 20-minute sessions over a period of three weeks whereas the children in the comparison group participated in regular preschool activities. The children completed the Life Theorizer questionnaire and pre- and post- Species Adoption (including biological reasoning questions) and Springer-Keil tasks.

CHAPTER IV

RESULTS

This chapter is divided into two sections. In the first section, the results of the t-tests, chi-square, and contingency table analyses are described. In the second section, the findings of this investigation are summarized.

Results

T-Test Analysis

The ages of the children in the Experimental and Comparison groups as well as the Life Theorizers and Non-Life Theorizers were calculated and compared to determine whether age may have acted as a covariate. The mean age of children in the Experimental group was 4.5 years and the mean age of children in the Comparison group was 4.2 years. The mean age for Life Theorizers (across Experimental and Comparison groups) was 4.35 years. The mean age for Non-Life Theorizers (across Experimental and Comparison groups) was 4.48 years. When the ages of the Experimental and Comparison group are compared statistically, no significant age difference existed ($t = -.87$, $df = 61$, $p = 0.927$). When the ages of the Life Theorizers and Non-Life Theorizers are compared, no significant difference between the ages of the two groups was found ($t = 1.62$, $df = 64$, $p = 0.847$).

Biological Reasoning Task #1 (Species Adoption Task)

Judgement categories were evaluated to determine whether it made sense to collapse some categories together in order to gain meaningful information from the data and to increase statistical power. Because the Canonical judgement category was the intended goal of the teaching intervention, the Canonical judgment category was contrasted against all other categories combined and re-labelled "Other." The Experimental and Comparison groups were compared to determine whether the groups were similarly represented in the "Other" category at pre-test. The "Other" category was of most interest at pre-test because it was the goal of the instruction program to effect change in these participants' judgment patterns so that they would more closely resemble Canonical Adult judgment patterns at post-test. Chi square analysis indicated that the Experimental and Comparison groups were comparable at pre-test $\chi 2 = 0.474$ (1, N=19) p=0.491. Participants' responses from pre- to post-test were compared to determine the number of participants whose pre-test judgment pattern initially placed them in the "Other" category, but whose post-test judgement pattern placed them in the "Canonical" judgement category. Chi square (Fisher's Exact Test) analysis indicated a statistically significant difference between the Experimental and Comparison groups in the number of participants whose response patterns changed from "Other" at pre-test to "Canonical" at post-test $\chi 2 = 4.263$ (1, N = 19) p=0.039. As Figure 1 and Table 1 show, the Experimental group outperformed the Comparison group.

Figure 1

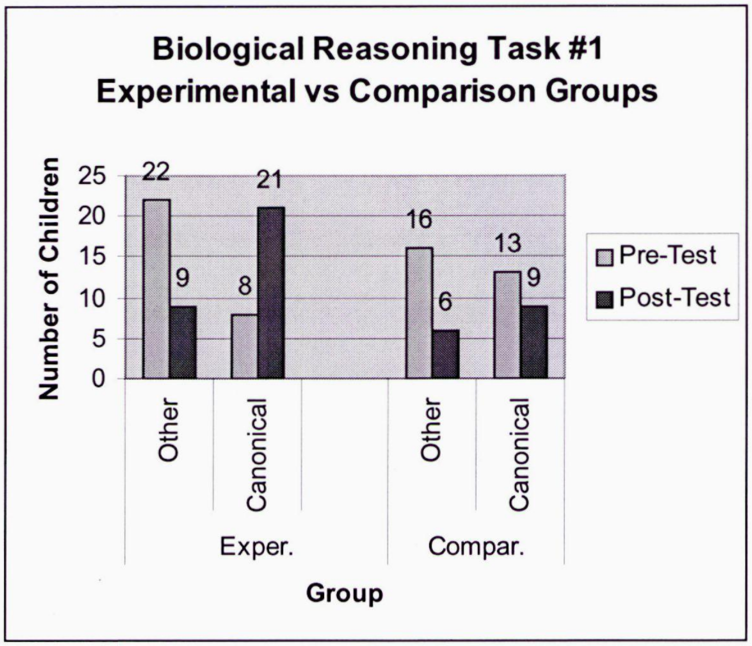

Table 1

Patterns of Change from Pre-Test to Post-Test Response Categories on Biological Reasoning Task #1 (Species Adoption Task), By Group Condition (Experimental Versus Comparison)

GROUP	Pre-Test Category	Post-Test "Other" Category	Post-Test "Canonical" Category	Total
Experimental				
	Other	8	14	22
	Canonical	1	7	8
	(Total)	9	21	20
Comparison				
	Other	11	5	16
	Canonical	2	4	6
	(Total)	13	9	22

Biological Reasoning Task #2 (Explanation of Judgment)

Due to low numbers of participant responses, chi square analysis was not possible to determine whether the Experimental and Comparison groups differed with respect to participants' explanations of why offspring physically resembled their parents. In this case, the correct response included reference to a "biological aspect of parentage" (Solomon & Johnson, 2000, p.90). Because the chi square analysis results were not reportable (2 cells contained counts of less than 5), layered contingency table analysis was conducted. As Figure 2 and Table 2 show, the trends in judgement pattern change in the Experimental and Comparison groups.

Figure 2

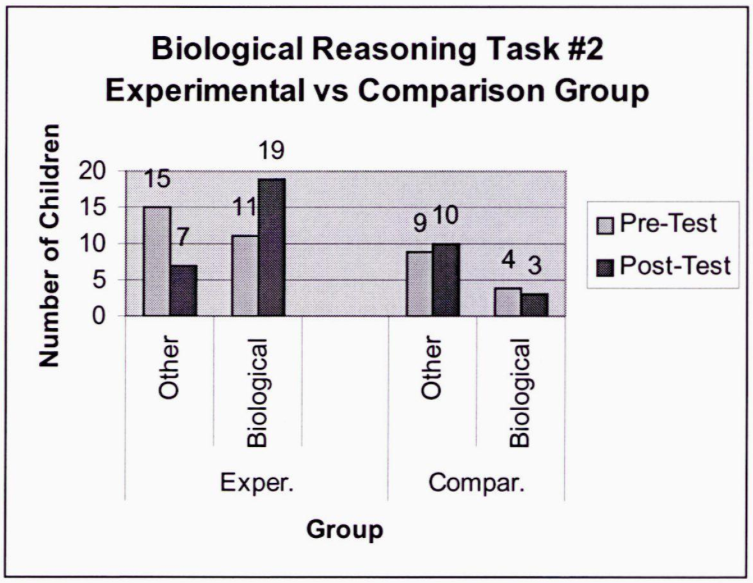

Table 2

Patterns of Change from Pre-Test to Post-Test Response Categories for Biological Reasoning Task #2 (Explanation of Judgment), By Group Condition (Experimental Versus Comparison)

	Pre-Test Category	Post-Test "Other" Category	Post-Test "Biological" Category	Total
Experimental	Other	6	9	15
	Biological	1	10	11

	(Total)	7	19	26
Comparison	Other	8	1	9
	Biological	2	2	4
	(Total)	10	3	13

A trend toward increasing numbers of participants in the Experimental group changing from the "Other" judgement pattern at pre-test to the "Biological" judgement pattern at post-test was evident. This is contrasted with the Comparison group's responses in which most participants whose responses placed them in the "Other" judgement category at pre-test also remained in the "Other" category at post-test. Of the participants in the Experimental group who were already in the "Biological" judgement category at pre-test, most participants remained in the "Biological" judgement category at post-test. In the Comparison group, only half of the participants who were in the "Biological" category at pre-test remained there at post-test. These results warrant further investigation with larger numbers of participants to determine statistical significance. Of note, is that one participant cited "genes" in her post-test explanation of why the baby had the same physical features as its parent. This participant was in the Experimental group (see Appendix E for examples of the children's actual responses).

Although all children were asked a second question pertaining to learned traits ("Tell me why the baby would know/ not know where special food was kept" (pre-test) or "Tell me why the baby would know/ not know where to hide in bad weather" (post-test)), it was not possible to categorize the children's responses into the three categories (Nature, Nurture, or Other). Therefore, the results from this question are not reported.

Biological Reasoning Task #3 (Springer-Keil Task)

The layered chi square analysis revealed unreliable results due to 3 cells containing counts of less than 5. To increase statistical power, the Species Bias and Parent Bias judgment categories were collapsed and a chi square analysis was run, but results remained unreliable. Therefore, a contingency table analysis was completed (see Figure 3 and Table 3).

Figure 3

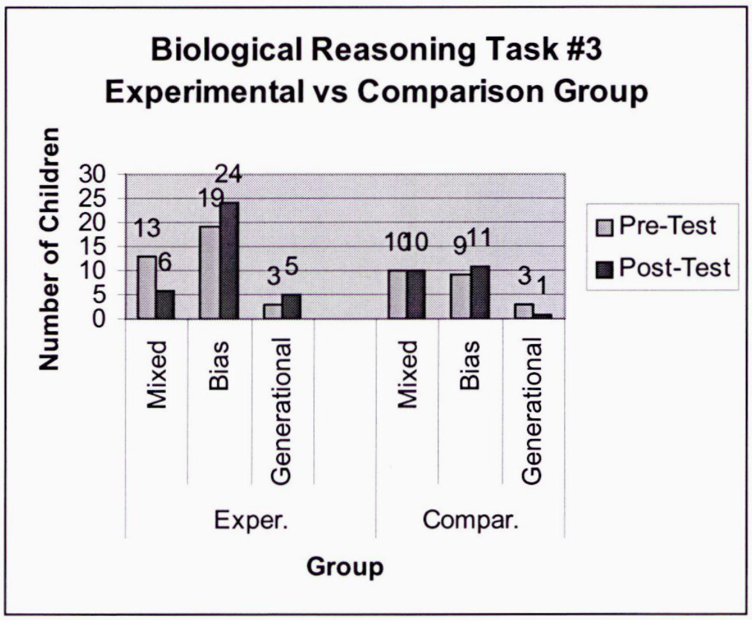

Table 3

Patterns of Change from Pre-Test to Post-Test Judgment Categories for Biological Reasoning Task #3(Springer- Keil Task), By Group Condition (Experimental Versus Comparison)

GROUP	Pre-Test Category	Post-Test "Mixed" Category	Post-Test "Bias" Category	Post-Test "Generational" Category	Total
Experimental					
	Mixed	2	8	3	13
	Bias	3	15	1	19

	Generational	1	1	1	3
	(Total)	6	24	5	35
Comparison					
	Mixed	6	3	1	10
	Bias	3	6	0	9
	Generational	1	2	0	3
	(Total)	10	11	1	22

The results presented in Figure 3 suggest that participants in the Experimental group demonstrated a decrease in the number of children represented in the "Mixed" category, an increase in the number of children in the "Bias" category, and an increase in the number of children in the "Generational" category at post-test. The Comparison group only increased its representation in the Bias category and, most notably, decreased its representation in the Generational category at post-test

Table 3 suggests that participants in the Experimental group whose responses were initially in the "Mixed" judgement category (i.e., no discernable pattern) at pre-test tended to change to the "Bias" category (i.e., showing a preference for either inherited or acquired characteristics) at post-test (8 participants) and some also changed to the target response, the "Generational" category (i.e., adult-like differentiation between inherited and acquired characteristics) at post-test (3 participants). Of the Experimental participants whose responses were in the "Bias" category at pre-test, most (15 participants) remained in the "Bias" category at post-test and 1 moved to the "Generational" category. The Comparison group demonstrated relatively less change from pre- to post-test. Of the participants who were initially in the "Mixed" category at pre-test, 6 remained in the "Mixed" category at post-test, 3 changed to the "Bias" category and 1 changed to the "Generational" category. Of the participants initially in the "Bias" category, 6 remained there at post-test, and 3 changed to the "Mixed" category.

The Life Theorizer Questionnaire

In order to address the question of whether children who have already obtained their first biological theory may learn new biological information differently than children who do not yet possess this theory, the Life Theorizer and Non-Life Theorizer conditions were analysed across the experimental and comparison groups.

Biological Reasoning Task #1 (Species Adoption Task)

Layered chi square analysis (Group x Division x Species Adoption Pre-Test x Species Adoption Post-Test) did not yield meaningful statistics due to the number of participants being too low. Therefore, contingency table analysis was completed (see Figure 4 and Table 4).

Figure 4

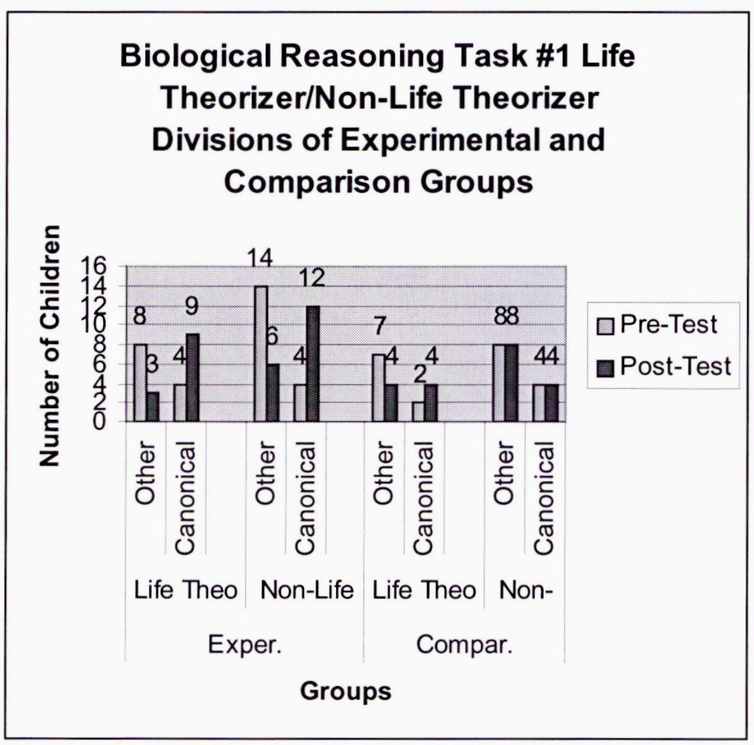

Table 4

Patterns of Change from Pre- to Post-Test: Life Theorizer/Non-Life Theorizer Divisions of Experimental and Comparison Groups

GROUP	DIVISION	Pre-Test Category	Post-Test "Other" Category	Post-Test "Canonical" Category	Total
Experimental	Life Theorizer				
		Other	2	6	8
		Canonical	1	3	4
		(Total)	3	9	12
	Non Life Theorizer				
		Other	6	8	14
		Canonical	0	4	4
		(Total)	6	12	18
Comparison	Life Theorizer				
		Other	3	4	7
		Canonical	1	1	2
		(Total)	4	5	9
	Non Life Theorizer				
		Other	7	1	8
		Canonical	1	3	4
		(Total)	8	4	12

Note. This table is read in the following way: of the participants in the Experimental group, Life Theorizer Division, who were categorized in the "Other" judgment category at pre-test, 2 participants were still in the "Other" category at post-test and 6 participants moved to the "Canonical" category at post-test for a total of 8 participants.

In the Life Theorizer division of the Experimental group, at post-test 3 children (25%) still remained in the "Other" category, but 9 children (75%) were in the "Canonical" category. Another way of looking at this table is that 6 children (50%) who were initially in the "Other" category at pre-test, changed to the "Canonical" category at post-test. In the Non-Life Theorizer division of the Experimental group, 6 children (33%) were in the "Other" category at post-test and 12 children (66%) were in the "Canonical" category at post-test. Eight children (44%) moved from the "Other" category at pre-test to the "Canonical" category at post-test. In the Life Theorizer division of the Comparison group, 4 children (44%) were in the "Other" category at post-test and 5 children (56%) were in the "Canonical" category at post-test. Four children (44%) changed from the "Other" category at pre-test to the "Canonical" category at post-test. Finally, in the Non-Life Theorizer division of the Comparison group, 8 children (67%) were in the "Other" category at post-test and 4 children (33%) were in the "Canonical" category. Only one child (8%) changed from the "Other" category at pre-test to the "Canonical" category at post-test. Only the Non Life Theorizer division of the Comparison group decreased its representation in the Canonical category at post-test. The results presented in Figure 4 and Table 4 suggest that with instruction, Non-Life Theorizers' responses more closely resemble those of Life Theorizers. Next, the data were evaluated to determine whether these same trends emerged in the children's explanations of why offspring physically resemble biological parents.

Biological Reasoning Task #2 (Explanation of Judgment)

Layered chi square analysis (Group x Division x Biological Reasoning Task #2 Pre-Test x Biological Reasoning Task #2 Post-Test) did not yield meaningful statistics due to the number of participants being too low. Therefore, contingency table analysis was completed (see Figure 5 and Table 5).

Figure 5

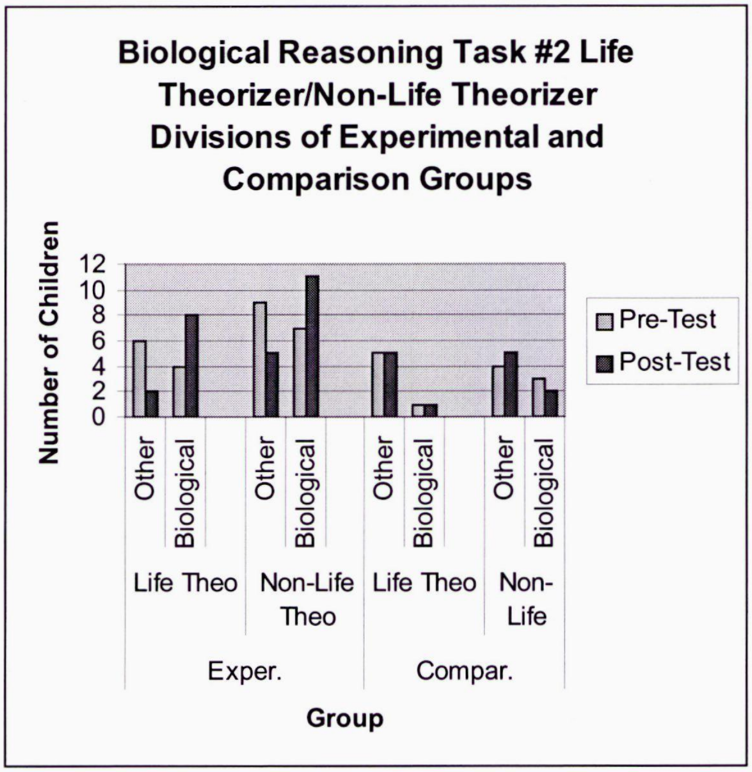

Table 5

Patterns of Change from Pre-Test to Post-Test on Biological Reasoning Task #2: Life Theorizer/Non-Life Theorizer Division of Experimental and Comparison Groups

GROUP	DIVISION	Pre-Test Category	Post-Test Other	Post-Test Biological	Total
Experimental	Life Theorizer				
		Other	2	4	6
		Biological	0	4	4
		(Total)	2	8	10
	Non Life Theorizer				
		Other	4	5	9
		Biological	1	6	7
		(Total)	5	11	16
Comparison	Life Theorizer				
		Other	4	1	5
		Biological	1	0	1
		(Total)	5	1	6
	Non Life				

	Theorizer				
		Other	4	0	4
		Biological	1	2	3
		(Total)	5	2	7

Note. This table is read in the following way: Of the participants in the Experimental group, Life Theorizer Division, who were categorized in the "Biological" judgment category at pre-test, 4 participants were still in the "Biological" category at post-test and 0 participants moved to the "Other" category at post-test for a total of 4 participants.

Of note in Figure 5 and Table 5 is that 3 out of the 4 Divisions by Group either maintained or increased their representation in the Biological category at post-test. The Life Theorizer division of the Experimental group had 4 participants who at pre-test were in the "Other" category, but at post-test were in the "Biological" category. The Non-Life Theorizer division of the Experimental group had 5 participants who moved from the "Other" category to the "Biological" category. The Life Theorizer division of the Comparison group also increased their representation in the Biological category with 1 participant changing from the "Other" category at pre-test to the "Biological" category at post-test. The only division that did not maintain or increase its representation in the Biological category from pre- to post-test was the Non-Life Theorizer division of the Comparison group.

Biological Reasoning Task #3 (Modified Springer-Keil Task)

Once again, chi square analysis was not reliable due to having too few participants for adequate cell sizes in the layered analysis. To increase statistical power, the Species Bias and Parent Bias judgment categories were collapsed and a chi square analysis was run, but results remained unreliable. To increase statistical power, the Species Bias and Parent Bias judgment categories were collapsed and a chi square analysis was run, but results remained unreliable. Therefore, contingency table analysis was conducted to investigate whether any trends in response category change were apparent (see Figure and Table 6).

Figure 6

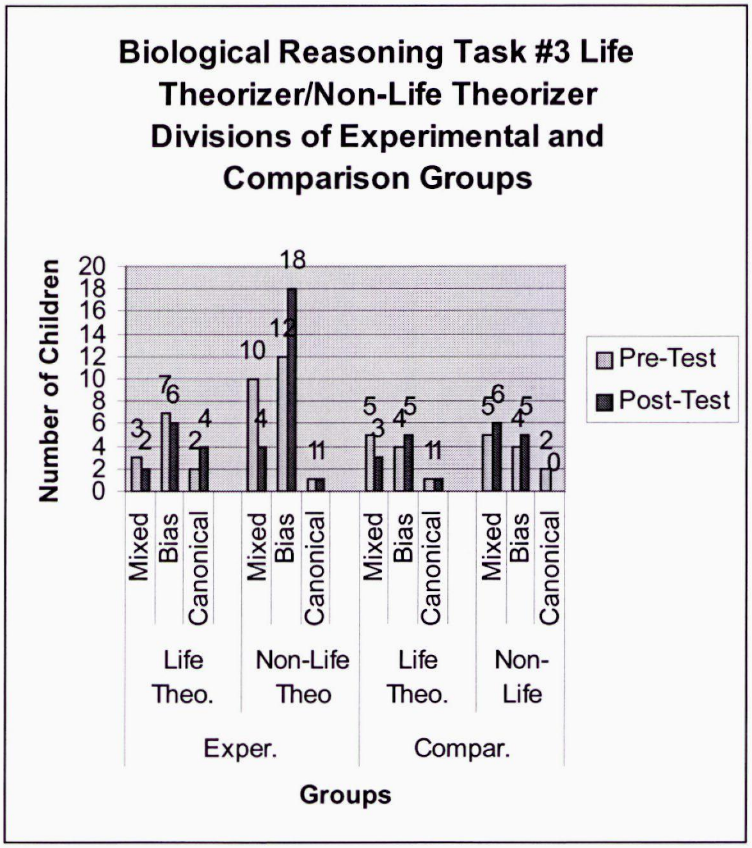

Table 6

Patterns of Change from Pre-Test to Post-Test on Biological Reasoning Task #3: Life Theorizer/Non-Life Theorizer Division of Experimental and Comparison Groups

GROUP	DIVISION	Pre-Test	Post Mixed	Post Bias	Post Generational	Total
Experimental	Life Theorizer					
		Mixed	0	1	2	3
		Bias	1	5	1	7
		Generational	1	0	1	2
		(Total)	2	6	4	12

	Non Life Theorizer					
		Mixed	2	7	1	10
		Bias	2	10	0	12
		Generational	0	1	0	1
		(Total)	4	18	1	23
Comparison	Life Theorizer					
		Mixed	3	1	1	5
		Bias	1	3	0	4
		Generational	0	1	0	1
		(Total)	3	5	1	10
	Non Life Theorizer					
		Mixed	3	2	0	5
		Bias	2	2	0	4
		Generational	1	1	0	2
		(Total)	6	5	0	11

Note. This table is read in the following way: Of the participants in the Experimental group, Life Theorizer Division, who were categorized in the "Mixed" judgment category at pre-test, 0 participants were still in the "Mixed" category at post-test and 1 participant moved to the "Bias" category, and 2 participants moved to the Generational judgment category at post-test for a total of 3 participants.

The results presented in Figure 6 indicate that in the Life Theorizer division of the Experimental group, representation in the "Mixed" and "Bias" categories decreased slightly at post-test, while representation in the "Generational" category increased at post-test from 2 children to 4 children. This is contrasted with the Non-Life Theorizers in the Experimental group whose representation in the "Mixed" category decreased at post-test from 10 to 4, representation in the "Bias" category increased from 12 to 18, and representation in the Generational category remained stable. The Life Theorizer division of the Comparison group demonstrated a similar pattern with a slight decrease in the number of children represented in the "Mixed" category at post-test (from 5 to 3), a slight increase in the number of children represented in the "Bias" category at post-test (4 to 5) and representation in the Generational category remained stable. Finally, the Non-Life Theorizer division of the Comparison group demonstrated a different trend with increased representation in the "Mixed" and "Bias" categories at post-test (5 to 6 and 4 to 5 respectively) and a decrease in representation in the Generational category (from 2 to 0) at post-test.

Table 6 appears to indicate that the only group to increase its representation in the Generational category at post-test was the Life Theorizer division of the Experimental group; two participants moved from the "Mixed" judgment category at pre-test to "Generational" at post-test, and one participant moved from the "Bias" category at pre-test to the "Generational" category at post-test. Only one participant in the Non-Life Theorizer division of the Experimental group moved to the Generational category at post-test. In the Comparison group, only one the participant in the Life Theorizer division moved from one of the other categories at pre-test to Generational at post-test and none of the Non-Life Theorizers moved from one of the other categories at pre-test to Generational at post-test.

Summary of Findings

The results of this study provide some support for the two hypotheses initially put forth. The first hypothesis predicted that there would be a statistically significant difference in the biological inheritance knowledge demonstrated by Experimental group children and the Comparison group children at post-test. Statistically significant differences were reported between the Experimental and Comparison groups at post-test on the Species Adoption task. In addition, contingency table analysis for Biological

Reasoning Task #2 (Explanation of Judgment on Species Adoption task) provided some initial support for an emerging difference between the Experimental and Comparison groups. With higher numbers of participants, chi square analysis would be able to confirm or disconfirm this trend. The second hypothesis predicted that there would be a statistically significant difference between the biological inheritance knowledge gained by children categorized as "Life "Theorizers" as compared to the children categorized as "Non-Life Theorizers." The results of this study provided some preliminary support for this hypothesis in that the Non-Life Theorizer division of the Comparison group tended to demonstrate relatively lower levels of participants moving to target judgment categories at post-test on all three biological reasoning tasks. In other words, the Life Theorizer divisions of the Experimental and Comparison groups out-performed their Non-Life Theorizer counterparts. However, the results also suggest that with instruction, Non-Life Theorizers' responses more closely resembled those of Life Theorizers.

CHAPTER V

DISCUSSION

In this final chapter the results of this study are summarized and the findings are interpreted. It begins with an introduction and brief description of the purpose and theoretical basis of the study. Next, the statistical analyses that were conducted on the data are presented along with a discussion of the results in relation to the existing literature. Then the limitations of the study are outlined in addition to the educational implications of the study and directions for future research and practice. Finally, the outcomes and conclusions drawn from the study are discussed.

Purpose and Theoretical Basis for Study

This study explored the feasibility of introducing biology instruction to pre-school aged (ages 3 to 5) children. Previous research found that five and six year-old children could be successfully taught to make more adult-like judgments about biological reasoning (Solomon & Johnson, 2000). Whereas Solomon and Johnson investigated whether an instruction program teaching biological inheritance could result in cognitive restructuring for early elementary school-aged children, the current study sought to extend Solomon and Johnson's results by investigating whether even younger children (pre-school aged children) were also capable of making these changes by participating in a similar instructional program. Therefore, in this study foundational assumptions similar to those of Solomon and Johnson were made: (a) preschoolers are capable of developing real theoretical thinking; (b) they already have some preliminary understanding of the phenomenon of biological inheritance consistent with a lay Western adult understanding; and (c) most preschoolers have not organized that knowledge in such a way as to allow them to invoke it appropriately in making predictions and giving explanations (p.91-92). Additionally, this study also furthered research in the area of children's conceptual understanding of biology by exploring whether children who have acquired their first biological theory learn biological concepts and information differently than children who have not yet acquired their first biological theory. Finally, this study was intended to contribute to the advance of developmentally appropriate science curriculum available for pre-school aged children.

Overview of Results

The two major research predictions I set out to test were: (1) preschool children (ages 3 to 5) can be taught a causal theoretical understanding of biological inheritance that will result in them making judgments which more closely resemble typical adult judgments and (2) children who have already acquired their first biological theory as measured by the Life Theorizer questionnaire will demonstrate a different trajectory of learning or be more conceptually advanced with respect to learning biological information than children who have not yet acquired their first biological theory.

Were these predictions supported by the present findings? Yes, they were, however not as completely, simply, and neatly as predicted. Results from the current study yielded preliminary support for the prediction that even younger children could be taught a causal theoretical understanding of biological inheritance.

The results of the Biological Reasoning Task #1 (Species Adoption) indicated statistically significant differences between the Experimental and Comparison groups at post-test. This finding is consistent with the results found in Solomon and Johnson's (2000) study in addition to previous findings (Gelman & Wellman, 1992; Hirschfeld, 1994; Solomon et al., 1993; Springer, 1992). The results of the current study suggests that the children in the Experimental group demonstrated more adult-like differentiation between biologically inherited (i.e., physical) and environmentally influenced (i.e., knowledge and habits) traits following instruction than the children in the Comparison group who did not participate in the instruction program. For example, at post-test when asked whether a baby born to a duck but raised by a chicken would have black eyes like the duck or brown eyes like the chicken, a higher proportion of the children in the Experimental group indicated that the baby would physically resemble the duck but would have knowledge and beliefs like the chicken.

The results of Biological Reasoning Task #2 in which the children were asked to explain some of their judgments on Biological Reasoning Task #1 (Species Adoption task) also indicated that the Experimental group demonstrated more adult-like reasoning at post-test than the Comparison group. Due to low numbers in some cells, statistical analysis did not yield meaningful results and therefore contingency table analysis was used to interpret the data. Based on this preliminary analysis, it appears that a higher proportion of children in the Experimental group cited birth or aspects related to birth as a causal factor in explaining why a baby would demonstrate the same physical characteristics as its biological parent. For example, one child offered this explanation when asked why he stated that the baby would have black eyes like the duck: "Because it hatched out of the duck." This type of response in which the child cited an aspect of birth in his or her response was contrasted with responses in which the child indicated that the baby would physically resemble the adoptive parent: "He [the chicken] raised the baby." Such a response suggested that because the adoptive parent raised the baby, the baby would look like the adoptive parent. In addition, some children gave responses that did not refer to either an aspect of birth or the adoptive parent, but instead gave another explanation for the baby's physical characteristics: "Because chickens like brown eyes." Although the data did not permit statistical analysis, the contingency table analysis indicated trends that were consistent with the results found by Solomon and Johnson (2000) in which the Experimental group offered a higher proportion of responses in which birth was mentioned as a causal factor. Future research, with higher numbers of participants, could confirm or disconfirm that the difference between the groups is statistically significant. In addition, the results of Biological Reasoning Task #2 were also consistent with Solomon and Johnson's results in that very few children made mention of genes in their explanations. In both studies, it was children from the Experimental group who mentioned genes in their explanations (only one child in the current study and 4 children in Solomon and Johnson's study).

Biological Reasoning Task #3 (Modified Springer-Keil task) did not yield statistically significant results. Of all of the Biological Reasoning tasks, Biological Reasoning Task #3 (Modified Springer Keil task) demonstrated the least amount of change from pre- to post-test. This is not surprising given that Springer and Keil (1991) found that four-year-olds did not differentiate between inherited and acquired characteristics. However, contingency table analysis suggested that the number of children in the Generational category (i.e., more adult-like responses) decreased for the Comparison group at post-test while the number of children represented in the Generational category for the Experimental group increased. This trend fits with results obtained by Solomon and Johnson (2000) who found that children who participated in their instructional program differentiated between inherited and acquired physical traits. Further research, with higher numbers of participants, could confirm or disconfirm whether the difference between the groups is statistically significant (as Solomon and Johnson found), or if younger children cannot differentiate between acquired and inherited traits (as Springer and Keil found).

If future research finds that a statistically significant difference does not exist between the children who have received instruction and those who have not participated in instruction, it may be that children go through several stages in their biological theory development. It may be that learning to differentiate between biologically inherited physical traits and environmentally-influenced beliefs and habits requires a more elementary conceptualization or theory of biological inheritance. It is possible that more advanced understanding of biological inheritance is required before children are able to reliably differentiate between inherited and acquired traits. This improved understanding may be based on improved understanding of the role that genes play in biological traits, which would help the children to understand, for example, that a cat that has no tail due to its genetic make-up (e.g., Manx cat) is different than a cat that has no tail due to frost-bite. Based on the typical adult conceptualizations of biological inheritance, the offspring of the two cats would be expected to be different. The cat whose tail was frost-bitten would be expected to have kittens with tails while the cat who has no tail due to its genetic make-up would be expected to have kittens without tails.[2] If this hypothesis were true, it may help explain why more children were in the "Bias" category at post-test. Whereas children who differentiated between characteristics that would be passed on to

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[2] In the current study, all Springer-Keil tasks were adapted so that both the mother and the father were described as having the same atypical feature, therefore avoiding the issue of more complicated understanding of gene theory, probability, and dominant and recessive traits.

offspring (genetic characteristics) and those that would not be passed on (acquired characteristics) may have applied a form of genetic theory to their responses, children with less sophisticated conceptualizations of biological inheritance may have applied their understanding of "like begets like" to make sense of the inherited versus acquired traits questions. This hypothesis would be an interesting area for future research to further investigate.

The second hypothesis predicted that there would be a statistically significant difference between the biological inheritance knowledge gained by participants characterized as "Life Theorizers" and participants characterized as "Non-Life Theorizers." The results of this study provided preliminary support for this hypothesis, and also indicated some trends that were not predicted.

On Biological Reasoning Task #1, although statistical analysis did not yield reliable results, contingency table analysis suggested that the Life Theorizer and Non-Life Theorizer divisions of the Experimental group both increased their representation in the Canonical Adult category at post-test. The Life Theorizer division of the Comparison group also increased its representation in the Canonical category. Only the Non-Life Theorizer division of the Comparison group did not increase its representation in the Canonical category at post-test. This finding supports hypotheses put forth by Jaakkola (1997) and Slaughter, Jaakkola, and Carey (1999) that children who already have a biological theory (i.e., Life Theorizers) will demonstrate a different trajectory of learning biological information than children who have not yet acquired their first biological theory (Non-Life Theorizers).

The results of the contingency table analysis for Biological Reasoning Task #2 revealed similar results as Biological Reasoning Task #1. In other words, the Life Theorizer and Non-Life Theorizer divisions of the Experimental group both demonstrated more adult-like responses at post-test. Once again, the Non-Life Theorizer division of the Comparison group was the only group to demonstrate a lower proportion of children citing birth as a causal factor in their explanations of why an animal would have the physical features it has.

The third Biological Reasoning task (Biological Reasoning Task #3 – Springer Keil task) revealed results with a somewhat different trend than the other two biological reasoning tasks. The Life Theorizer division of the Experimental group was the only group to increase its representation in the Generational category at post-test and the Non-Life Theorizer division of the Comparison group was the only group to decrease its representation in the Generational category at post-test. The Non-Life Theorizer division of the Experimental group and the Life Theorizer division of the Comparison group both remained stable in their representation in the Generational category from pre- to post-test. Both the Non-Life Theorizer division of the Experimental group and the Life Theorizer division of the Comparison group increased their representation in the "Bias" category (Non-Life Theorizer division of Experimental group = 12 children in "Bias" category at pre-test and 18 children at post-test while Life Theorizer division of Comparison group = 4 children at pre-test and 5 children at post-test). The Non-Life Theorizer division of the Comparison group similarly slightly increased in the proportion of children represented in the Bias category at post-test from 4 at pre-test to 5 at post-test. These results appear to suggest that the children in the Life Theorizer division of the Experimental group had a considerable advantage over the children in the Non-Life Theorizer division of the Comparison group. In addition, only the Life Theorizer division of the Experimental group demonstrated a decrease in the number of children represented in the "Bias" category at post-test. One possible explanation for this finding is that the children in the Life Theorizer division of the Experimental group may have had an advantage in generalizing the biological inheritance instruction. They may have had more advanced conceptualizations of biological inheritance. If, as mentioned above, differentiation between inherited and acquired physical traits requires a more advanced understanding of biological inheritance, then it would make sense that the only group to demonstrate an increase in the Generational category was the Life Theorizer division of the Experimental group. This is because they demonstrated improved biological theorizing prior to instruction (being categorized as Life Theorizers) and they also participated in instruction on the topic. Conversely, on the opposite end of the spectrum, the children who did not demonstrate having an integrated biological theory at pre-test (Non-Life Theorizers) and did not receive instruction demonstrated lower levels of adult-like biological reasoning at post-test. In the middle of the spectrum, the Non-Life Theorizer division of the Experimental group demonstrated the highest proportional increase in the number of children represented in the "Bias" category at post-test. This may be because these children were attempting to apply what they may have learned from the instruction – that like begets like – to the more sophisticated problem of the passing on of inherited versus acquired traits.

It appears that having acquired a first biological theory may be associated with acquiring other biological information at an increased rate relative to others who have not yet acquired a first biological theory. The trajectory of learning demonstrated by Life Theorizers in the Comparison group relative to the Non-Life Theorizers provides preliminary support for this hypothesis. Neither group received instruction regarding biological inheritance, yet the proportion of Life Theorizers whose understanding of biological inheritance became more sophisticated across the three tasks appears to have increased from pre- to post-test while Non-Life Theorizers did not appear to demonstrate this trend. These results were contrasted by the findings from the Experimental group in which contingency table analysis indicated that both the Life Theorizers and the Non-Life Theorizers in the Experimental group made gains in their understanding of biological inheritance.

Therefore, taken altogether, the preliminary results of this investigation appear to indicate that although having acquired a first biological theory may be a protective or predictive factor for learning new biological information, if instruction takes place (i.e., if children are directly and developmentally appropriately taught about biological inheritance), the gap between Life Theorizers and Non-Life Theorizers narrows. Further investigation with higher numbers of participants would be able to confirm or disconfirm whether the trends noted in the contingency table analyses constitute statistically significant differences.

Interpretation of Findings and Linking Findings with Past Research

The results of the current study indicated that preschool children can be taught to demonstrate more adult-like reasoning in the area of biological inheritance. The results of this study also indicated preliminary support for the hypothesis that children who have already acquired their first biological theory demonstrate a different trajectory of learning from children who have not yet acquired this first theory. This was most evident in the fact that the children in the Non-Life Theorizer division of the Comparison group consistently demonstrated lower levels of change in their biological judgments than the Non-Life Theorizers in the Experimental group and the Life Theorizers in the Experimental and Comparison groups. How might these results fit with the existing conceptual development literature?

The children's increasingly adult-like judgments as evidenced in the Experimental group's responses that more closely resembled adult canonical judgments at post-test and their explanations of their judgments on the first question of the Species Adoption task may have been examples of what Carey refers to as "weak restructuring." This suggests that although the children did make adjustments to their biological theorizing, this change was more of a surface change or addition of information to an existing system rather than a complete restructuring of the system. This hypothesis would account for why the children appear to have learned the causal theory and were able to correctly apply it to some cases, although when asked to give explanations of their responses on some of the questions from Biological Reasoning Task #1 (Species Adoption task), the children did not demonstrate their understanding of the causal theory. This may also explain why the children in the Experimental group were not significantly different from their Comparison group counterparts on the Springer-Keil task.

The notion of weak restructuring in biological theorizing is supported by Springer's Naïve Theory of Kinship (NTK) theory (Springer, 1995), which states that children have a partially-defined theory of biological inheritance. Springer suggests that teaching children the facts of birth as a causal factor builds on their previous knowledge, but does not result in the creation of a new theory or overall restructuring of the old theory.

Although not explicitly stated by Solomon and Johnson (2000), their results also fit with Springer's NTK in that they were not able to conclude whether gene instruction was actually responsible for the children demonstrating improved understanding of biological inheritance following their teaching intervention. They conceded that one of the problems in their study was the possibility that they did not account for what Wellman and Gelman (1991) called an "essentialist bias," meaning that young children tend to judge that offspring of a particular species will resemble that species regardless of other information that might suggest otherwise. Rather than complete theory reconstruction, the children may have appended the instruction regarding genes to their existing essentialist bias.

Overall, then, the results of the current study would appear to support Solomon and Johnson's hypothesis. The children in the Experimental group of the current study were able to demonstrate more adult-like judgments after instruction in that they were able to judge offspring to share physical characteristics with birth parents and beliefs and habits with Adoptive parents (Biological Reasoning Task #1, Species Adoption task). It also appeared that the Experimental and Comparison groups were becoming more different with respect to the children's explanations of why offspring would physically resemble birth parents (i.e., citing birth as a causal factor) in Biological Reasoning Task #2. The results of Biological Reasoning Task #3 (Springer Keil task), although demonstrating the least amount of change of all of the Biological Reasoning tasks, may suggest that Solomon and Johnson were correct in their hypothesis regarding essentialist bias (because the children who did have a biological theory but participated in biological inheritance instruction demonstrated a dramatic increase in applying the rule of "like begets like"). In addition, the results of Biological Reasoning Task #3 (Springer Keil task) also appear to suggest that children who already have a biological theory, when instructed, surpass using an essentialist bias, possibly making use of elementary gene theory in their reasoning.

Limitations of the Current Study

As with any empirical investigation, this study had certain limitations. Most notably, the small sample size did not allow for adequate statistical power to determine definitively whether significant differences between the groups existed at post-test. To some extent, the number of participants appeared to have been negatively impacted by two factors. First, some parents indicated that the legal-sounding consent form concerned them and they suggested that if such a consent form were needed, then they were concerned about a possible negative impact of participating in the program on their children. Second, because the program spanned over five weeks (including pre- and post-testing in addition to the three weeks of instruction), the some children were lost due to attrition. Another limitation of the study was the layered chi square analysis. Because the chi-square analysis was layered (particularly for investigating the results of the Life Theorizer and Non-Life Theorizer divisions of the Experimental and Comparison groups), an even larger sample size would have been required to increase statistical power. The study also included participants whose ages spanned from 3 years old to five years old. A homogeneous age group (e.g., four-year-olds or five-year-olds) in the sample would help to increase the specificity of the program to target age-groups and the generalizability of the results to those age-groups. Finally, because the children in the study were so young, it is difficult to know if limited receptive and expressive language may have impacted their understanding of instruction and/or their responses to the biological reasoning tasks. It may be that the results of the biological reasoning tasks, particularly Biological Reasoning Task #2 in which the children were asked to explain their responses, may have represented an underestimate of the children's conceptualization due to difficulties in expressing their knowledge.

Considerations for Future Research

The results of the current research suggest several areas for future investigation. First, because many of the results discussed in the current study are based on contingency table analysis, an obvious suggestion for future research involves replicating the current study with a larger sample size to determine whether the trends found in this study are statistically significant. The results of this study also revealed more questions and hypotheses for future research. If another biological reasoning instructional study were completed on another biological topic (such as illness, growth, or life properties), would the same trends also be found (Experimental group out-performing Comparison group, Life Theorizers generally out-performing Non-Life Theorizers, but Non-Life Theorizers in the Experimental group also performing better than Life Theorizers in the Comparison group)? Another question for future research is whether different stages in biological reasoning exist. For example, do children who can reliably differentiate between inherited and acquired traits have a more sophisticated conceptualization of biological inheritance than those who differentiate between inherited physical traits and learned traits? Do they make use of an elementary gene theory in their reasoning? If so, what steps would be necessary to bridge instruction from making decisions based on essentialist bias to making decisions based on an elementary gene theory?

In a somewhat related vein, future research into children's biological conceptualization may also benefit from taking genre into account when designing the study and when interpreting what young children's explanations of biological phenomena. It could be that the children in the current study were not sure of the intent of the tasks they were being asked to complete. The children may not have known which genre they were supposed to use as a point of reference when answering the questions posed to them. For example, the fact that the children were told stories about animals for the Biological Reasoning Task #1 (Species Adoption task) and then asked to explain their reasoning in their responses on Biological Reasoning Task #2 may have confused them. Often, when children are told stories, they are encouraged to enter the world of pretend and make believe. Such possible confusion over frame of reference may have led the children to give responses that did not reflect the development of their reasoning abilities in the area of biological inheritance.

Walters, Siegal, and Slaughter (2000) investigated the role of conversational understanding in young children's understanding. They found that wording of reasoning tasks significantly influenced young children's (ages four, five and six) performance in scientific reasoning. They also found that on faked evidence tasks, children's judgments were influenced by the need to understand the intent of the investigator's questions about causal relations. In other words, they found that in some instances the children gave different responses depending on what the children perceived to be the situational constraints within the conversational environment.

An appropriate direction for future research would involve instruction and evaluation measures with their intent and frame of reference being made explicit. This does not mean that stories are not an effective medium for instruction, only that "the development of scientific reasoning can be facilitated through attention to the need to make questioning specific in order to maintain the focus of the task as one that requires scientific rather than local concerns" (Waters et al., 1993, p. 393).

Finally, another consideration for future research in the area of children's science instruction is the increased use of pictorial mnemonics to aide instruction and improve comprehension. Although some pictorial mnemonics were used in the current study, greater and more effective use of pictorial mnemonics may have assisted the children in making larger conceptual leaps as a result of presenting information in more than one modality (McKeough, Davis, & Forgeron, under review). For example, greater use of pictorial mnemonics may have proven to be more helpful in the instruction of the elementary gene theory. Following the steps for developmental bridging outlined by Case (1985, 1993; Case & McKeough, 1990), and McKeough and Sanderson (1996), it would be suggested that the pictorial mnemonic be used to bridge the children's understanding of the concept with the next developmentally appropriate level followed by gradual removal of the cuing supports. In targeting the children's prior conceptions and then scaffolding their learning with the next developmentally appropriate step, it may be possible to determine typical developmental trends in children's conceptualization regarding biological inheritance.

Potential Applications

The results of the current study are particularly applicable to preschool and kindergarten educators. Preschool and kindergarten educators can use this research to inform their curriculum choices and approaches. Compared to other subject areas taught in preschool and kindergarten classrooms, science is an area that tends to receive relatively less attention from educators. The results of the current study can be used by preschool and kindergarten educators to expand their own thinking around including more science into their curriculum, especially biological science. For example, many preschool and kindergarten teachers do a unit called "All About Me" in which children learn about themselves and discuss families in general. This type of unit could be adapted to include more of a biological science approach by incorporating the types of lessons taught in the current study. The results of this study suggested that preschool aged children are interested in learning about biological inheritance and that even younger children than previously thought can improve their reasoning in the area of biological inheritance through direct instruction. The current research also exemplified how stories, circle-time activities, and discussion can be an effective method for exploring science, including abstract concepts, with children. Lastly, the results of the study suggested that while children may enter class with varying levels of conceptual development, (e.g., Life Theorizers versus Non-Life Theorizers), direct instruction that is properly scaffolded can help to narrow the gap.

Conclusion

The current study sought to extend prior research in the area of conceptual development in the area of biology. Previous findings suggested that it was possible to teach 5- and 6- year-old children to make more adult-like judgments regarding biological inheritance. Research also suggested that children develop their first biological theory between the ages of 4 and 6. Although the results of this study must not be over-stated and must be verified with larger sample sizes in which more statistical analyses are possible, the current study extended prior research and offered insights that will be useful for future research.

The current study extended prior research by suggesting that younger children (ages 3-5) could be taught to make more adult-like judgments regarding biological inheritance. Results of this study also supported prior research by Jaakkola (1997) and Slaughter et al. (2000) who found that between the ages of 4 and 6 children demonstrate various levels of biological reasoning. In her own study, Jaakkola discussed that one of the limitations of her study was that the cut-off's she used for categorizing children into Life Theorizer and Non-Life Theorizer categories were somewhat arbitrary. While this may be true, the results of the current study suggest that the categories used by Jaakkola were meaningful because Life Theorizers tended to out-perform Non-Life Theorizers. More convincing of the validity of Jaakkola's suggestion that Life Theorizers have acquired their first biological theory is that when the responses of the Life Theorizers who participated in instruction was compared to Non-Life Theorizers who also participated in instruction, the Life Theorizers demonstrated higher levels of more adult-like reasoning at post-test. Life Theorizers may have had the advantage of having an integrated biological theory upon which to map new information.

An unexpected finding of the study was that it appears that children may pass through stages in their conceptual development regarding biological reasoning. This will be an exciting area for further research in the future. Another unexpected finding was that instruction that is developmentally appropriate and properly scaffolded can narrow the gap between children who are at more advanced levels of conceptual development (e.g., Life Theorizers) and children who are at less-advanced levels of conceptual development (Non-Life Theorizers). This finding is particularly exciting because it suggests that direct instruction that is developmentally appropriate and properly scaffolded can help to "level the playing field" for students who enter the learning environment at an apparent conceptual disadvantage.

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Appendix A
Life Theorizer Task

"What is/are X (e.g., brain, muscles, heart) for?" "What would happen if someone didn't have a/an X ?"

Heart
1.) ______________________________
2.) ______________________________

Blood
1.) ______________________________
2.) ______________________________

Eyes
1.) ______________________________
2.) ______________________________

Muscles
1.) ______________________________
2.) ______________________________

Brain
1.) ______________________________
2.) ______________________________

Tongue
1.) ______________________________
2.) ______________________________

Stomach
1.) ______________________________
2.) ______________________________

Lungs
1.) ______________________________
2.) ______________________________

Teeth
1.) ______________________________
2.) ______________________________

Nerves
1.) ______________________________
2.) ______________________________

Bones
1.) ______________________________
2.) ______________________________

Skin
1.) ______________________________
2.) ______________________________

Hands
1.) ______________________________

2.) ____

Food – Why do we eat food? ____________________________________

What happens when we eat food? ____________________________

Air – Why do we breathe air? ___________________________________

What happens to the air we breathe? __________________________

Appendix B

Biological Reasoning Task #2 (Species Adoption Task) Stories

Pre-Test Story

Once upon a time there was a farmer with a big barn filled with all different kinds of animals. In the barn he had a sweet lady horse. One night the horse gave birth to a little baby. That same night the lady horse got very sick and died without ever having seen the baby. Fortunately, there was a kind and gentle lady cow living in the barn with her family. The lady cow immediately adopted the little baby. The lady cow raised the baby with her other children so they all grew up together. They played together, ate together, and slept together. The little baby was very happy living in the barn with his wonderful family. Now the baby is all grown up and I'm going to ask you some questions about what he's like as an adult.

Post-Test Story

Once upon a time there was a farm with a big barn and a pond. On the edge of the pond lived a family of ducks. One day the mamma duck laid an egg in her nest. But that night she accidentally knocked the egg out of the nest and lost it in the dark grass. The next day the farmer came along and found the egg. He thought it must have rolled out of the chicken coop, so he picked it up and took it to the mamma chicken's nest. The mamma chicken sat on the egg along with all her other eggs. And when the egg hatched, she raised the baby with her other children so they all grew up together. They ate together, and played together, and slept together. The little baby was very happy living in the chicken coop with his wonderful family. Now the baby is all grown up and I'm going to ask you some questions about what he's like as an adult.

Appendix C

Biological Reasoning Task #3 (Modified Springer-Keil Task)

Pre-Test

This is Mr. And Mrs. Dog. Mr. Dog was born with a pink heart. Mrs. Dog was also born with a pink heart. Their pink hearts make them extra strong. They have a son named Herman Dog. When Herman was born do you think that he will have a pink heart like Mr. And Mrs. Dog or will he have the normal colour of heart like the other dogs?

This is Mr. And Mrs. Mouse. They were in an accident and now they have no hair on their bodies, so they get cold at night. Later, they decided to have a baby and named him Fred Mouse. When Fred is born, do you think that he would have no hair on his body like his parents, or would he have hair on his body like the other mice?

This is Mr. And Mrs. Pig. Mr. Pig was born with big eyelashes. Mrs. Pig was also born with big eyelashes. Their big eyelashes kept the things like dirt from getting in their eyes. Later, they decided to have a baby and named her Elsa Pig. When Elsa is born, do you think that she would have big eyelashes like her parents, or will she have regular sized eyelashes like the other pigs?

This is Mr. And Mrs. Monkey. One day Mr. And Mrs. Monkey ate some food that gave them a white stomach inside. After that they could eat a lot and stay strong. Later they decided to have a baby named Larissa Monkey. When Larissa is born, do you think she will have a white stomach just like her parents or will she have the normal colour of stomach like the other monkeys?

This is Mr. And Mrs. Elephant. Mr. Elephant and Mrs. Elephant were in an accident and their trunks were cut short. Now it is harder for them to drink water. Later, they decided to have a baby and named him Ned. When Ned is born, do you think that Ned will have a short trunk like his parents, or will he have a normal trunk like the other elephants?

This is Mr. And Mrs. Flamingo. Mr. Flamingo was born with long wings. Mrs. Flamingo was also born with long wings. Mr. And Mrs. Flamingos' long wings help to keep them warm at night. Later, they decided to have a baby named Olaf Flamingo. When Olaf is born, do you think he will have long wings, just like his parents, or will he have the normal size of wings like the other flamingos?

This is Mr. And Mrs. Robin. Mr. Robin was born with a soft beak. Mrs. Robin was also born with a soft beak. Mr. And Mrs. Robin have a hard time getting worms to eat because of their soft beaks. Later, they decided to have a baby named Sue Robin. When Sue is born, do you think she will have a soft beak, just like her parents, or will she have a normal beak like the other robins?

This is Mr. And Mrs. Deer. Mr. Deer and Mrs. Deer ate something one day that caused their bones to turn gray. After that, they noticed that they found it easy to jump high. Later, they decided to have a baby named Mary Deer. When Mary is born, will she have gray bones like her parents, or will she have normal bones like the other deer?

Post-Test

This is Mr. and Mrs. Squirrel. They were in an accident and their tails got cut short. Now they have a hard time balancing. Later, they decided to have a baby named Precilla. When Precilla was born, do you think that she had a short tail, just like her Mom and Dad, or a normal tail like the other squirrels?

This is Mr. and Mrs. Giraffe. Mr. Giraffe was born with a short neck. Mrs. Giraffe was also born with a short neck. Their short necks help them to eat from the lower branches of trees. Later, they decided to have a baby named Axel. When Axel was born, do you think that he had have a short neck, just like his parents, or a normal neck like the other giraffes?

This is Mr. and Mrs. Rabbit. Mr. Rabbit was born with big lips and Mrs. Rabbit was also born with big lips. Their big lips make it hard for them to hop a long way because they are heavy. Later, they decided to have a baby named Rose. When Rose was born, do you think that she had big lips like her parents or normal lips like the other rabbits?

This is Mr. and Mrs. Lion. Mr. Lion was born with big lungs and Mrs. Lion was also born with big lungs. Their big lungs make it easy for them to run a long way. Later, they decided to have a baby named Marcus. When Marcus was born, do you think that he had have big lungs, just like his parents, or normal lungs like the other lions?

This is Mr. and Mrs. Bear. One day something happened and they each lost a finger so now they only have four fingers. Their four fingers make it hard for them to get berries to eat. Later, they decided to have a baby named Celine. When Celine was born, do you think that she had four fingers like her Mom and Dad, or the normal number of fingers like the other bears?

This is Mr. and Mrs. Eagle. They were in an accident and now they each only have one leg. Having one leg makes it hard for them to walk or fly. Later they decided to have a baby named Allister. When Allister was born, do you think he had one leg like his parents, or two legs like the other eagles?

This is Mr. and Mrs. Cat. They had an operation and their livers accidentally got put back on the wrong side. Now their livers are super strong. Later they decided to have a baby named Sabrina. When Sabrina was born, do you think her liver was on the wrong side like her parents or on the normal side like the other cats?

This is Mr. And Mrs. Sheep. Mr. Sheep was born with really hairy ears and Mrs. Sheep was also born with really hairy ears. Their really hairy ears make it easier for them to stay warm. Later they decided to have a baby named Harry. When Harry was born, do you think that he had hairy ears like his Mom and Dad, or did he have normal ears like the other sheep?

Appendix D

Inheritance Unit Lessons

Lesson 1

1.) Read Story: *Are you my mother?* By P.D. Eastman

2.) Questions:

- "How does the baby know which one is its mother?"
- "Why is that one his mother?" → Babies are the same kind as their parents. They look like their parents.
- "Why do you look like you do?"
- "Has anyone ever told you that you look like someone in your family? Why do you think you might look like someone in your family?"
- "Let's think about what you look like…"
- "Raise your hand if you have…"
    - Brown eyes
    - Blue eyes
    - Dark hair
    - Light hair
    - Freckles
    - No Freckles
    - Light skin
    - Dark skin

2.) Body Graphing

Choose selected features discussed above (e.g., eye colour) and have all children with one version of the feature (e.g., brown eyes) line up one behind the other. Then, have all children with a different version of the feature (e.g., blue eyes) line up one behind the other. Ask the children questions such as which line has more people.

Lesson 2

"Today we're going to talk about 2 different kinds of birds. First, we're going to do a finger play. See if you can figure out what kind of bird we're talking about."

1.) Finger Play "The Duck"

I waddle when I walk
(hold arms and elbows high and twist trunk side to side or squat down)
I quack when I talk
(hold fingers and thumb like a duck's bill and place at your mouth)
And I have webbed toes on my feet
(spread fingers wide)
Rain coming down, makes me smile, not frown
(smile, frown)
And I dive for something to eat
(put hands together and make a diving motion)

2.) Brainstorming

- "Tell me what a duck is like"
- On half of a large piece of paper, the instructor writes/draws what the children say about the features of ducks
- "Tell me what a swan is like"
- On the other half of a large piece of paper, the instructor writes/draws what the children say about the features of swans.

3.) Story: *The Ugly Duckling* by Hans Christian Anderson.
4.) Questions:

- "Why did the ugly duckling look different from the other ducks?"
- "What was the ugly duckling really?" → A SWAN
- "Was it (point to picture of ugly duckling) ever a duck?"
- "It hatched from an egg. Was it a duck egg or a swan egg?"
- "What kind of bird must have laid the egg?"
- "What kind of bird must have laid the other (duck) eggs?"

Lesson 3

1.) Questions

(Use felt-board and felt cut-outs of animals and physical features such as fuzzy tails, tusks.)

- "Do you think that a horse could have tusks?" (Put horse cut-out on felt-board, add felt tusks)
- "Could a horse have a fuzzy, round tail?" "Why not?"
- "If this horse is black, how do you think it got black?" "Why would it be black?"

2.) "Where do babies come from?" → Mothers' bellies

(show picture of bunny with big belly)

- "What kind of babies would come out of this bunny's belly?"
- "How do you know that bunnies would come out and not dogs or people?"

3.) Gene Explanation

"We all have tiny things called genes inside us that make us what we are. People have people genes and rabbits have rabbit genes. When a baby is being made in the mother's belly it gets rabbit genes from her so it becomes a rabbit. Not only do rabbits have rabbit genes, but they also have long ear genes and bushy tail genes. Rabbits with brown fur have brown fur genes and rabbits with white fur have white fur genes."

4.) Application of Gene Theory to Real-Life Situations

- "Who is a person?" (put up hand) → "You have people or human genes"
- "Who has dark hair?" (put up hand) → "You have dark hair genes"
- "Who has light hair?" (put up hand) → "You have light hair genes"

- "I have blue eyes. What kind of genes do I have?" → "I have blue eye genes"

5.) Tell Finch Story (Solomon & Johnson, 2000)

This is a finch [show picture of yellow finch]. It was born from inside a mommy finch's tummy. What kind of genes did it get from its mommy? Yeah, so it has finch genes. When this finch has a baby in its tummy, what kind of genes will its baby have? So what will the baby be when it is born?

Now let me tell you a quick story about this finch. Ms. Warren is an artist who likes to draw pictures of birds. She decided that she wanted to draw a picture of a bluebird, but she didn't have a real bluebird to copy. She did have a pet bird that was a yellow finch, and she decided to paint her finch blue. But the blue paint started to come off when the bird jumped around in its cage, so Ms. Warren had to paint over it every morning before she started drawing. She taught it to sing like a bluebird. Here's how it looks now [show picture of bluebird]. Is it a bluebird or a finch?

What kind of animal does it look like? What kind of animal is it really? What kind of animal was its mommy? What kind of genes did it have when it was born? What kind of genes does it have now? When it has a baby in its tummy, what kind of genes will the baby get? She when the baby is born, what will it be? When the baby is born, will it look like a finch or like a bluebird?

Lesson 4

1.) Review from last lesson: Genes

2.) Questions:

- "What are genes?"
- →"Genes are tiny things that make us what we are. People have people genes and rabbits have rabbit genes. When a baby is being made in its mother's belly it gets genes from her. Rabbits have rabbit genes, alligators have alligator genes, and people have people genes. Not only that, but brown rabbits have brown rabbit genes and long ear genes, white rabbits have white fur genes."

3.) Story

"Let's read a story about different kinds of babies and we'll talk about what kind of genes the babies in the story have."

- *Alligator Baby* by Robert Munsch
- Ask children about what kind of genes the different animal babies would have such as alligator genes, green genes, etc.
- Point to some animals and ask what kind of genes they would have if they were… painted, learned to growl/swim/snort/sing… (i.e., would the genes change if the animal **learned** something new?)

4.) Re-tell finch story on felt-board.

Lesson 5

1.) Read Story: *David's Father* by Robert Munsch

2.) Questions:

- "What does "adopted" mean?"

→ "means a baby grows in one mother's tummy but then lives with another family."

- "David's father and his grandmother were giants. Will David be a giant when he grows up?"

→ "No, I don't think he will be a giant. David is adopted so he has different genes from his family. They were born with genes that make them giants and David was born with genes that make him normal-sized."

4.)Refer to *The Ugly Duckling* to Discuss Adoption

- "Remember the story of the Ugly Duckling? I wonder what kind of genes the Ugly Duckling was born with?" → Swan genes.
- (If answers incorrect, ask the following questions)
    - What kind of bird was the "Ugly Duckling?" → A swan.
    - What kind of egg did the ugly duckling hatch from? → Swan
- "If the ugly duckling had a baby what kind of baby would it be?" → Swan
- "I wonder what kind of family the Ugly Duckling lived with?" → Duck. The Ugly Duckling was adopted.
- "We know that the Ugly Duckling is really a swan. If it learned to "quack" like a duck, would it be a duck? What if we made it look like a duck by putting a

costume on it?" → No, it's really a swan. It has swan genes and genes make it what it is forever.

Appendix E

Sample Responses on Biological Reasoning Task #2 (Explanation of Judgment)

1. "Tell me why the baby would have a brown/ black nose (pre-test) / black/brown eyes (post-test)"

Nature

"Because it was a horse."
"Because it's a horse."
"Because she would be like her mom"
"Because it's a duck"
"Because it was born in the mommy **genes**"
"Because it was a baby duck."
"Because he was born from it."
"Because duck has black eyes."
"Because he's a duck."
"Because it hatched out of the duck."
"Because it's a duck."
"Because it was his mother, then it has to be the same."
"Because the horse growed the baby and then the baby was born like a horse instead of like a cow."
"'Cause it's a horse."
"Cause it's a horse."
"The egg was laid from the duck."
"Because it's was a duck egg."
"That guy [duck] laid the egg. Him have black eyes like the mamma duck."

Nurture

"Because he's a cow"
"'Cause he lived with the cows."
"From the cow [lives with the cow, therefore has black nose like cow].
"Because it's a duck."
"He [the chicken] raised the baby."

Other

"Because she was gonna grow up"
"Because they always see in the duck."
"Because the horse looks beautiful."
"So he could get away from the hunters."
"Because ducks do"
"Because that's what cows have."
"Because it's a baby."

"Because when babies grow up they have black eyes."
"Because it likes brown eyes."
"Because chickens like brown eyes."