8-1994

Children's Tool Making Capabilities: Implications for Hominid Intelligence Models and Skill Acquisition Theory

Jill S. McCleary

CHILDREN'S TOOL MAKING CAPABILITIES: IMPLICATIONS FOR HOMINID INTELLIGENCE MODELS AND SKILL ACQUISITION THEORY

by

Jill S. McCleary

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Anthropology

Western Michigan University
Kalamazoo, Michigan
August 1994

ACKNOWLEDGMENTS

I wish to thank the members of my committee, Dr. Tal Simmons, Dr. Erika Loeffler, and Dr. Robert Sundick for their continued support, guidance, and most of all, patience through the revision process. I especially would like to extend my sincere appreciation to Dr. Simmons for the additional time devoted to this project as my advisor.

In addition, my sincere thanks to the people at Waukazoo Elementary School, for allowing me to complete my research there. This, of course includes classroom teachers Ms. Craig, Ms. Calnin, and Ms. VanGenderen for their unrelentless flexibility, and the 39 terrific students who participated in making stone tools. I would also like to thank the parents who believed in the school, and in the study enough to allow their child to participate.

I would also like to acknowledge my family and friends for their continued encouragement and understanding. Specifically, I would like to thank my parents, Glen and Judy Windemuller. By providing countless words of inspiration, and by instilling a sense of self-confidence they have contributed in countless ways to all of my life accomplishments, including this one. Also playing a chief role in shaping my life was my grandfather, Fred TerVree. Because of his faith in me, I have continued to set high goals for myself. Therefore, I wish to dedicate this thesis to his memory.

Jill McCleary

CHILDREN'S TOOL MAKING CAPABILITIES: IMPLICATIONS FOR HOMINID INTELLIGENCE MODELS AND SKILL ACQUISITION THEORY

Jill S. McCleary, M.A.

Western Michigan University, 1994

The focus of this study was on morphological differences in stone tools that could be attributed to varied instruction and cognition levels.

In this study two groups of children, one second grade class and one fourth grade class, were selected to make stone tools. The tools that they made included both Oldowan-type flake tools and Acheulean-type handaxes. The primary variables considered in this study were the subjects' level of cognitive development (pre-operational versus concrete operational) as determined by a series of Piagetian tests, and the effects of varied instructional techniques.

Results suggest that Oldowan flake tools can be produced, at a rudimentary level, by individuals of both pre-operational and concrete operational levels of cognitive development, regardless of the instruction. In contrast, in order to produce the more advanced Acheulean tools, either concrete operations or demonstrative instruction is required. The findings also suggest that the hominids that produced quality axes were more likely to be true quality flake producers.

TABLE OF CONTENTS

Table of Contents—Continued

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Anthropologists are interested in stone tools for a number of reasons. Not only are they plentiful at certain sites, or the only surviving indicator of behavior at the earlier hominid sites, but they also appear to mark an important transition in life style, learning, and technology. In our society and that of early hominids, tools and technology are utilized in everyday activities to acquire and process food, in defense against predators, in travel, to shield our bodies from the extremes of the environment, and in communication. Therefore, paleoanthropologists consider stone tools to have been crucial to the evolutionary success and adaptation of early hominids.

There are many questions surrounding the use and manufacture of these early stone tools. Which species utilized this technology? What were the skills and knowledge required to manufacture stone tools? What were the social repercussions associated with this technology? How were the tool-production skills transmitted from one individual to the next?

Currently, two groups of hominids found in association with the earliest stone tools. The first are the robust (large-muscles) hominids known as either Australopithecus robustus (South Africa) or Australopithecus boisei (East Africa). This group is thought to have developed a specialization of large cheek teeth and jaw muscles for eating tough plant food. The second group, considered by many to be a direct ancestor of late modern humans is Homo habilis. H. habilis, when compared to the "robust" australopithecines, was more gracile, possessed a larger brain, and was considered to be more of a dietary generalist. For about a million years, until approximately 1.2 million years ago, australopithecines lived in the same African landscape as the Homo lineage. This coexistence is critical when trying to determine who the actual tool users were.

The earliest reliable dated tools date from 2.4 million and were found in the Omo Valley in Ethiopia (Toth 1987). At these sites paleoanthropologists have found quartz, pebble fragments, and other rocks that have been intentionally shattered. Other sites, such as Koobi Fora and Olduvai Gorge have yielded not only simple stone artifacts as old as 1.8 to 1.9 million years, but also well preserved bone.

There appears to be a growing consensus that although these tools have been found in association with both early hominid species, Homo is and always has been the only tool maker. This view is reflected by Schick and Toth (1993) when they argued that an enlarged cranial capacity the cerebral asymmetry indicative of lateralization and potential right-handedness, the lack of tools found contemporaneously with earlier australopithecines, and the large masticatory system possessed by "robusts" australopithecines, all support the hypothesis that only H. habilis were making these tools. Others such as Wynn and McGrew (1989) and Susman (1991), offer a different perspective. Susman argued that all available evidence (geochronological, archaeological and diagnostic evidence of the hands) points to the conclusion that Australopithecus and H. habilis were both early tool makers, and that A. robustus may have been the first maker of stone tools. Wynn and McGrew (1989) support this argument when they suggested that because these early tools require only ape-grade adaptations, it would be counter productive to assume that H. habilis was the sole tool maker.

The early tools, found in association with sites dated 2.4 million to 1.6 million years old are generally referred to as Oldowan, in reference to the Tanzanian site, where such artifacts were first described by Louis and Mary Leakey. Most of the Oldowan implements were lava cobbles or quartz and quartize block that had been struck with a cobble hammer, resulting in a core and flakes or fragments. At the time of their discovery, Oldowan tools were classified according to the shape of the core, and its possible functions. More recently, Toth (1987) suggested that these core forms could simply be the by-products of flake manufacture, and consequently the flakes were probably as important as the cores, especially for animal butchery.

One and a half million years ago a new technology was added to the Oldowan repertoire. This technology is known as the Acheulean, and its defining characteristic is that the raw material for the implement was often not a small river cobble, but a large flake struck from a boulder. These flakes, some'more than 20 centimeters long (Toth 1987) were made into large bifacial forms that anthropologists have called picks, handaxes, or cleavers.

Anthropologists have yet to reach consensus regarding who the earliest tool makers were, not to mention how the tools were used, and how the skill was learned and transmitted. Numerous studies have attempted to provide answers to these questions by filling in piece by piece the enormous puzzle surrounding the early hominids of Africa. Experimental studies, such as those conducted by Toth (1985; 1987), Schick and Toth (1991), Isaac (1978), and Washburn and Moore (1974) aid in determining the possible uses of early stone tools and the probable techniques which created them.

Additional studies have been conducted using non-human primates in an effort to better understand how tool manufacturing skills develop, and the cognitive and physical skills required to produce them. Several researchers note the significance of tool-using behavior among non-human primates, not only because they demonstrate that tool manipulation is possible among non-Homo species, but because these primates can provide clues to early hominid tool behavior. Anderson, Williamson and Carter (1983) observed chimpanzees in the forests of Liberia using stone hammers to break open nuts. Parker and Gibson (1977) examined tool use in both cebus monkeys and great apes, and concluded that intelligent and context-specific tool use is an adaptation to certain feeding conditions. In 1989 Chevalier-Skolnikoff completed a similar study which suggested that the strong tool-using propensity among primates was based on advances in sensorimotor ability, rather than fortuitous discovery. Additional research (Jordan 1982, McBeath and McGrew 1982, Nishida and Hiraiwa 1982, and Boesch and Boesch 1984) continued to confirm the tool-using behavior of non-human primates in the wild.

In addition to the general observational studies, there are those that attempt to draw more direct correlations between human and non-human primate species and tool use. Sumita, Kitanara-Frisch, and Norikoshi (1985) recorded the behavior of five captive chimpanzees, and as a result were able to outline learning stages of tool use skills. Westergaard and Suomi (1994) completed a study which suggests that the cognitive and biomechanical conditions which facilitate the use and modification of lithic tools, can facilitate the development of simple bone-tool technology. Another example of a study with early hominid implications was conducted by Boesch and Boesch (1981), in which it was concluded that flaked stones could have been produced by early hominids when they used stones as hammers in gathering activities (as illustrated by Tai chimpanzees).

Similar studies, such as those conducted by Sugiyama, Fushimi, Sakura and Matsuzawa (1993), and Vauclair and Bard (1983) also offer hominid behavioral insights as a result of pongid research, but for the purpose of this research the most significant study was conducted by Toth, Shick, Savage-Rumbaugh, Sevcik and Rumbaugh in 1993. In this study, a nine-year old male bonobo chimpanzee named Kanzi mastered the basic skills required to remove simple flakes from stone cores using freehand, hard-hammer direct percussion, and subsequently used these flakes for cutting activities. This behavior was acquired by observational learning of human models, followed by long periods of trial-and-error learning. Kanzi, however, has not yet mastered the concept of searching for acute angles on cores from which to detach flakes efficiently, or intentionally using flake scars on one face of the core as striking platforms for removing flakes from another face (Toth et al., 1993). According to the authors, Kanzi has exhibited a low degree of technical finesse. Consequently, Kanzi's progress as a tool maker suggests that early Oldowan hominids may have exhibited a much greater cognitive understanding of the principles and mechanics of tool making than modern apes seem to be able to develop (Schick and Toth 1993).

In contrast, comparable observational studies conducted by Wright (1972) and Wynn and McGrew (1989) appear to lead to more optimistic conclusions concerning analogous ape and hominid ability. Wright's (1972) study of an orangutan lead him to conclude that it is improbable that australopithecines were prevented from imitating stone flaking by deficiencies in their intelligence and manipulative skills—the skill is easy to acquire at a pongid level. Wynn and McGrew (1989) appear to support Wright's conclusion when they state that all behavior that can be inferred from Oldowan tools falls into the range of the ape adaptive grade. In fact, according to Wynn and McGrew (1989), there is nothing exclusively human-like about the oldest known archaeological assemblages. McGrew (1992) reiterated this point in his later work focused specifically on chimpanzee tool behavior. He stated that the relative number of points of similarity between apes and early hominids have increased (including analogies of tool use, scavenging, and diffusion of tool use) and those of dissimilarity have declined.

The aforementioned studies, along with other related research, indicate that studying non-human primates is valuable for understanding hominid stone tool behavior. Observations conducted both in the wild and in captivity clearly illustrate that apes are capable of both making and utilizing early stone tool technology. However, the question remains as to how many inferences should be conservatively drawn. The leap from consideration and understanding of extant anthropoids to extinct ones, is indeed great. Therefore, additional studies in cognition, cranial structure and social transfer of information complements the data gained by observing non-human primates tool use. These studies consider cognitive development, cranial capacity, intelligence, and learning in an effort to better understand how tool-using skills are developed, transmitted, and the minimum mental competence required to acquire the skills.

For example, Holloway's (1974; 1976) work with endocasts suggested that brain size was not as important as brain organization, with respect to evolutionarily significant skills such as tool manipulation, while it was Washburn (1959) who first noted the importance of motor cortex organization. These studies can be contrasted with work conducted by Tobias (1971; 1987) in which cranial capacity is thought to be the determining feature separating the skills and intelligence of Homo from the australopithecines. Additional studies (Boesch and Boesch 1984, Jolly 1985, Parker and Poti 1990, Povinelli, Boysen and Nelson 1990, Parker 1990a b, Gibson 1990a b, Bard 1990, King 1991) conducted with non-human primates have also provided anthropologists with information about the mental capabilities of our closest relative, their stages of learning, gestures which facilitate social tool use, and the developmental rates of intelligence.

The research conducted using experimental studies of stone tools, non-human primate analogies, as well as the work focused on learning, intelligence, cranial capacity and organization has contributed to the establishment of a framework for understanding tool use among early hominids. It has provided clues as to which species was more likely to utilize tools based on cranial capacity and cranial organization, the benefits attributed to stone tool use (especially for food processing and acquisition), the stages of learning the hominids had likely progressed through when developing the skills, and the cognitive and manipulative abilities required for the different types of tool production. However, the problem that continues to remain is one of limited comparative models. Researchers have not only relied on analogies between different genera, but have continually limited themselves to anthropoids with largely different mental abilities and cognitive structures. In response to these limitations, this study focuses on human children as a way to determine who the tool users were, how the skills of tool manufacture were acquired, and what affect (if any) cognitive development and instruction have on stone tool production.

Children were chosen as the subjects for two reasons. First, because they are classified in the same genus as Homo habilis, and second, because they have cognitive abilities similar to the earliest hominids (Wynn 1979; 1981). This allowed for a more accurate comparison than could be achieved using pongid models. The general purpose of this study was to test existing hypotheses of hominid intelligence as they apply to stone tool products and to analyze the effects attributed to varied instructional techniques and cognitive development on stone tool morphology. The experiment was conducted among two groups of elementary school aged children over a one month period. One of the groups was a second grade class, the other a fourth grade class. The earlier sessions were structured to ascertain the cognitive development stage of each participant, as well as to explore informational processing abilities, and to test strength and coordination. The remaining sessions were allocated to stone tool manufacture. The students were divided into one of three experimental groups. These groups differed as to the type of instruction they received: (a) no instruction, (b) oral instruction, or (c) modeled instruction. Students were introduced to both Oldowan and Acheulean tool production techniques. Both types of tools were examined for reflections of morphological variations attributed to cognitive development, instructional methods, reinforcement, information processing, or strength and coordination variables.

Two hypotheses were tested in this study:

1. The higher a subject's level of cognitive development, the better the quality of stone tools he or she is able to produce.

2. Subjects who are able to observe stone tool making will acquire the skills necessary to produce tools at a faster rate than subjects who are just told what to do, without benefitting from observational learning.

The theoretical framework for this study was previously outlined by Wynn (1979; 1981; 1985). Using Piaget's stages of cognitive development, he argued that the morphology of stone tools could provide clues as to the minimum cognitive skills needed to produce these skills. Wynn (1979; 1981) reached the conclusion that Oldowan tools required fewer cognitive skills than did Acheulean artifacts.

This study was initiated with the hope of answering questions such as: (a) Are knapping activities necessarily social? (b) What is the significance of this for theories involving campsite or living floor hypotheses? (c) What can be inferred about the manner in which the skill of tool making was transmitted from one hominid to another? (d) Was it possible for a hominid at a lesser stage of cognitive development to transmit these skills, or would it require a higher level of cognitive development to be an effective teacher? (e) Could this indicate what species were the tool makers? and (f) How do tools found in the archaeological record differ as a result of practice/teaching, reinforcement and/or cognitive development? These questions have not been addressed in the literature, and therefore are the focus of this study.

CHAPTER II

MATERIALS AND METHODS

Organization of the Study

The initial part of this study was intended to provide cognitive development information about the students. The theoretical background for this was Piagetian. Wynn (1985: 32-33) explained why this theory is the theory of choice among anthropologists:

> For a theory of intelligence to be workable for an archaeologist, it must be evolutionary in scope and it must deal with categories of behavior that are visible in the archaeological record. Intelligence must be defined as a set of behaviors that varies from species to species in measurable fashion and that can change through time within a single evolving line. The theory must also be capable of assessing archaeological patterns. The theory must define criteria that archaeologists can apply to such mundane behaviors as butchering, structure building, and most importantly, stone tools—the most abundant residue of prehistoric behavior.

Consequently, according to Wynn (1985), Piagetian theory fulfills the basic requirements of a workable theory of intelligence. It is evolutionary, cross cultural, depicts stages, has an emphasis on spatial concepts, and it relies on qualitative criteria. Wynn also pointed out that even with a workable theory, archaeologists are susceptible to a problem inherent in the nature of archaeological evidence—the problem of minimum necessary competence. In other words, it is not possible to determine the actual cognitive ability that produced a stone tool, only the minimum cognitive skills that would be required to produce such a tool. Furthermore, he recognized that Piagetian theory has other limitations as well. When only geometric criteria can be used, as in the case with stone tools, the resolution of the analysis is not very fine, and we are limited to applying Piaget's coarse major stages. As a result, subtler differences in intelligence are missed.

To better understand the applications of Piagetian theory, a further explanation is required. Piagetian theory is a structural theory that defines intelligence in terms of organizational ability. It is based on the proposition that structures are patterns of brain activity, and it is the action of the organism in its environment that leads to elaboration of structure. The theory is based on three stages of development: (1) sensorimotor intelligence, (2) pre-operational intelligence, and (3) operational intelligence (subdivided into concrete and formal operations) (Wynn 1985). The sensorimotor stage is depicted by physical sequencing. It is regulated by reflexes such as gripping, sucking, arm waving, grasping, and pulling. The pre-operational stage occurs when the action schemes of the sensorimotor stage are internalized (now performed in thought). The semiotic ability allows consideration of the past and projection into the future. However, because pre-operational structures are internal imitations of action sequences, they are restricted to organizations that can be performed by action. Because action can only act on one quality at a time, internalized action can consider only one variable at a time. The final stage, operational thought, requires reversibility and coordination of operations. It includes abstract thinking, perspective taking, and multiple variable considerations. Piagetian theory is based on the assumption that cross-culturally, sequencing is always the same, although the age at which a person may reach a particular stage may change (Wynn 1981).

Piaget not only devised a theory of cognitive development, but he also created a means by which to determine what stage a person was currently in. Most useful for the purpose of this study, are the tests to distinguish pre-operational from concrete-operational capabilities. These include tests which pose questions relating to constancy of form, constancy of size, object permanence, perceptual causality, seriation, and classification (Piaget and Inhelder 1969).

Jolly (1985) suggested that it is possible to rank cognitive tasks from simpler to more abstract problems, and indeed, children do progress from simple learning (such as habituation) to dealing with concepts of class, conservation, and analogy. However Piaget fails to correlate social and cognitive development in many spheres into his theory of cognitive development. It is now known that humans show disjunction between logically similar abilities as revealed in different stages.

There are, of course, other theories of cognitive development and further explanations of cognitive phenomena. These include associationist and reinforcement theories which focus on stimuli, reinforcement, and practice; information processing theories which consider cognitive functioning to be similar to successive circuits monitored by check points (linked to the study of cybernetics); and social learning theories, which emphasize a reciprocal relationship between the process of cognition and the information derived from the environment (Rosenthal and Zimmerman 1978).

Although these alternatives are definitely worthy of consideration, and despite the weaknesses of Piagetian theory, the theory proposed by Piaget will remain the primary theory utilized in this research because of the numerous practical benefits and widespread use in the anthropological literature.

In order to determine the developmental stage of a child, the following tests, developed by Piaget and Inhelder (1969), were applied to both classrooms and all participants:

1. Conservation — One of two clay balls of equal size was rolled out into a narrow, long shape. The pre-operational (PO) child is not able to see that the amount of clay was conserved through the process, and will say that the longer piece has more clay because it is longer. The concrete operational (CO) child understands conservation and will state that both shapes contain the same amount of clay.

2. Conservation — One-half cup water was poured into two identical glasses. Then the water was poured into two other glasses, one short and wide, the other tall and thin. The PO child will state that the taller glass has more water, while a CO child will know they still contain the same amount.

3. Conservation — Two rows of pennies were displayed, each containing seven coins. One of the rows was elongated (leaving more space between coins), and the other row had the coins in touching position. When asked which row had more pennies, a CO child will count the pennies and state that both rows have the same number, while a PO child will believe the elongated row has more because it is longer.

4. Perspective Taking — The child is asked to sit at one side of a table with an object on it (a mug). Then the child is told to draw the mug from the perspective of a bird flying overhead, without moving from the chair. A PO child will be unable to take the birds perspective and will instead draw it the way he or she sees it. In contrast, the CO child will not have difficulty taking the other perspective (Figure 1).

5. Part-Whole Relationships — Seven black beads and three white beads, all plastic, are laid out on the table. The child is asked if there are more black beads or more plastic beads. The PO child will answer "black" not taking into account the whole picture, while a CO child will realize that what an object is made of is unrelated to color.

6. Irreversibility — The child is asked to visually reconstruct a falling stick using straws to illustrate steps. A CO child will line up the straws in a fan like pattern to show the falling motion demonstrating the starting position of the stick, the intermediate points of its descent, and its final resting position. A PO child will not consider the falling process, and will likely use only one straw to illustrate the starting or ending position of the stick.

The information acquired from the Piagetian tests are applicable to the later stone knapping sessions in that they allow a comparison of stone tool products based on the cognitive development of the subject. In fact, this was the primary reason for selecting both second grade (7-8 years of age) and fourth grade (9-10 years of age) students for this study. Piaget believed that dramatic changes occur when a child enters the stage of concrete operation (7-11 years) from the pre-operational intuitive

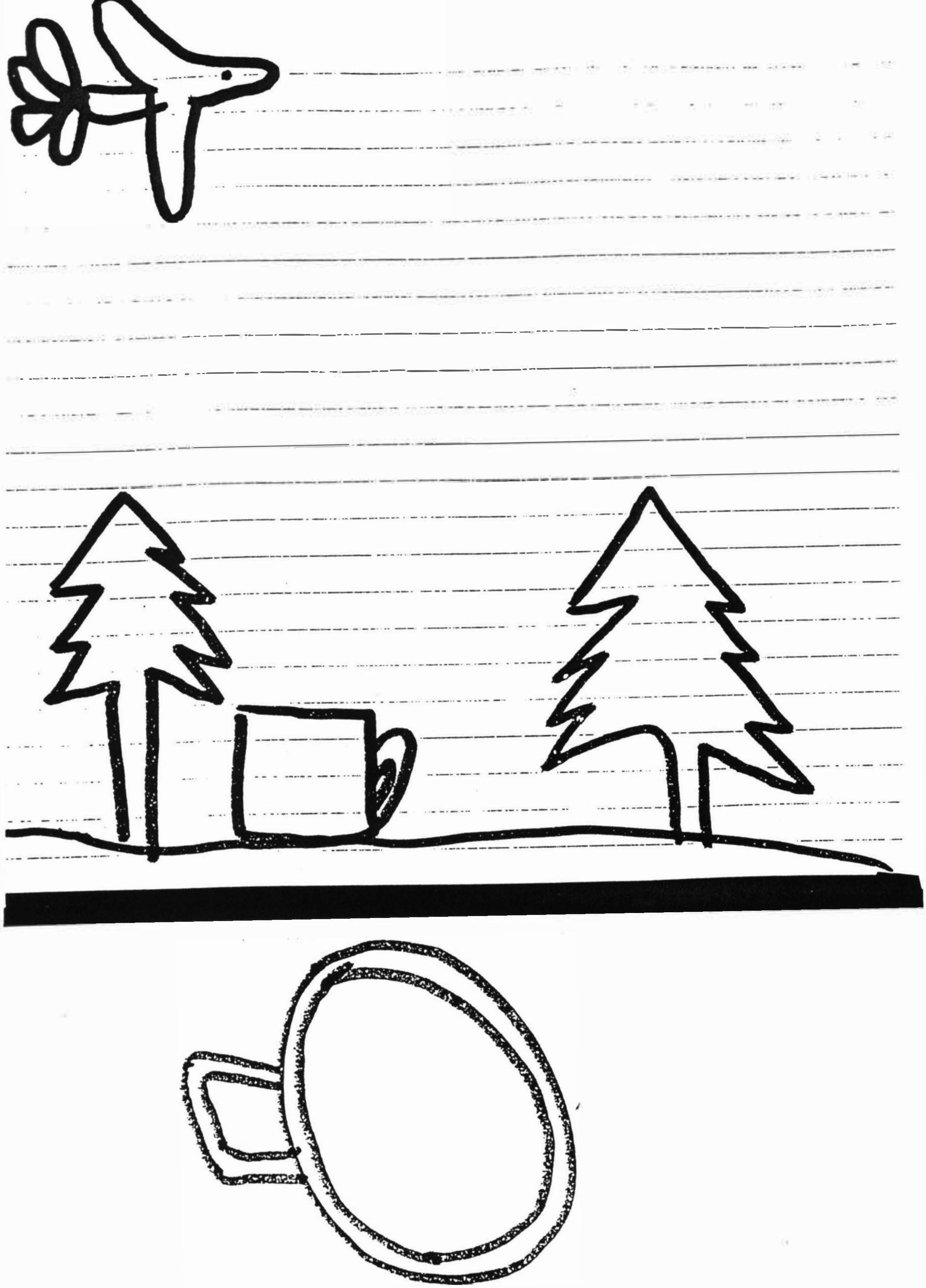


Figure 1. Comparison of Drawings Produced During Piagetian Experiments Reflecting Pre-Operational and Concrete Operational Differences.

period (4-7 years). Therefore, it was suspected that by considering both age groups, the research could address the abilities associated with both cognitive stages.

With obvious significance for the study of stone tools, Piaget also considered three types of geometry: Euclidean, projectile, and topological. According to Wynn (1981; 1985), the spatial concepts necessary to manufacture the Oldowan tools are rather simple; neither Euclidean nor projectile geometry were necessary, only topological relations. Topology is the geometry of simple relations such as proximity and surrounding (Wynn 1981; 1985). Wynn reached this conclusion after conducting both Acheulean and Oldowan tool studies. After examining late Acheulean artifacts found at the Isimila, Tanzania site he argued that these tools required the organizational ability of operational intelligence, and that the knappers were not significantly less intelligent than modern adults. Wynn (1979) looked particularly at the Piagetian concepts of reversibility and conservation used to assess the spatial concepts used by the hominids. He suggested that four specific kinds of operational spatial organization was applied in the manufacture of these artifacts (each of these infralogical operations requires reversibility and conservation):

1. Whole/Part—indicated by the fact that the artifacts were biface (flakes struck from both ventral and dorsal surfaces) and by the amount of retouch.

2. Qualitative—the straightness is significant because in order to produce artificial straightness, the knapper had to have related each flake removed to all the other flakes, and also to have a single stable point of view.

3. Spatio/temporal—indicated by the regular cross sections of bifaces. This required mental rearrangement of elements and relations.

4. Symmetry—the form was "mirrored" across a reference line.

In 1981 Wynn took the same approach and analyzed the Oldowan tools. He argued that the intelligence of the Oldowan hominids was on par with that of modern pongids. He attributed this to the fact that the minimum competence necessary to produce these tools is pre-operational organization, and therefore it is likely the crudity of the Oldowan artifacts reflects an ability to organize space that was much less sophisticated than that of modern humans. He noted that it was unnecessary for the knapper to have considered more than one affect of his action at a time, and that the Oldowan patterns could easily have been achieved by a process of trial and error. In 1985 and 1991 Wynn reiterated his arguments. In 1985 he stated that the Oldowan knappers need not have had a relatively complete plan of action and need not have employed operational thinking. If the Oldowan hominids had pre-operational intelligence, then they were a little more intelligent than modern apes, and this would imply that the process of hominid evolution prior to 1.5 million had little to do with increasing intelligence (Wynn 1985; 1991).

It should be noted that Piaget's theory has been criticized in recent years, primarily for the inflexibility of the progressive stages. Thus, although Piagetian models were utilized as the primary determinant of cognitive abilities, which provided for a more reliable comparison to the studies conducted by Wynn (1979, 1981), informational processing abilities were also examined in this study (Appendix A). The informational processing approach does not yield the definite and homogeneous picture of cognitive development one finds with Piaget's tests; nonetheless, an academic concern with a child's perceptual, attentional, memory, and problem-solving capabilities does help support and refine the data gathered as a result of Piagetian theory. Therefore, each subject was not only asked to respond to each of the six Piagetian experiments, but each child also answered questions which tested mental and physical map construction, memorization, sequencing skills and concept ordering. Combined, these activities provided a more complete view of each subject's partial competencies, as well as developmental stage.

The first two weeks of the study were devoted to these types of testing situations. After that the sessions became focused on stone tool making. In order to test the independent variables of modeling versus oral instruction versus no formal instruction, and the independent variables of pre-operational versus concrete operational cognitive development, each class was divided into six separate experimental groups according to the dependent variable of the variations of stone tools produced. These groups are defined below:

Concrete Operational and Pre-Operational Group A — These students were simply shown the intended outcome (i.e., flake or handaxe) and then allowed the time and raw materials to produce tools, without further instruction.

Concrete Operational and Pre-Operational Group B — These students were "talked through" the process several times. They were told what to look for and what makes an effective tool, but the actual technique was not demonstrated.

Concrete Operational and Pre-Operational Group C — These students had the technique of stone tool making demonstrated (modeled) to them at the beginning of the experiment as well as whenever the students requested a demonstration.

Second grade and fourth grade students attended separate experimental sessions throughout the study. However, with respect to cognitive development, pre-operational and concrete operational students worked side by side in the different instructional groups. Both the Piagetian and tool work sessions were conducted in a small group setting, usually consisting of four to five students. This structure worked most efficiently by limiting the number of students requiring monitoring at one time, and allowing for more effective manipulation of the variables.

The hypothesis was that the outcome of this experiment would reflect the following hierarchial order with respect to finer quality tools, and the speed at which the skill was acquired: (1) Concrete Operational Group C, (2) Concrete Operational Group B, (3) Concrete Operational Group A, (4) Pre-Operational Group C, (5) Pre-Operational Group B, and (6) Pre-Operational Group A. The hypothesis rests on the assumption that cognitive ability carries more weight in stone tool production than does variations in instructional methods; with greater cognitive development capabilities, instructional differences can be overcome through trial and error. Two types of tools were produced by the students: (1) flakes (a tool from the Oldowan industry) and (2) handaxes (a tool from the Acheulean industry).

The quality of tools was determined using three criteria. The first criteria was actual utility. Chopping of a sapling, scraping a branch to sharpen it, hide-working, and animal butchery are all thought to be possible Stone Age uses for flakes. Cores, handaxes, and cleavers could have been used for more complex tasks such as bone breaking and wood working. Therefore, the tools produced must be able to fulfill several of these functions in order to be considered of good quality. Second, size and shape of the tool was considered. An intentional flake would differ from simple waste by possessing certain features including a platform, bulb of percussion, concentric ripples, a flake release surface, and a dorsal flake release surface. Handaxes of good quality would not only be workable, but would also have great symmetry and be very thin relative to the width (Shick and Toth 1993). Lastly, general technique was observed. "Platform preparation" means to strike a flake off so there is a platform (<90°) produced which would then act as the ideal spot to strike off additional flakes (Toth 1987). This is a skill that only develops after numerous hours of practice. In addition, the exact location of blows was recorded because it appears that the very best knappers strike very close to the edge—so close that they frequently miss the rock completely.

Further criteria are offered by Toth et al. (1993). These include degree of decortication of cores and size of flakes removed. Both of these provide a basis for further analysis of the tools.

When analyzing the data, it is important to note that the focus was on the classroom comparison of products and differences reflected between the six experimental groups, not individual variations. In this way, the study stressed the effects of the variables on the particular stone tool products, and specific attributes of these products. It is unrealistic to expect the tools produced by the children to greatly resemble those produced by the hominids, because of the strength factor. The importance of hand strength in tool manufacture was demonstrated by Susman (1991) when he examined the qualitative differences between ape and human hand function, power versus precision grip, phalange structure and the absence or presence of the flexor pollicis longus muscle.

During the last research visit the variables were revised in an effort to explore the wider issues of learning and social transmission of information. Two students who were at nearly identical stages in tool making skill were observed to acquire information on the effects of negative and positive feedback on tool making. One student received only positive comments in the form of praise and the other received negative comments in the form of mild criticism directed toward their efforts. All negative feedback was directed toward problems evident in the stone tool, no personal criticism was given. The other group of students formed the control group. There was one more addition made to the experiment at this point; two subjects form concrete operational Group C and two subjects from pre-pperational Group C were asked to teach a combined group of Group A subjects the skill of tool making. This provided data as to the affect intellectual development has on transmitting stone tool making skills to others. In both cases, stone tool product variation could be described as possibly contingent upon reinforcement and the cognition level of the teacher.

Subjects

During the first day of research, a brief introduction was given to the students to recruit volunteers for this study. The orientation included information about the the researcher's education, area of study, and it explained to the students their potential role in the study. It was explained exactly what the research involved, and outlined the information included in the parental permission form (Appendix B). In general, the students they were being asked to make stone tools so that it could be better understood how people, early in our history, first learned to make tools. It was made clear that the students were not required to participate, and if they wanted to participate their parents must approve and sign the consent form. All forms were distributed the first day, and work began with the students who returned their forms the following week. Therefore, the number of subjects was contingent upon the number of students returning the appropriate assent (Appendix C) and consent forms. This process yielded 13 second grade and 26 fourth grade students who were both willing and able to participate in this research.

Of the thirteen second grade students, five of the subjects were female and eight were male. Second grade students are seven or eight years of age. The majority (11 out of 13) of the participants were Caucasian, and two were Hispanic. The fourth grade students were between the ages of nine and ten years old, and the female to male ratio was much more unbalanced as the females outnumbered the males 16 to 10. The ethnic background of the students in the fourth grade class was similar to that found in the second grade: 22 out of 26 were Caucasian, 3 were Hispanic, and 1 was a Vietnamese student. The socioeconomic background of these students was varied, but it did appear to reflect the primarily middle to upper-middle class economic community in which the school was located (including a small percentage of impoverished and wealthy households). All subjects in both classes were assigned a random identification number, for reference purposes throughout this study. For example a number such as 2/13 signifies that the subject was in the second grade group with an identification number of 13.

Setting

For safety purposes, all students were required to wear heavy gloves that fit snugly, and safety goggles. They worked in well ventilated areas, primarily outdoors. The subjects were also required to wear shoes, socks, long pants, and long-sleeved shirts as well as to stand a minimum of seven feet away from each other while knapping. Furthermore, the raw materials were chosen more for safety reasons than workability. For example, one of the finest raw materials for flaking is obsidian, but it is extremely sharp, and therefore was not considered. The same is true of glass blocks. In contrast, the materials chosen (chert and sandstone) were easily flakable, required less force when striking, and the flakes themselves were less likely to cut upon impact.

Materials

The raw materials provided were chert and sandstone. Cherts are similar to flints, typically light in color, often found within limestone deposits. Silicified sandstone, on the other hand, is formed when silica cements relatively unconsolidated rocks. Both of these materials are examples of sedimentary rocks. To be suitable for flaking such rocks should be fine grained and made up of very small quartz crystals, as both of these materials appeared to be. Although personal experience indicated that sandstone is easier to flake and easier to acquire in large quantities, chert can produce tools that are better for actual utilitarian purposes, and therefore proved to be the better material for this experiment. All subjects were required to work with chert. In addition, hammer stones were provided because the technique demonstrated to the participants was hard-hammer percussion. This technique, consisting of hitting one rock with another, was most common at the earliest archaeological sites (Schick & Toth 1993). Hammer stones are small river cobbles, typically slightly rounded or egg-shaped.

The materials used for the Piagetian experiments were eclectic. They included: (a) two containers of playdough; (b) one box of plastic straws; (c) two plastic glasses (one stout, the other tall and narrow), each of them able to hold one-half cup liquid, fourteen pennies, seven black beads and three white beads (all plastic); (d) a ten-inch long wooden dowel; and (e) a ceramic mug.

The strength and manual dexterity of children of this age posed a methodological problem. It would be difficult to attribute the quality of the tool solely to cognitive development or instructional techniques, and not physical development if this variable could not be controlled. In an effort to do this, a measure of forearm and finger strength was conducted using a grip test. The instrument used was a Tec Jamar Hand Dynamometer (model number 10100263). In addition, observations of eye-hand coordination were made from three trials of paddleball. These variables were later considered for their possible impact on stone tool production.

CHAPTER III

RESULTS AND CONCLUSIONS

Observations

Technique

The first day of research all students exhibited the same general tool making technique. After the students were shown the stone tool they were asked to replicate, they immediately began striking the top surface of the rock with the hammer stone, attempting to, but rarely succeeding in, shattering the rock into numerous pieces at one time. The groups which were given oral and visual instruction were quickly told to strike the rock near a thin edge. After continual reminding, these students were soon able to point out, if asked, what type of edge they were looking for. However, as evidenced by the blow marks on several of the rocks, the students still continued to hit further from the edge than is optimal (1 cm). It would seem reasonable to expect that those students who received some type of instruction the first day would be able to produce a greater quantity of flakes, because they would strike near the edge sooner. However, the data does not support this assumption. In fact, the students receiving some form of instruction produced an average of 17 flakes the first day, while the students not receiving instruction produced an average of 19 flakes the first day. This difference in productivity may have been caused by the time take out for instruction.

At the start, none of the children attempted to hold the larger rock while flaking. In fact, the only students who attempted this technique were the students who had seen this technique used by the instructor during the demonstration, but most discontinued this practice because of the hand discomfort it caused (Figures 2 and 3).

Figure 2. Children's Stone Tool Making Technique: Using Ground Surface.

The second day of flaking did not reflect much improvement in technique. It did, however, appear that all the students, regardless of their instructional group, determined that it was easier to chip the rock on the edges, thus they were all able to produce at least a small amount of sharp thin flakes. However, none of the children demonstrated forethought in regard to platform preparation, and none of the children were producing large quantities of thin workable flakes consistently.

Figure 3. Children's Stone Tool Making Technique: Holding the Raw Material.

The technique utilized to acquire Acheulean handaxe tool making skills can best be termed as random confusion. When shown a bifacial handaxe the students were eager to begin, but they had no idea how to hit the rock with the hammer stone to produce the desired effect. The students who were receiving some type of instruction, quickly learned that flaking at the edge of the stone would reduce the circumference of the stone, but the majority of students were unable to decrease the thickness of the raw material.

Tool Description

As a result of the haphazard technique discussed above, the flakes were, in general, small, irregular, and largely nonutilitarian. The average size of the flakes produced was approximately ¾ to 1 inch in diameter, with a range from ¼ inch to 3 inches. The majority of the flakes were thick and "chunk-like" with several irregular sides and angles. In fact, less than 40 percent of them were actually thin enough to even be considered a flake by most paleoanthropologists. When closely examining the flakes, one does not find the physical characteristics thought to differentiate intentional flakes from debitage. There is no evidence of platform bulbs nor concentric ripples on any of the flakes/fragments—this includes even the more utilitarian flakes.

In regards to workability, out of the 1343 flakes produced by the 39 children, only 278 could be considered potentially useful as stone tools. This was taking into consideration the sharpness, strength and size required for such tasks as hide working, chopping, and scraping.

The handaxes were even more varied in size and shape. They ranged in size from 3 inches to 10 inches (measurements taken from base to apex) and in weight from less than 1 pound to 6 pounds. The average handaxe was 5-6 inches in length, and 4 pounds in weight. The morphology variation was extreme. Some of the "axes" were small and fragile, almost resembling small arrow heads, while others were large, thick, and rounded (Figure 4). Most of the edges were dull, and many of the blow marks indicated the child was making small frequent hits over the entire surface of the axe. Common among 30 of the axes was a general triangular shape, however due to the thickness of these tools, and the absence of sharpness, only two could be used to cut substances such as meat, roots, branches, etc. Symmetry was also reflected in five of the tools (Wynn, 1979).

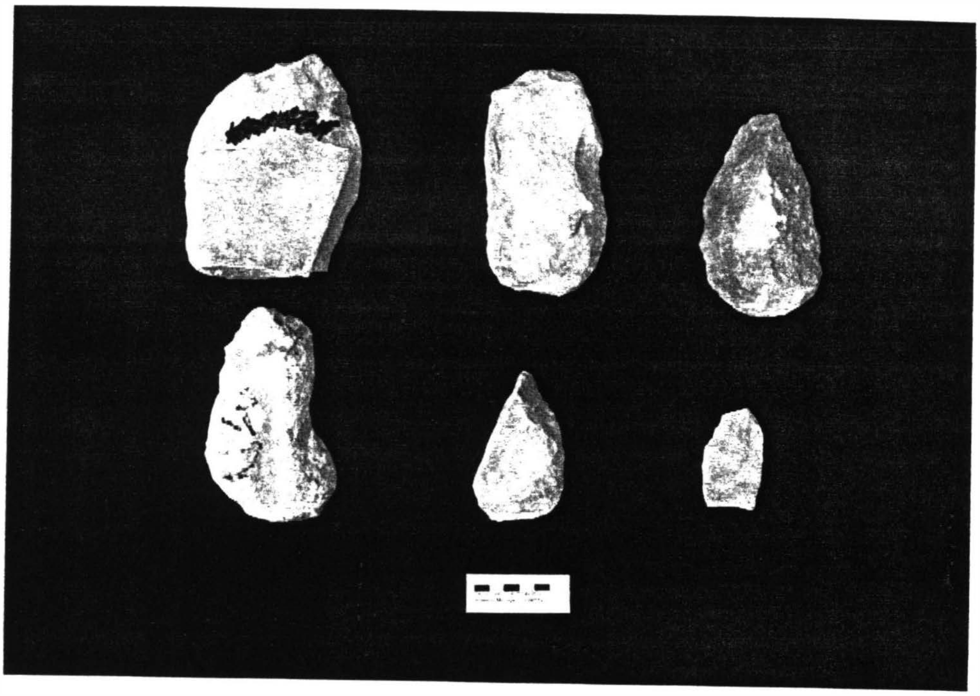


Figure 4. Handaxe Variation (Scale in cm).

Group Variation

After completing the experiment, the tools ,were divided and analyzed based on the three instructional categories: (1) A = no instruction, (2) B = oral instruction, and (3) C = modeled instruction. The criteria used to define the quality of the tools, as outlined previously, consisted of three elements: (1) actual utility, (2) morphology, and (3) technique. Therefore, tools were considered to be of good quality if they were able to perform functional tasks (such as butchery or wood working), and were thin, sharp, and not easily broken, and were produced by striking near a platform edge. Initial observations indicated that among the second grade students, Group C, in general, made better handaxes, and more uniform flakes. Surprisingly, Group A, appeared to produced better quality stone tools than Group B in second grade. The fourth grade students in Group A tended to produce a poorer quality handaxe when compared to their fellow classmates and Group B and Group C produced a wide variety of tools, but in general seemed to make better quality flakes.

After these general observations, the tools were laid out based on the cognitive development test results. Children who responded to the majority of tests in a concrete operational fashion were ranked as exhibiting a more advanced level of cognitive development, while students who responded to the majority of tests with pre-operational answers were considered to occupy a lower level of cognitive development (Appendix D). Based on the results of the six Piagetian tests, a child who responded with concrete operational answers to all the tests would be considered to have reached a higher stage of cognitive development at this time than a child who responded to the six tests with pre-operational answers. Thus, based on students' cognitive development, the tools were ranked from high to low, and each student was given a number based on his or her place in this continuum.

Three additional general observations were made at this point based on the new categories. First, the students who produced the overall weakest tools in terms of workability, technique, and morphology were identified (18 students). This group did not contain any of the top seven cognitively ranked students. In other words, the top-ranking students on the cognitive development scale were not the worst tool makers. However, the cognitively lowest-ranked students were not the worst tool makers either; in fact, the middle group (in terms of cognitions) made the greatest number of poor quality tools. Second, the examination of students who produced the overall better quality tools (4/7, 2/9, 2/2, 2/6, and 2/3) suggests that neither the cognitive nor instructional variable was significant. But, surprisingly, second grade students, even though generally at a lower cognitive level, produced better tools that the fourth grade students. Lastly, the students whose flakes showed most improvement in terms of quality, from day 1 to day 2 were studied. Based on the four students who showed the most improvement (4/23, 4/7, 4/5, and 2/6), there appears to be no significant correlation based on cognition or instruction.

To facilitate a more detailed analysis, the flakes were ordered for each student from best to worst quality (Appendix E). Then, the student's cognitive ranking, instruction group, and axe quality were considered for possible correlation. The result was that neither instruction nor cognition appeared to be a significant factor in the act of flaking (Tables 1 and 2). For example, out of the top ten flake-producers, five received no instruction, three received oral instruction, and the remaining two received demonstrations. In addition, it was noted that the top flakers among fourth grade students appeared to have above average cognitive development rankings (2, 4, 22, 19, 15, and 28, respectively), but the second grade students who ranked 34, 29, 38, and 39 were still in the top ten tool makers. In terms of related axe quality, only 1 of the 10 students produced a "good" axe, while six produced "fair" axes, and the remaining three children produced a "poor" axe. Thus, it appears possible to produce workable Oldowan tools without being able to produce workable Acheulean tools.

Table 1

Summary of Varied Instruction Effects on Oldowan Flake Tools

	Instructional Group		
Flake Quality	A	B	C
Good	1	1	3
Fair	5	3	6
Poor	8	8	4

Table 2

Summary of Cognitive Level Effects on Oldowan Flake Tools

	Cognitive Development Ranking							
Flake Quality	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-39
Good	1	0	1	0	0	3	0	0
Fair	3	2	0	2	2	1	1	3
Poor	1	3	4	3	3	1	4	1

The same process was followed with handaxes. The axes were ordered from good to poor quality in terms of shape, size and overall workability (Appendix F). Again, cognitive levels (as demonstrated by the Piagetian tests), instructional variation, and in this case, flake quality was considered (Tables 3 and 4). Here, tentative

Table 3

Summary of Varied Instruction Effects on Acheulean Handaxes

	Instructional Group		
Axe Quality	A	B	C
Good	2	2	2
Fair	6	4	4
Poor	6	6	7

Table 4

Summary of Cognitive Level Effects on Acheulean Handaxes

	Cognitive Development Ranking							
Axe Quality	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-39
Good	2	0	1	0	0	1	1	1
Fair	3	1	1	3	2	2	0	2
Poor	0	4	3	2	3	2	4	1

relationships begin to emerge. First it was noted, as it was previously, that the second grade group was capable of producing better quality tools when compared to the fourth grade group, even though they were considered to be of lower cognitive development. This was especially evident with attempted handaxe production. Eight of the eleven axe producers were second grade students, ranked 29, 13, 26, 30, 39, 38, 34, and 36 cognitively (listed in order of decreasing tool quality). The top fourth grade Acheulean tool makers, on the other hand, were ranked higher cognitively (5, 4, and 18).

When considering instruction, it was noted that the top five students (second grade) were of lower cognitive ranking and that four out of five axe makers received modeled instruction. Looking at the other end of the spectrum, it was noted that the worst tool making second graders (16, 37, 32, 31, 36, and 34, cognitively) all received oral instruction, or no instruction at all. The top fourth grade tool makers, with higher cognitive levels, were among varied instructional groups. This could potentially indicate that, in regard to a more complex form of tool making, cognition and instruction could play an interrelating role. If a person is at the cognitive level of concrete operations, instruction may not be important in acquiring the skill (Figure 5) while a person at the pre-operational level may require visual instruction to achieve the same results (Figure 6).

In addition, there does appear to be a be a potential relationship between quality axes and flakes. When examining the flakes produced by the top nineteen axe makers, five of them made flakes considered to be of "good" quality and eight made flakes classified as "fair". However, when considering the bottom twenty axe makers, only one was classified as a "good" flake maker, and six classified as "fair" flake makers. More specifically, five of the top ten axe producers made "good" quality flakes, whereas only one of the lower quality axe producers produced "good" flakes.

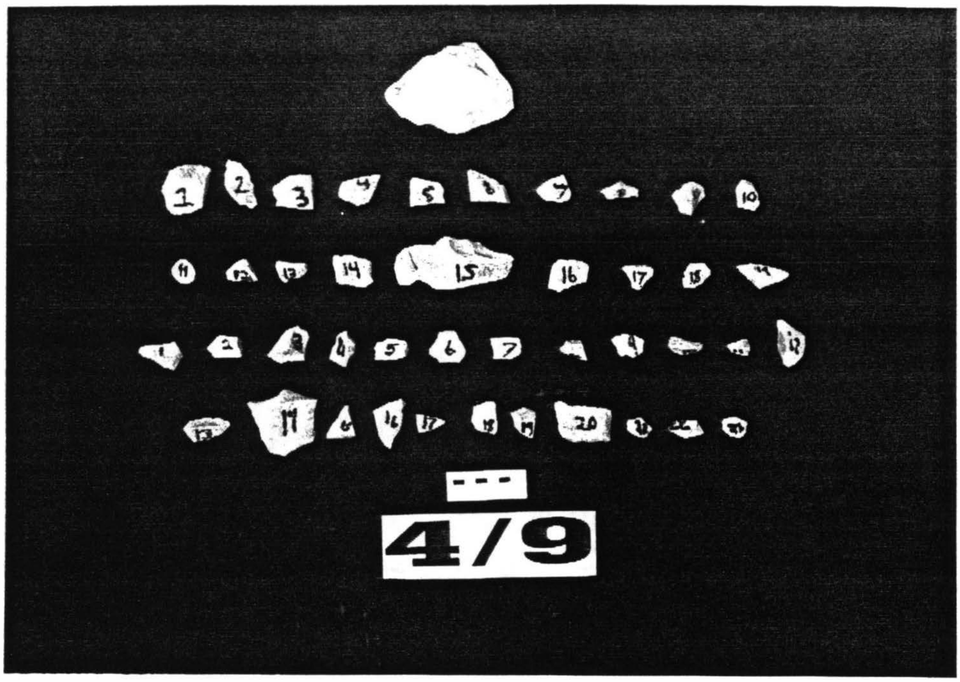


Figure 5. Tools Produced by Child With Concrete Operations Receiving No Instruction (Scale in cm).

In an effort to take into consideration remaining factors, the tools were examined with respect to grip strength, eye-hand coordination (as reflected by the paddleball results), and informational processing abilities of the tool makers. Flakes and handaxes, on both ends of the quality continuum, were ranked, and patterns between students were considered. All three variable results were classified as either average, below average, or above average. The average range for the grip test was determined to be 11-14 kg, the average range for the best of three trials of paddleball was determine to be 4-10 seconds, and the average performance on the information processing activity was determined based on overall class performance. The results,

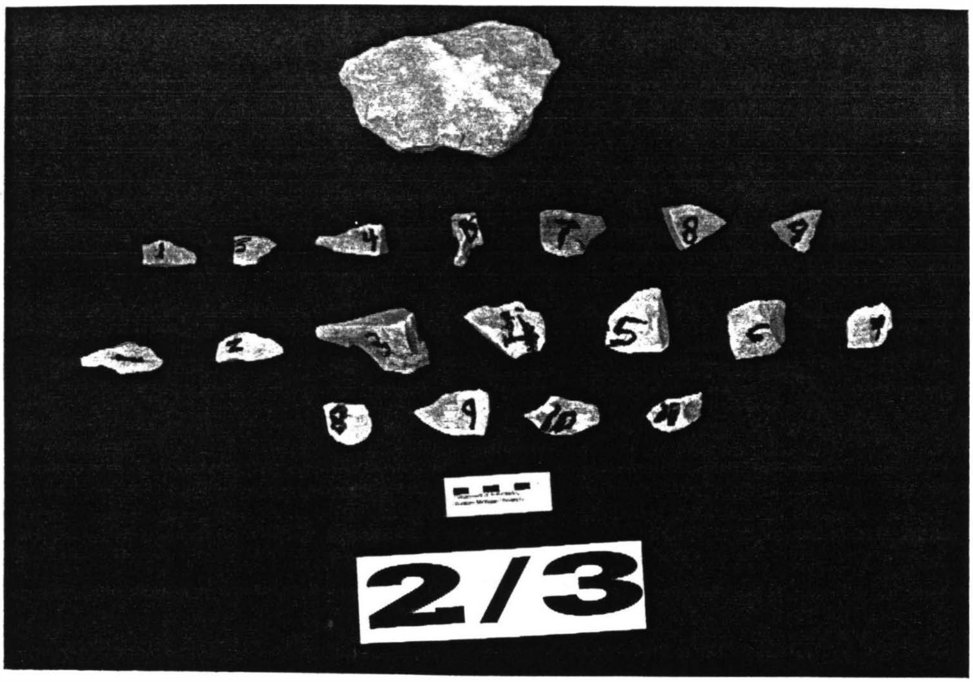


Figure 6. Tools Produced by Child With Pre-Operations
Receiving Formal Instruction (Scale in cm).

for the most part, were inconclusive (Appendix G). Strength and coordination do not appear to directly influence tool making outcomes, maybe due to the relative uniformity of these variables among the children. The data does, however, appear to indicate that information processing may play a role. Out of the ten students who produced the poorest quality flake tools, six performed below average on the information processing activity. Likewise, of the ten students producing the poorest quality handaxes, six performed below the class norm on the information processing activity. This could indicate that general informational processing abilities may play a more important role in tool making than level of cognitive development.

Summary and Discussion

There are several significant conclusions that can be drawn from this study. First, different cognition levels (namely concrete operational versus pre-operational) do not appear to impact the ability to produce Oldowan-type flake tools nor the general quality of those tools. As illustrated in Tables 2 and 4 (pp 34 and 35) students ranked in the top 15 cognitively did not produce a significantly greater number or greater percentage of quality tools (2 “good” tools) when compared to the students ranked at a lower cognitive level (3 “good” tools). In addition, this is also supported by the fact that the second grade students produced better quality tools than their fourth grade counterparts, even through most had not acquired the cognitive attributes associated with concrete operations.

Second, different instructional methods (absence versus oral versus visual demonstration) do not appear to impact the ability to produce the Oldowan-type flake tools nor the general quality of those tools. However, the results of this study do call for continued research in this area. Table 1 (p 34) shows that although the results obtained do not depict definite correlations between cognitive level and flake quality, students in instructional Group C did produce the greatest number of “good” flakes (3 out of 5) and the lowest number of “poor” flakes (4 out of 20).

Third, the results acquired from the Acheulean component of this study suggest that individuals considered to be at a pre-operational level of cognitive development appear to require visual demonstration in order to produce workable Acheulean-type tools and individuals considered to be at a concrete operational level of cognitive development appear able to produce workable Acheulean-type tools regardless of instructional technique. In other words, it is apparent that formalized instruction was not a prerequisite for quality axe production for the fourth grade students who were of concrete operations; whereas, the second grade students who were still at the level of pre-operations cognitively, produced quality axes if they were given tool making demonstrations.

What appears most contrary to other studies and conclusions (Wynn 1979, Schick and Toth 1993) is that this study appears to indicate that pre-operational individuals are able to produce the more advanced Acheulean stone tools (at least similar to the crude thick forms found at Lower Acheulean sites), if they are provided demonstrative instruction. This information leads us to formulate two tentative conclusions: (1) the Acheulean industry is not necessarily a reflection of an increased cognitive development level, and (2) a pre-operational individual living during this time period would not have been able to acquire the skill unless they came into contact with an individual who had acquired the skill and could demonstrate it. This is based on the apparent complementary relationship between visual instruction and lower cognitive levels, when producing better quality handaxes.

Fourth, this study also indicates that better axe producers tend to be better flake producers (even though the reverse is not true). This was suggested by the fact that five out of ten of the top quality axe producers made quality flakes, whereas, only one of the lower quality axe producers made quality flakes. When increasing the scope, it was also noted that five out of nineteen of the top axe makers made "good" flakes, and only one out of twenty poorest axe makers manufactured "good" flakes. This could lead to the hypothesis that the better Acheulean tool makers may have derived from the better Oldowan tool makers. Furthermore, this may indicate a continued lineage of tool production among groups in which the first Acheulean tool makers were recipients of a skill developed generations before by quality Oldowan tool makers.

Fifth, increased information processing abilities appear to correlate with an increased ability to produce quality tools. Six out of ten of the worst tool makers (both Oldowan and Acheulean) performed below average on the information processing activities. This is another area which requires further study before additional conclusions can be made.

Finally, initial explorations suggest that the two pre-operational and concrete operational students appear to prefer the instructional technique of modeling when given a choice and effects attributable to positive versus negative feedback remain inconclusive. This was determined on the final day with the students. The differentiating affects of positive and negative feedback, and the feasibility of a pre-operational individual to teach another individual were considered. Two students (4/26 and 4/22) were selected to receive different feedback. They were selected for three reasons: (1) because they appeared to be at the same tool making skill level, (2) at the same cognitive level, and (3) were both in the same instruction group (C). The student who received the positive feedback (4/26) was able to produce a slightly more utilitarian axe. However, due to the small scale of this experiment, this potential result of varied feedback is extremely speculative.

In addition, child 2/3 (pre-operational Group C) and 2/9 (concrete operational Group C) were selected to teach the skill of handaxe making to a mixture of Group A students (4/5, 4/8, 4/20). In both cases, the children found it difficult to verbally explain the steps necessary to make the tools. As a result, they decided to demonstrate their technique to the others. The other children watched intently, and then tried to replicate the technique. It did appear to aid the Group A's understanding of the technique but there was no apparent link to the cognitive level of the instructor, since both used the same method with the same success.

Thus, although this segment of the study was extremely small in scale, it could suggest that verbal instruction may not be necessary to produce stone tools, and that both pre-operational and concrete operational individuals would be capable of modeling the techniques to one another. From this we could construct a scenario in which a pre-operational hominid could transfer the skill of tool making through imitative instruction, in the same way a concrete operational hominid could, but the tools would not be of the same quality.

In summary, this research directs attention to the cognitive abilities required for two types of Stone Age technologies. Even though Wynn (1981; 1985) based his original conclusions on the earlier premise that the cores, not the flakes were the essential components of the Oldowan industry, his conclusion still appears valid. The skills required to produce the Oldowan tools are simple, and therefore do not appear to require a more progressive stage of cognitive development.

This finding is consistent with the pongid stone tool experiments conducted by Wright (1972) and Toth et al. (1993), in which an orangutan and a bonobo chimpanzee were shown to have developed flaked tool technology, even though they are not thought to employ operational concepts (Parker and Gibson 1977). Schick and Toth (1993), do , however, make an important distinction when contrasting the tools the chimpanzee was able to produce with the tools from the early Stone Age archaeological record. According to them, Kanzi (the bonobo) lacked the understanding of flaked angles that the Oldowan hominids had; he tended, instead, to bash and crunch the edges of the cores rather than to use highly controlled and forceful blows. This same "crude" method was also observed among the children in this study (of both cognitive levels). This could be thought to indicate that hominids of both cognitive levels were able to produce these early stone tools, but to produce a higher percentage of workable flakes some other mental development must occur, one that perhaps occurs with experience or with more advanced informational processing skills. However, one must be cautious when making inferences about cognition level affecting the quality of the tools when it is possible that with continued practice both the children and the pongids would be able to produce quality tools. This study reflects only the early stage of trial and error in tool manufacture. In order to substantiate the importance of cognitive ability to Oldowan manufacturing techniques and the number of quality tools produced, a longitudinal study would need to be undertaken.

Conclusion

To review, two hypotheses were tested in this study:

1. The higher a subject's level of cognitive development, the better the quality of stone tools he or she is able to produce.

2. Subjects who are able to observe stone tool making will acquire the skills necessary to produce tools at a faster rate than subjects who are just told what to do, without benefitting from observational learning.

Based on the data acquired in this study, the original hypothesis offered in this study must be rejected. The children did not acquire the skill of tool making in the order projected (Concrete Operational C, Concrete Operational B, Concrete Operational A, Pre-Operational C, Pre-Operational B, and Pre-Operational A) Cognitive development, although playing a potential role in tool production, was not a clear determinant of tool quality. In addition, instruction and cognition do appear to play a complementary part in quality handaxe production but there was no indication of earlier mastery of the skills. Nonetheless, this study does succeed in sparking interest for research into other areas of hominid stone tool evolution and behavior.

For example, this study suggests that both the "robust" australopithecines and H. habilis were capable, from a cognitive development standpoint, of producing workable stone tools at a very early stage in evolutionary history. Previous studies indicate that pongids can produce Oldowan-type flake tools, and this study reaffirms those findings—illustrating that school children at an early stage of cognitive development can not only produce Oldowan-type tools, but crude Acheulean tools as well. The question, however, remains one of quality. The tools produced by pongids and the tools produced by children do not compare, in terms of quality, with those of the Stone Age. For Australopithecus or Homo to produce the tools they did another element must have been added to the picture. It may have been: (a) more intensive formal instruction, (b) increased information processing abilities, (c) a higher degree of creativity, (d) increased cranial capacity or cranial restructuring, (e) a more efficient hand/arm anatomy, or (f) simply more leisure time devoted to trial and error. Whatever the case, it is not possible to assert that the australopithecines could not produce tools because of limited cognitive development abilities. But were they able to produce quality tools that would increase their chances of survival, and did they have the cognitive capabilities to acquire and transmit the more complex skills of stone tool production? At this point, a definite answer can not be provided.

In conclusion, this study opens the door for much needed additional research in the area of children's stone tool making capabilities. Non-human primate studies have contributed a great deal to our understanding of hominid stone tool use, but until this time the value of children as models has been largely overlooked. Children provide an unprecedented opportunity to study stone tool manufacture at a different stage of cognition, a different level of creativity; while at the same time allowing the researcher to ask questions and interact more directly with the subjects.

Recommendations for further studies would include a longitudinal study, taking into consideration the same variables employed in this preliminary study. It would be valuable to determine if children take longer to acquire the skills than adults, and if so, could this be attributed to differences in cognitive development? This could provide insight into the time it took these early hominids to acquire the skills for both industries. Furthermore, although this study did not yield significant morphological differences attributed to instruction or intelligence, it is possible that such differences would appear in an extended study. Further work needs to be done on determining under what conditions pre-operational children acquire the ability to make Acheulean tools, as well as the morphological effects of widely varied strength and eye-hand coordination and additional impacts of information processing abilities. Another facet worth exploring is that second grade students seem to do better, at least initially, in stone tool making than older children. This suggests the factor of creativity. As children grow older and progress through the educational system,. manual creativity is constrained by the urge to conform. This could indicate that younger children, because they are able to demonstrate unrestrained creativity, are better able to produce quality tools at a faster rate. All of this indicates that the potential for additional research in this area is vast, and it is my hope that this study initiates continued work by paleoanthropologists. The questions surrounding,hominid stone tool production continue to exist, but our culture and technology originates with this period in time, and to completely understand who we are today we must continue to search for answers to these questions.

Appendix A

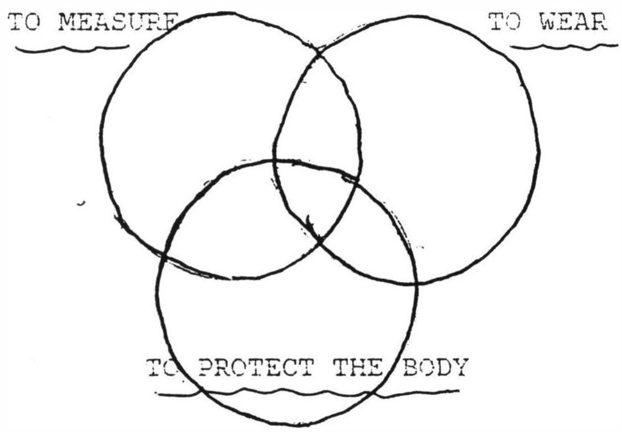
Informational Processing Worksheet

NAME________________________________

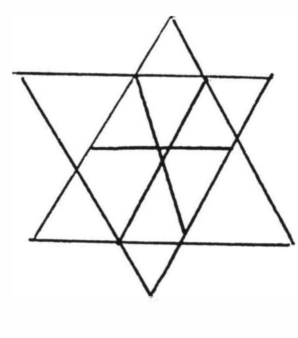
1. IF SUE DOES BETTER THAN RON ON A TEST, AND PETE DOES BETTER THAN SUE, WHO DID THE BEST? ______________________

2. GROUP THE FOLLOWING OBJECTS ACCORDING TO WHAT THEY DO. USE THE OVERLAPPING AREAS TO SHOW THAT SOME OBJECTS DO MORE THAN ONE THING.

- -Scale
- -Stick
- -Shoes
- -Jewelry
- -Umbrella
- -Raincoat



3. HOW MANY TRIANGLES ARE IN THIS FIGURE?



4. COMPLETE THIS PATTERN OF NUMBERS:

1, 4, 7, 10, 13, ___, ___, ___, ...

5. LIST THE POSSIBLE WAYS TO GROUP THESE OBJECTS, AND WRITE DOWN THE OBJECTS THAT WOULD BELONG TO EACH GROUP:

mirror, marshmallow, soap, marble, paper clip, sugar cube, peanut, hair roller, pine cone, pencil, hamburger

HOW?_______________ HOW?_______________

_______________ _______________
_______________ _______________
_______________ _______________
_______________ _______________
_______________ _______________

HOW?_______________ HOW?_______________

_______________ _______________
_______________ _______________
_______________ _______________
_______________ _______________
_______________ _______________

6. IN THIS SPACE, DRAW A MAP OF YOUR SCHOOL, AND SHOW THE PATH FROM THE FRONT DOOR TO YOUR CLASSROOM:

STOP-PUT YOUR PENCILS DOWN, AND WAIT FOR THE MEMORY QUESTION!

7.

Appendix B

Parental Consent Form

WESTERN MICHIGAN UNIVERSITY

Department of Anthropology

Principal Investigator-Dr. Tal Simmons

Research Assistant-Jill S. McCleary

I understand that my child has been invited to participate in a research project entitled "Children's stone tool making capabilities: Implications for hominid intelligence models and skill acquisition theory". The purpose of the study is to determine whether or not factors such as cognitive development, reinforcement, and teaching techniques affect how people make stone tools. I further understand that the purpose of this project is to fulfill Jill McCleary's M.A. thesis requirement.

My consent for my child to participate in this project means that beginning in March and continuing into May, my child will have the opportunity to take part in four one hour experimental sessions in which he/she will get to make stone tools, like those thought to be associated with the early Stone Age. Prior to these sessions, my child will be asked to respond to a few experimental situations so that the research may determine his/her current stage of cognitive development, and their current strength and coordination. These situations will be based on Piaget's theory of cognitive development, and will involve my child moving from station to station drawing pictures from different perspectives, counting colored beads, and answering questions about which ball of clay or which glass of water is larger. In addition, as the study progresses, pictures may be taken of my children's hands while working with the tools. Throughout these sessions, my child will be supervised by both the classroom teacher, and the researcher who is a certified secondary teacher (Mrs.

McCleary). Youngsters are free at anytime to choose not to participate. If my child refuses or quits, there will be no negative effect on his/her school programming and no negative effect upon academic evaluations/activities. I also understand that there are benefits to my child for participating. Not only will my child learn about the early Stone Age and the tools used, but the researcher/teacher has agreed to provide mini-lessons on Stone Age archaeology throughout the research period. These lessons will include slides of Kenya, and a discussion of interesting fossils, and chimpanzee social behavior.

I also understand that all test data will remain confidential. That means that my youngster's name will be omitted from all test forms and a code number will be attached. A separate list of all the youngster's names and corresponding codes will be kept in a locked file, and this list will be destroyed six months after the experiment. No names will be used if the results are published or reported at a professional meeting.

I understand that the risks include minor physical injury as a result of working with stones. I understand the researcher has taken many precautions to minimize this risk. These include requiring that all students must wear heavy gloves that fit, safety goggles, shoes, socks, long sleeved shirts and long pants. The students will all work in well ventilated areas and will be required to stand a minimum of seven feet from each other while knapping(making stone tools). A raw material that is not very sharp was also chosen for safety reasons. As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however no compensation or treatment will be made available to my child except as otherwise stated on this consent form.

I understand that I may also withdraw my child from this study at any time without any negative effect on services to my youngster. If I have any questions about this study I may contact Jill McCleary at 392-3517. I may also contact the Chair of Human Subjects Institutional Review Board or the Vice President for Research with any concerns I have at (616) 387-8293.

My signature below indicates that I give my permission for____________________ (Child's Name) to take part in this anthropology experiment, in which he/she will make stone tools in the classroom, respond to cognitive development experiment questions, and have his/her hands photographed with tools.

Signature____Date_________

Appendix C

Subject Assent Form

WESTERN MICHIGAN UNIVERSITY
DEPARTMENT OF ANTHROPOLOGY
Principal Investigator-Dr. Tal Simmons
Research Assistant-Jill S. McCleary

I understand that I have been asked to take part in Mrs. McCleary's "Stone Tool Experiment". During this experiment, we will be making stone tools in order to learn more about how people a long, long time ago made tools and learned about tools from each other.

I understand that if I agree, I will first be asked to answer some questions based on mini-experiments. Then, for four one-hour sessions in April I will be actually making stone tools. During these days, I will need to dress in long sleeve shirts and long pants. Mrs. McCleary will also make sure we are wearing goggles and gloves.

I understand that if I choose to participate, I will not get any extra credit, and if I don't wish to participate, there will be no effect on my school grades. And even if I agree today to take part in this study by signing this form, I can change my mind any time during the experiment.

I understand that my name will not be on any forms, and a code number will be used instead. The list with names and code numbers will be destroyed six months after the experiment.

If I have any questions or concerns about this study, I may contact Mrs. McCleary at 392-3517 (home), Dr. Tal Simmons at 387-3973, or the Human Subjects Institutional Review Board at 387-8293.

My signature below means that I agree
1) To take part in the beginning mini experiments
2) To take part in the stone tool making experiments
3) To have my hands photographed while making tools

Print name here____________________Today's Date__________

Sign name here______________________________

Appendix D

Piagetian, Grip and Paddleball Test Results

Appendix D

Piagetian Grip and Paddleball Test Results

Student ID	Clay Test 1	Water Test 2	Coins Test 3	Cups Test 4	Beads Test 5	Straws Test 6	Paddleball (seconds)	Grip (kg)	Cognitive Development
2/1	P	P	C	P	C	P	3	11	31
2/2	C	P	U	C	P	P	2	12	29
2/3	P	U	P	P	P	P	2	15	39
2/4	U	P	U	C	P	P	5	25	25
2/5	U	P	C	C	P	P	5	11	26
2/6	P	U	C	P	P	P	3.5	13	34
2/7	U	U	U	P	C	P	3	10	30
2/8	P	U	U	P	P	P	2	11	37
2/9	U	C	P	P	C	C	3	12	13
2/10	P	P	C	P	P	P	4.5	15	38
2/11	P	C	C	C	P	P	4	14	16
2/12	P	U	U	P	P	P	3	11	36
2/13	P	C	C	P	P	P	4	15	32

Appendix D —Continued

Student ID	Clay Test 1	Water Test 2	Coins Test 3	Cups Test 4	Beads Test 5	Straws Test 6	Paddleball (seconds)	Grip (kg)	Cognitive Development
4/1	P	U	U	C	C	P	4	14	18
4/2	U	U	U	C	P	U	4	17	21
4/3	P	U	U	C	P	P	2	20	24
4/4	P	U	C	C	C	C	5	14	7
4/5	P	P	C	U	P	P	5	17	33
4/6	C	C	C	C	P	C	1	17	3
4/7	C	C	C	C	P	C	14	20	4
4/8	C	U	C	C	C	P	2	21	6
4/9	C	C	U	P	P	P	8	18	28
4/10	C	U	C	C	P	P	3	16	12
4/11	U	C	U	P	C	P	0	16	20
4/12	C	U	U	C	C	U	2	18	11
4/13	C	U	C	U	C	C	4	21	5
4/14	C	U	C	C	C	C	2	18	1
4/15	C	P	C	C	P	U	1	16	14

Appendix D—Continued

Student ID	Clay Test 1	Water Test 2	Coins Test 3	Cups Test 4	Beads Test 5	Straws Test 6	Paddle Ball (seconds)	Grip (kg)	Cognitive Development
4/16	U	U	C	C	P	P	7	17	19
4/17	P	U	C	C	P	P	9	15	23
4/18	P	P	C	C	P	C	4	21	15
4/19	P	U	C	C	P	P	6	23	22
4/20	P	U	C	C	P	U	4	19	27
4/21	U	U	C	C	P	P	2	17	7
4/22	C	C	C	C	P	P	5	22	9
4/23	C	U	C	C	C	C	3	18	2
4/24	C	C	C	P	C	P	3	17	10
4/25	P	U	C	P	P	P	2	18	35
4/26	C	C	C	C	P	P	5	20	8

Appendix E

Ranking of Oldowan Flake Tools and Variable Comparisons

Appendix E

Ranking of Oldowan Flake Tools and Variable Comparisons

	Student ID	Cognitive development ranking	Axe quality	Instructional method group
1	4/23	2	Poor	B
2	2/16	34	Fair	A
3	4/7	4	Fair	B
4	4/19	22	Fair	B
5	4/16	19	Poor	C
6	4/18	15	Poor	A
7	2/2	29	Good	A
8	4/9	28	Fair	A
9	2/10	38	Fair	A
10	2/3	39	Fair	C
11	4/4	7	Poor	C
12	2/11	16	Poor	B
13	2/9	13	Good	C
14	2/7	30	Good	C
15	4/24	10	Poor	B
16	4/11	20	Poor	A
17	4/13	24	Poor	B
18	4/25	35	Poor	A
19	2/12	36	Fair	A
20	4/13	5	Good	B
21	4/2	21	Fair	C
22	4/1	18	Fair	C

Appendix E—Continued

	Student ID	Cognitive development ranking	Axe quality	Instructional method group
23	4/14	1	Fair	A
24	4/6	3	Fair	B
25	4/5	33	Poor	A
26	4/10	12	Poor	A
27	4/20	27	Poor	A
28	4/8	6	Poor	A
29	2/5	26	Good	C
30	4/22	9	Fair	C
31	2/8	37	Poor	B
32	4/17	23	Poor	C
33	4/15	14	Poor	B
34	4/21	17	Fair	C
35	4/12	11	Poor	C
36	2/13	32	Poor	B
37	4/26	8	Fair	C
38	2/1	31	Poor	A
39	2/4	25	Poor	B

Flakes ranked according to quality and workability.

A = No instruction
B = Verbal instruction
C = Modeled instruction

Appendix F

Ranking of Acheulean Handaxe and Variable Comparisons

Appendix F

Ranking of Acheulean Handaxes and Variable Comparisons

	Student ID	Cognitive development ranking	Flake quality	Instructional method group
1	2/2	29	Good	A
2	2/9	13	Good	C
3	2/5	26	Poor	C
4	2/7	30	Fair	C
5	2/3	39	Good	C
6	4/13	5	Fair	B
7	2/10	38	Fair	A
8	4/7	4	Good	B
9	4/1	18	Poor	C
10	2/6	34	Good	A
11	2/12	36	Fair	A
12	4/19	22	Fair	B
13	4/21	7	Poor	C
14	4/26	8	Poor	C
15	4/9	28	Fair	A
16	4/4	1	Fair	A
17	4/22	9	Poor	C
18	2/4	25	Poor	B
19	4/6	3	Fair	B
20	2/1	31	Poor	A
21	4/2	21	Fair	C
22	4/24	10	Poor	B

Appendix F—Continued

	Student ID	Cognitive development ranking	Flake quality	Instructional method group
23	2/13	32	Poor	B
24	4/5	33	Poor	A
25	4/12	11	Poor	C
26	4/3	24	Poor	B
27	4/8	6	Fair	A
28	4/4	7	Good	C
29	2/8	37	Poor	B
30	4/20	27	Poor	A
31	2/11	16	Fair	B
32	4/10	12	Poor	A
33	4/17	23	Poor	C
34	4/18	15	Fair	A
35	4/16	19	Fair	C
36	4/25	35	Poor	A
37	4/15	14	Poor	B
38	4/11	20	Poor	A
39	4/23	2	Good	B

Axes ranked according to quality and workability.

Appendix G

Strength, Coordination, and Informational Processing
Variable Comparison

Appendix G

Strength, Coordination, and Informational Processing Variable Comparison

	Student ID	Grip	Eye-hand	Informational processing
Top 10 — Oldowan Flakes				
1	4/23	Average	Below	Above
2	2/6	Average	Average	Below
3	4/7	Above	Average	Average
4	4/19	Above	Average	Average
5	4/16	Average	Average	Below
6	4/18	Above	Average	Average
7	2/2	Average	Average	Above
8	4/9	Average	Average	Average
9	2/10	Average	Average	Below
10	2/3	Above	Below	Below
Bottom 10 — Oldowan Flakes				
39	2/4	Above	Average	Average
38	2/1	Average	Below	Average
37	4/26	Above	Average	Below
36	2/13	Above	Average	Below
35	4/12	Average	Below	Below
34	4/21	Average	Below	Below
33	4/15	Average	Below	Below
32	4/17	Average	Above	Below
31	2/8	Average	Below	Average
30	4/22	Above	Average	Average

Appendix G—Continued

Top 10 — Acheulean Handaxes

1	2/2	Average	Below	Above
2	2/9	Average	Average	Average
3	2/5	Average	Average	Average
4	2/7	Average	Below	Below
5	2/3	Above	Average	Below
6	4/13	Above	Average	Average
7	2/10	Average	Average	Below
8	4/7	Above	Above	Average
9	4/1	Average	Average	Average
10	2/6	Average	Below	Below

Bottom 10 — Acheulean Handaxes

39	4/23	Average	Below	Above
38	4/11	Average	Below	Below
37	4/15	Average	Below	Below
36	4/25	Average	Below	Below
35	4/16	Average	Average	Below
34	4/18	Above	Average	Average
33	4/17	Average	Average	Below
32	4/10	Average	Below	Average
31	2/11	Average	Average	Average
30	4/20	Above	Average	Below

Appendix H

Human Subjects Institutional Review Board Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: March 22, 1994

To: Jill McCleary

From: M. Michele Burnette, Chair

Re: HSIRB Project Number 94-02-05

This letter will serve as confirmation that your research project entitled "Children's tool-making capabilities: Implications for hominid intelligence models and skill acquisition theory" has been **approved** under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

You must seek reapproval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: March 22, 1995

xc: Simmons, Anthro.

BIBLIOGRAPHY

Anderson, J., Williamson, E., & Carter, J. (1983). Chimpanzees of Sapo Forest, Liberia: Density, stone tools and meat-eating. Primates, 24, 594-601.

Bard, K. (1990). "Social tool use" by free-ranging orangutans: A piagetian and developmental perspective on the manipulation of an animate object. In S. Parker & K. Gibson (Eds.), Language and intelligence in monkeys and apes: Comparative developmental perspectives (Chap. 13, pp. 356-378). New York: Cambridge University Press.

Boesch, C., & Boesch, H. (1981). Sex differences in the use of natural hammers by wild chimpanzees: A preliminary report. Journal of Human Evolution, 10, 585-593.

Boesch, C., & Boesch, H. (1984). Mental map in wild chimpanzees: An analysis of hammer transports for nut cracking. Primates, 25(2), 160-170.

Chevalier-Skolnikoff, S. (1989). Spontaneous tool use and sensorimotor intelligence in cebus compared with other monkeys and apes. Behavioral and Brain Sciences, 12, 561-627.

Gibson, K. (1990a). New perspectives on instincts and intelligence: Brain size and the emergence of hierarchical mental constructional skills. In S. Parker & K. Gibson (Eds.), Language and intelligence in monkeys and apes: Comparative developmental perspectives (Chap. 3, pp. 97-128). New York: Cambridge University Press.

Gibson, K. (1990b). Tool use, imitation, and deception in captive cebus monkeys. In S. Parker & K. Gibson (Eds.), Language and intelligence in monkeys and apes: Comparative developmental perspectives (Chap. 7, pp. 205-218). New York: Cambridge University Press.

Holloway, R. (1974). The casts of fossil hominid brains. Scientific American, 231(1), 106-114.

Holloway, R. (1976). Early hominid endocasts: Volumes, morphology and significance for hominid evolution. In Primate functional morphology and evolution (pp. 393-416). Chicago: Distributed in the USA and Canada by Aldine.

Isaac, G. L. (1978). The food-sharing behavior of protohuman hominids. Scientific American, 238(3), 90-108.

Jolly, A. (1985). The evolution of primate behavior (pp. 345-460). New York: Macmillian.

Jordan, C. (1982). Object manipulation and tooluse in captive pygmy chimpanzees (Pan paniscus). Journal of Human Evolution, 11(1), 35-39.

King, B. (1991). Social information transfer in monkeys, apes and hominids. Yearbook of Physical Anthropology, 34(2), 97-115.

McBeath, N, & McGrew, W. C. (1982). Tools used by wild chimpanzees to obtain termites at Mt. Assirik, Senega: The influence of habitat. Journal of Human Evolution, 11(1), 65-72.

McGrew, W. C. (1992). Chimpanzee material culture: Implications for human evolution. New York: Cambridge University Press.

Nishida, T., & Hiraiwa, M. (1982). Natural history of a tool-using behavior by wild chimpanzees in feeding upon wood-boring ants. Journal of Human Evolution, 11 (1), 73-99.

Parker, S. (1990a). Origins of comparative developmental evolution studies of primate mental abilities. In S. Parker & K. Gibson (Eds.), Language and intelligence in monkeys and apes: Comparative developmental perspectives (Chap. 1, pp. 3-64). New York: Cambridge University Press.

Parker, S. (1990b). Why big brains are so rare: Energy costs of intelligence and brain size in anthropoid primates. In S. Parker & K. Gibson (Eds.), Language and intelligence in monkeys and apes: Comparative developmental perspectives (Chap. 4, pp. 129-154). New York: Cambridge University Press.

Parker, S., & Gibson, K. (1977). Object manipulation, tool use and sensorimotor intelligence as feeding adaptions in cebus monkeys and great apes. Journal of Human Evolution, 6, 623-641.

Parker, S., & Poti, P. (1990). The role of innate motor patterns on ontogenetic and experiential development of intelligent use of sticks in cebus monkeys. In S. Parker & K. Gibson (Eds.), Language and intelligence in monkeys and apes: Comparative developmental perspectives (Chap. 8, pp. 219-243). New York: Cambridge University Press.

Piaget, J., & Inhelder, B. (1969). The psychology of the child (Chap. 2, pp. 28-35). New York: Basic Books.

Povinelli, D., Boysen, S., & Nelson, K. (1990). Inferences about guessing and knowing by chimpanzees, Journal of Comparative Psychology, 104(3), 203-210.

Rosenthal, T., & Zimmerman, B. (1978). Social learning and cognition (pp. 1-87). New York, San Francisco, London: Academic Press.

Shick, K., & Toth, N. (1993). Making silent stones speak: Human evolution and the dawn of technology. New York: Simon and Schuster.

Sugiyama, Y., Fushimi, T., Sakura, O., & Matsuzawa, T. (1993). Hand preference and tool use in wild chimpanzees. Primates, 34(2), 151-159

Sumita, K., Kitanara-Frisch, J., & Norikoshi, K. (1985). The acquisition of stone-tool use in captive chimpanzees. Primates, 26(2), 168-181.

Susman, R. (1991). Who made the oldowan tools?: Fossil evidence for tool behavior in plio-pleistocene hominids. Journal of Anthropological Research, 47(2), 129-151.

Tobias, P. (1971) The brain in hominid evolution (pp. 11-61, 96-116, & 134-152). New York: Columbia University Press.

Tobias, P. (1987). The brain of Homo habilis: A new level of organization in cerebral evolution. Journal of Human Evolution, 16(1), 171-761.

Toth, N. (1985) The Oldowan reassessed: A close look at early stone artifacts. Journal of Archaeological Science, 12(3), 101-120.

Toth, N. (1987) The first technology. Scientific American, 256(4), 112-121.

Toth, N., Shick, K., Savage-Rumbaugh, S., Sevcik, R., & Rumbaugh, D. (1993). Pan the tool-maker: Investigations into the stone tool-making and tool-using capabilities of a bonobo (Pan paniscus). Journal of Archaeological Science, 20(1), 81-91

Vauclair, J., & Bard, K. (1983). Development of Manipulations with objects in ape and human infants. Journal of Human Evolution, 12(1), 631-645.

Washburn, S. L. (1959) Speculations on the interrelations of the history of tools and biological evolution. Human Biology, 31(1), 21-31.

Washburn, S. L. (1960). Tools and human evolution. Scientific American, 203,(3) 63-75.

Washburn, S. L., & Moore, (1974). Ape into man: A study of human evolution (pp. 61-82, & 155-191). Boston, MA: Little, Brown & Co.

Wells, L. (1959) 'Human', 'hominine', 'hominid'. Man, 59(1), 30-31.

Westergaard, G.C., & Suomi, S. (1994). The use and modification of bone tools by capuchin monkeys. Current Anthropology, 35(1), 75-77.

Wright, R. (1972). Imitative learning of a flaked stone technology—The case of an orangutan. Mankind, 8(4), 296-306.

Wynn, T. (1979). The intelligence of later Acheulean hominids. Man, 14(1), 371-391.

Wynn, T. (1981). The intelligence of Oldowan hominids. Journal of human evolution, 10(1), 529-541.

Wynn, T. (1985). Piaget, stone tools and the evolution of human intelligence. World Archaeology, 17(1), 31-43.

Wynn, T. (1991). Archaeological evidence for modern intelligence (Chap. 4, pp. 52-65). In R. A. Foley (Ed.), The origins of human behavior. Boston, MA: Unwin Hyman.

Wynn, T., & McGrew, W. C. (1989). An ape's view of the oldowan. Man, 24(1), 383-398.