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THE EFFECTS OF VOCATIONAL SPECIALIZATION AND CONTENT
FAMILIARITY ON FORMAL OPERATIONAL PERFORMANCE

City University of New York

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The Effects of Vocational Specialization
and Content Familiarity
on Formal Operational Performance

by

Kimberly Kinsler

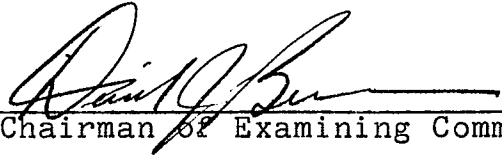
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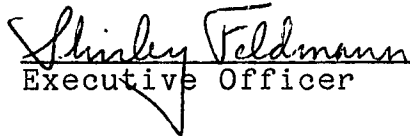
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Abstract

The Effects of Vocational Specialization
and Content Familiarity
on Formal Operational Performance

by

Kimberly Kinsler

Adviser: Professor David Bearison

This study investigated formal operational performance on problem solving tasks using materials familiar to subjects' vocational specialization. Subjects were 60-male vocational high school carpentry and electrical wiring majors. Three formal operational reasoning tasks were administered. Each required an isolation and control of variables (ICOV) strategy for solution. One task was an adaptation of Inhelder and Piaget's (1958) rod flexibility task. The other two tasks were experimenter designed, each reflecting one subject groups' area of vocational specialization. A series of six prompts, which gradually revealed and modelled the ICOV strategy, was administered to those subjects who failed to spontaneously evidence full formal reasoning on each of the two vocational tasks. It was hypothesized that subjects would obtain higher stage level scores and would require fewer prompts to demonstrate full formal reasoning on the reasoning task of a vocationally familiar content.

It was found that the vocationally trained subjects performed as well, or better on the rod flexibility task than on the two vocational tasks. In addition, task content familiarity was found to have both facilitative and inhibitory effects on operational performance and prompt utilization depending on subjects' previous experience with the content materials. Previous training in electrical wiring classes provided both subject samples with strategies for use with the wiring task materials which were similar to the ICOV strategy. As a result, subjects' operational performance and prompt utilization needs were facilitated. However, previous training in carpentry classes differentially provided both subject samples with perceptual and behavioral strategies that were incompatible with ICOV use on the carpentry task. As a result, subjects' operational performance and prompt utilization needs were inhibited. The inhibitory effects of previous training in carpentry were even found among subjects who had previously demonstrated formal operational ability on other problem solving tasks. Subjects' prompt utilizations needs were also found to be related to their most advanced operational performance.

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INTRODUCTION

In The Growth of Logical Thinking from Childhood to Adolescence, Inhelder and Piaget (1958) postulated formal operations as the last stage of cognitive development in all normal adults. Subsequent to this publication, several researchers sought to substantiate, refute, or simply clarify aspects of formal operational development. Much of this research was unsupportive, however, and criticized Inhelder and Piaget's (1958) formulation on three grounds: lack of universal appearance of the stage, lack of consistent evidence of a unitary structure or factor of formal operations, and lack of consistent generalizeability of formal operational behavior. In response to these criticisms, Piaget (1972) modified several aspects of the earlier, 1958, formulation. The present study seeks to test the 1972 reformulation of formal operational theory to arrive at a better understanding of factors affecting the development and application of formal reasoning.

In order to understand the 1972 reformulation and the relative contribution of the present work, it is necessary to place formal operations within the context of Piaget's general theory of cognitive development. Toward this end, the first section of this work describes the general characteristics of formal operations and traces its roots in earlier stages of cognitive development. In the second section, early research bearing on the 1958 formulation and Piaget's subsequent response are reviewed. Finally, research after the 1972 reformulation is summarized.

Piaget's Theory of Formal Operations

...formal thinking is essentially hypothetical deductive. ...deduction no longer refers directly to perceived reality, but to hypothetical statements, i.e., it refers to propositions which are formulations of hypothesis, or which postulate facts or events independently of whether they actually occur.... This type of thinking proceeds from what is possible to what is empirically real.... The most distinctive property of formal thinking is (this) reversal of direction between reality and possibility. (Inhelder and Piaget, 1958, p.251)

In their original treatise on the stage of formal operations, Inhelder and Piaget (1958) reported that between the ages of 11 and 15 years, the cognitive functioning of individuals is characterized by the development of a combinatorial system. This system is composed of a lattice structure and a representation of the Klein group of four transformations. The elements of this transformational group consist of identity, negation, correlativity, and reciprocity (INCR). The lattice structure enables the formal reasoner to systematically generate all possible subsets, or "n" by "n" combinations of "n" variables. For example, given two variables, p and q, formal reasoners not only generate a four-fold table (p.q, p.q̄, p̄.q, p̄.q̄), they also generate all combinations of these groupings (o, p.q, p.q̄, p̄.q, p̄.q̄, p.q + p.q̄, p.q + p̄.q, p.q + p̄.q̄, p.q̄ + p̄.q, p.q̄ + p̄.q̄, p̄.q + p̄.q̄, p.q + p.q̄ + p̄.q, p.q + p.q̄ + p̄.q̄, p.q + p̄.q + p̄.q̄, p.q̄ + p̄.q + p̄.q̄, p.q̄ + p̄.q̄ + p̄.q̄, p.q + p.q̄ + p̄.q̄ + p̄.q̄). The 4-group enables the formal reasoner to understand the logical relations between propositions generated by the

combinatory system. Together, lattice and transformational structures enable the formal reasoner to evidence reasoning that is at once hypothetically deductive and abstract.

Formal operational structures are gradually constructed by individuals through a series of transformations rooted in earlier stages of development. According to Piaget (1960, 1969) precursory structures to formal operations are in evidence in both infancy and childhood. During infancy, individuals construct a sensori-motor intelligence, or, an intelligence of action (Piaget, 1968, 1969). For example, by the age of 18 months, toddlers evidence behaviors which reflect both a sensori-motor logic of classes, exemplified by a hierarchical organization of schemes of action (e.g., pulling a coverlet to grasp a rattle which lay on top of it), and a sensori-motor logic of relations, exemplified by the stacking and nesting of rings or boxes. In addition, infants demonstrate a rudimentary understanding of spatial relations and the reversibility of certain kinds of trajectories. Throughout childhood, individuals elaborate more advanced precursors to formal operations. The operational structures which result are more complex class and relational organizations. Piaget (1960, 1970) stated that during this period, individuals elaborate a concrete operational logic of classes (enabling them to perform hierarchical classification) and a concrete operational logic of relations (enabling them to seriate inequalities). However, these systems at best constitute only "semi-lattices" or "groupings" because they are unable to

combine as a single system. The development of concrete operations begins around the age of two and continues through the eleventh year. Although it constitutes an advance over sensori-motor intelligence, concrete operational intelligence is limited by its applicability to cognitive transformations of experienced reality into classificatory and relational schemes. The final step in the evolution of intelligence is the elaboration of formal operations. At this point, the previously described structured whole, or group emerges encompassing all the partial fields of concrete operations and coordinates them into a single system.

Consistent with an organismic model, Piaget did not posit particular environmental events which motivate or direct evolution towards formal operational functioning. He asserted that organisms naturally seek to maintain a balance or dynamic equilibrium between external environmental forces and internal organismic forces. In the maintenance of this dynamic equilibrium, structural perturbation, or disequilibrium is resolved through a process of reequilibration. During reequilibration, subjects may create novel cognitive structures and coordinations of actions out of preexisting coordinations. With each successive constructive reorganization (or stage of development), cognitive structures attain higher forms of equilibrium as they achieve greater interconnectedness between elements of the whole, and the mechanisms of thought become increasingly dissociated from content. Thus in

seeking equilibrium, structural systems inherently evolve toward organizations characteristic of the stage of formal operations.

In their 1958 work, Inhelder and Piaget outlined 15 problem solving tasks used to assess formal operational reasoning. In several of these tasks subjects were asked to determine which of a number of possible factors influenced some observed effects, e.g., the flexibility of a set of metal rods, or the rate at which a pendulum swings. Subjects were to postulate the possible independent variables and systematically devise proofs to test the validity of each hypothesized, independent variable. To produce tests that were at once scientifically unconfounded and rigorous, subjects were to generate all possible combinations of the hypothesized variables and systematically control all but the variable(s) under investigation. According to Inhelder and Piaget (1958), these problem solving strategies were spontaneously evidenced by all formal reasoners regardless of the experienced reality of the tasks' content.

After Inhelder and Piaget's original treatise (1958), several researchers studied the incidence of formal operations and the outlined characteristics of formal operational structure in age appropriate populations. A review of this literature follows.

REVIEW OF LITERATURE

Early Research

After the publication of The Growth of Logical Thinking from Childhood to Adolescence, much of the succeeding research criticized Inhelder and Piaget's concept of formal operations on three grounds:

(1) According to Elkind (1961), Piaget reported that Genevan children attained full formal functioning in 75 percent of the cases sampled. However, several studies (Jackson, 1963; Dulit, 1972; Tomlinsen-Keasey, 1972; Luria, 1976; and Cole, Gay, Glick, and Sharp, 1971) were unable to replicate these findings. These studies showed a smaller percentage of formal operational behavior in some samples and virtually none in others. Using some combination of Inhelder and Piaget's (1958) 15 formal operational reasoning tasks, the majority of western studies (Jackson, 1963; Dulit, 1972; and Tomlinsen-Keasey, 1972) seldom found that more than 50 percent of the subjects tested performed at the combined early and advanced formal levels. When task performance was restricted to full formal functioning, this statistic seldom exceeded 30 percent. Cross cultural studies sampling the reasoning strategies of rural Russian peasants (Luria, 1976, 1980) and Liberian tribespeople (Cole, 1971) found an absence of formal operational functioning in many older adolescents and

adults. These studies, which presented subjects with problems requiring syllogistic reasoning (which requires propositional logic for proper solution) found rural, uneducated adults generally unable to correctly respond to these verbal problems. Thus, the above cross cultural and western research supported Dulit's (1972) conclusion that fully developed formal stage thinking seems to be far from commonplace among normal adolescents and adults, and appears in only a modest proportion of the population.

(2) Research by Jackson (1963), Neimark (1970), and Ross (1973), found that many subjects who attained formal operational functioning failed to evidence behavior consistent with the presence of a unitary factor or an integrated structure of formal operations. This contrasts with Inhelder and Piaget's (1958) notion that formal operational structures exist as an organized whole whose various operations are revealed by subjects' performance on one or more of the 15 problem solving tasks. Performance on these tasks should be highly intercorrelated. The above researchers, using various combinations of these classical tasks, found that subjects failed to exhibit consistent use of formal reasoning strategies across the various tasks. Ross (1973) concluded that a unified factor of formal operational thinking failed to emerge and thus, "present and previous findings question the assertion that formal Piagetian tasks are measuring a singular dimension" (p. 175).

(3) Several cross cultural and western studies also cast doubt on the dissociation of formal operational thought from its specific or experienced content and the resultant generalizability of these strategies across content domains. Luria (1976, 1980) found a failure in many rural Russian peasants to go beyond the experienced realities to respond to syllogisms. Many of the subjects stated that as they had never been in, or experienced the particular situation, they could not possibly know the answer to the problem. In two related studies of concrete operations which examined object categorization, Maccoby and Modiano (1966) and Greenfield, Reich and Olver (1966) found that Mexican adolescents and older Eskimo children were seldom able to group objects on an abstract, symbolic basis. Greenfield et al (1966) concluded that these subjects faced a problem in overcoming the embeddedness of objects in particular settings. Western research by Bart (1971), which investigated cross content generalization, found poor intercorrelations between four Piagetian tasks and three, structurally parallel reasoning tasks in three content areas (biology, history and literature). Together, these findings suggested that the dissociation of formal thought from its specific content was not always found among adolescent and adult populations.

Many of these early researchers looked for environmental and organismic factors to account for the inconsistent appearance of abstract reasoning characteristic of formal operations. Research which investigated environmental factors focused on the effects of

technological, or institutional differences between cultures which led to cognitive constructions or reorganizations of a more abstract nature (Bruner, 1966; Vygotsky, 1968; and Luria, 1976). Much of this literature emphasized experience with western modes of schooling (Goodnow, 1962; Goodnow and Bethune, 1966; Bruner, 1966; and Maccoby and Modiano, 1966) and advanced levels of schooling (Ross, 1973; and Tomlinsen-Keasey, 1972) as factors associated with an increase in the appearance of abstract thought. Research which investigated organismic factors primarily focused on the effects of I.Q. (Goodnow and Bethune, 1966) and sex differences (Dulit, 1972). These studies found that advanced mental age (MA) and being male were associated with an increase in the appearance of formal operations. Summarizing previous research, Lovell (1971) listed the following variables as significant factors capable of influencing the appearance of formal operational reasoning: task content, credibility of variables, attitude toward the subject matter, attained level of logical thought within the subject matter, and the influence of schooling.

In summary, these research findings raised several problematic issues. The failure of significant numbers of adolescents and adults to evidence formal reasoning strategies challenged the validity of formal operations as a universal stage of cognitive development. In addition, the inability of formal operations to appear as a unitary factor questioned the integrated nature of its underlying structure, a key postulate of formal operational, and stage

theory. Moreover, the failure of many formal reasoners to evidence the type of dissociation from concrete reality and generalizability across content domains described by Inhelder and Piaget (1958) questioned an important behavioral characteristic of formal operations. Finally, a wide array of organismic and environmental factors were shown to significantly affect the appearance of formal operational behavior. Taken as a whole, the above research findings presented a major challenge to Inhelder and Piaget's (1958) formulation of the stage of formal operations.

Theory Modifications

Two major attempts were made to account for these apparent contradictions to Inhelder and Piaget's (1958) conception of formal operations. In 1969, Flavell and Wohlwill suggested the incorporation of a competence-performance model to explain the failure of previous studies to find consistent use of operational strategies across tasks and content areas, and Piaget, in 1972, made several significant modifications to his earlier formulation to account for the low incidence of formal reasoning among diverse populations and the apparent effects of schooling on formal operational performance.

Flavell and Wohlwill's Competence-Performance Model

Adapting Chomsky's (1957, 1965) analysis of transformational grammar, Flavell and Wohlwill (1969) made a distinction between a competence model and an automaton-performance model. The competence model consisted of a formal, logical representation of the structure of any domain, while the automaton-performance model consisted of a psychological representation of the processes by which information embedded in competence actually gets accessed and utilized. Flavell and Wohlwill asserted that Inhelder and Piaget's (1958) formulation of formal operations, with its groups and lattices, constituted a structural model. Using this structural formulation as the prototype for competence, Flavell and Wohlwill postulated a four-phase competence-performance model which described how behavioral and task factors interrelate with the development of underlying structural competence.

In phase one, the operation or structure in question is lacking. Therefore, all problems demanding this operation are failed. During the next two phases, the subject is acquiring and consolidating structural competence and the negative effects of task related variables gradually decreases from a maximum, at the start of phase two, to a minimum, at the close of phase three. In the fourth and final phase, structural competence is complete and the subject is able to successfully bring the operation to bear irrespective of organismic and task related variables.

Flavell and Wohlwill further proposed a reclassification of previous (training) literature on the basis of its affinity to the automaton or competence side of the model. They argued that one set of studies used subjects who had already acquired the operation at the competence level but failed to apply it in a given situation. For these subjects, automaton factors were operating and their exposure to the task materials (or training) would facilitate access to the operation "by stripping away the cobwebs laying in the path" (p. 107) of operational functioning. On the other hand, the second group of studies used subjects who were still in a state of transition with respect to the operation or structure. For these subjects competence factors were operating and exposure to task materials (or training) would produce conceptual "instability, inconsistency and lack of generality" (p. 108).

Piaget's Reformulation

Addressing research contradictory to the 1958 work, in 1972, Piaget stated that his observations regarding the characteristics and incidence of formal operational thought were not necessarily disconfirmed by studies which found age appropriate subjects unable to dissociate thought from experienced reality or which found the incidences of formal operational performance well below the norms obtained in Geneva. Rather, he viewed these studies' findings as

indicative of variance in the rate at which, or domains in which individuals acquired formal operational thought. Accordingly, all normal adults attain the stage of formal operations between the age of 15 and 20 years, if not between 11 and 15 years. However, subjects reach this stage in different areas according to their aptitude and professional specialization (e.g. advanced studies in different types of apprenticeships for various trades). The seeming inability of some age appropriate subjects to evidence formal operations was explained by the inappropriate physical and logico-mathematical nature of the original formal operational reasoning tasks for many non-schooled and trade populations.

Let us consider the example of apprentices to carpenters, locksmiths and mechanics who have shown sufficient aptitude for successful training in the trades they have chosen but whose general education is limited. It is highly likely that they will know how to reason in a hypothetical manner in their speciality.... They will therefore be capable of thinking formally in those fields whereas faced with certain ideas that are particularly familiar to children still in school or college, would hinder them from reasoning in a formal way and they would give the appearance of being concrete. (Piaget, 1972, p.10)

Although not explicitly stated by Piaget, vocational training often does not begin until adolescence or young adulthood and may account for the age modifications stated above. Piaget continued that this hypothesis would also explain the inability of some subjects to dissociate reasoning from its specific or experienced content, as it is one thing to dissociate thought from content in a field

familiar to the subject (and with which he can apply his curiosity and initiative) and another to "generalize this same spontaneity of research and comprehension to a field foreign to the subject's career and interests" (p. 10).

The 1972 reformulation thus placed formal operations within all normal adults between the ages of 15-20 years and extended the possible variables affecting access to these structures. Piaget attributed the low incidence of formal reasoning in many age appropriate subjects to an improper matching of assessment tools to populations and implied that the tasks described in the 1958 work were perhaps biased in favor of "children still in school". He additionally attributed poor cross task generalizability to differential application and use "by each person according to his particular activities" (p. 10). In concluding Piaget asserted the need to establish these hypothesized interrelationships by experimental methods.

The modifications made by Piaget (1972) and Flavell and Wohlwill (1969) both suggested a closer look at the effects of specific organismic and task related variables on the manifestation of formal reasoning. Flavell and Wohlwill directed attention to the interrelationship between task variables and the subject's level, or phase of operational competence. Piaget's reformulation called for a better match between the subjects' area of cognitive specialization and the content of the task.

Subsequent Research

Most of the research on formal operations subsequent to the modifications suggested by Piaget (1972), and Flavell and Wohlwill (1969) continued to study organismic and task related variables affecting its manifestation. This research was divided on the issue of positing formal competence as the invariant final stage of all normal cognitive development. Researchers who argued against this view either postulated alternate models to represent final stage attainment or focused on variables leading to the construction of formal, or abstract thought. Researchers who posited formal operations as the invariant final stage of development accordingly focused on task and organismic variables which might elicit formal operational competence.

Dulit (1972) and Berzonsky (1978) assumed the former position and although they accepted Piaget's first two stages of cognitive development as universal, they proposed an alternate model to represent the final form of cognitive attainment. They contended that Piaget's first two stages formed a "single path" along which most individuals developed, and that in adolescence, there was a branching into three parallel tracts (Dulit, 1972). One of these tracts appears to be formal operations, but only a minority proceeded down this road. Dulit and Berzonsky differed in their hypotheses on the nature of the alternate paths to formal operational thought. Dulit (1972) proposed two alternate modes of reasoning, a standard method and an

inspirational method, which he associated with partial or minimal development of the capacity for formal stage thinking. Berzonsky's (1978) model proposed two alternate forms of knowledge, one aesthetic and one personal, which he viewed as a functions of interest and training. The paths individuals take depend upon aptitude, instruction (Berzonsky, 1978) and societal demand (Dulit, 1972).

Most cross cultural research also denied the universal existence of a formal competence and emphasized the effects of societal and social demands on the construction of operational intelligence. Many of these studies continued to stress the importance of school experience in this regard (Cole and Scribner, 1973, 1974). These researchers argued that the decontextualization of language, coupled with the use of common operations applied to a multitude of tasks, underlies the tendency of schooled populations to generalize rules and operations across a number of seemingly different stimuli and problems. Laurandean (1975) concurred, asserting that school attendance appeared to be an essential factor in stimulating intellectual development and was perhaps necessary for attaining the level of abstract operations.

While the first group of researchers focused on the areas of subject specialization in which individuals are disposed to reason (Dulit, 1972; and Berzonsky, 1978), the second group of researchers focused on environmental factors affecting task comprehension and task familiarity (Cole and Scribner, 1973, 1974; and Laurandean, 1975). However,

subject specialization and task comprehension/familiarity has also been investigated from the perspective of those who view formal competence as present within all normal age appropriate individuals although latent in some individuals. Researchers in this category have typically looked for organismic and task variables which masked existing formal competence.

Two studies investigating organismic factors (Diamond, Keller, and Mobley, 1977; and White and Festenberg, 1978) examined the effects of academic specialization on tasks requiring formal reasoning. Diamond et al. (1977) found that formal operations correlated significantly with interest in the physical sciences, while White and Festenberg (1978) found that science majors performed significantly better than nonscience majors on the Inhelder and Piaget (1958) problems.

Research studying task factors has primarily investigated the effects of task familiarity and instructional clarity. Awareness of the significance of task familiarity preceded Piaget's 1972 reformulation. Earlier studies (Cole et al, 1971; and Greenfield, 1966) used culturally familiar items while retaining Inhelder and Piaget's (1958) task formats, or Bruner's (1966) item categorization formats. More recently, several researchers attempted to formulate problem solving tasks involving everyday situations which required the use of formal reasoning strategies for proper solution (Sinnott, 1975, 1978; Kuhn and Brannock, 1977; and Mandler, 1980). For

example, Sinnott (1977) asked subjects to alter cake recipes and organize children for a camping trip. In this study, and in a later one, Sinnott (1975, 1978) found that task familiarity improved his subjects' performance by as much as 25 percent.

Research on the effects of increasing instructional clarity also found a corresponding increase in formal operational performance. Using a series of graduated verbal and modelled prompts, Danner and Day (1977) successfully elicited formal operational reasoning in adolescents whose previous pretest performance categorized them as concrete operational. Through 1980, Day interpreted these results, and the spontaneous improvement of her control group in a later study (Stone and Day, 1978) as evidence for the widespread existence of a "latent" formal operational ability (i.e., competence) in these subjects. Stone and Day (1980) then reinterpreted their earlier data from a Vygotskian perspective. Stone and Day now concurred with Vygotsky's (1978) assertion that the assessment of what a child can do on his own differs from what he can do with the help of others. The difference between the two assessment procedures Vygotsky referred to as the "zone of proximal development", which represents the ability of adults to facilitate a cognitive reorganization within the child. This reinterpretation would place Day in the company of researchers denying formal competence. Notwithstanding Day's new interpretation, she has shown that factors affecting task communication and clarity have a significant

affect on formal performance and that the use of a prompt series can more accurately produce a true assessment of the individual's ability.

In summary, in all the above studies focusing on the organismic variable (Dulit, 1972; White and Festenberg, 1978; Diamond et al, 1977; and Laurandean, 1975), researchers have asked subjects with divergent interests and aptitudes to solve classical Piagetian problems requiring formal reasoning. Studies focusing on task variables have either used materials the researchers believed were culturally familiar to the subjects (Greenfield, 1966; Cole et al, 1971), or constructed tasks considered common to the everyday existence of individuals in a particular culture (Sinnott, 1975, 1978; and Kuhn and Brannock, 1977). All of these studies have shown that both organismic and task related variables significantly affected formal operational performance.

STATEMENT OF THE PROBLEM

A common problem with all of the above research has been its failure to simultaneously match the task to the subject's area of interest and specialization as suggested by Piaget in the 1972 reformulation of formal operational theory. Dulit (1972) and Ross (1973) compared average and intellectually gifted adolescents and adults while White and Festenberg (1978) and Diamond et al (1977) compared science and nonscience majors on an array of classical Piagetian problems. In these studies no attempt was made to devise tasks geared to the specific interests of the particular subject populations. Laurandean (1975) asked schooled and unschooled children to solve classical Piagetian tasks of formal reasoning despite Piaget's (1972) warning that these tasks may be biased in favor of a schooled population. Laurandean's findings of greater similarity of response between the schooled Rwandese children and the schooled French-Canadian children is consistent with Piaget's assertion. Studies which have investigated the task variable have attempted to make the task more familiar to a general population by using either culturally familiar objects, or by constructing everyday tasks. Again, none of these studies has sought to construct tasks appropriate to the specific interests and/or specialization of their target population. As a consequence, all of the above studies have failed to adequately test Piaget's (1972) modification by matching the task to the special interests of the subjects.

In response to these problems, the present study sought to assess the use of formal operational reasoning strategies by subjects trained in a technical skill or trade on tasks of a familiar and unfamiliar content to their vocational specialization. Vocational high school students specializing in carpentry and electrical wiring were given three formal operational reasoning problems; two experimenter designed tasks, one in carpentry, the other in electrical wiring, and a third task which was an adaptation of Inhelder and Piaget's (1958) rod flexibility task. The vocational tasks were structurally parallel to the rod flexibility task and required a separation and control of variables strategy for solution. Comparisons between the unfamiliar and familiar content tasks permitted a direct test of Piaget's (1972) reformulation of formal operational theory. In addition, subjects who failed to evidence full formal reasoning in response to an open ended administration (typical of Piaget's interview format) were given a series of graduated verbal prompts (adapted from the 1977 Danner and Day study). This phase of the study was intended to manifest possibly latent or transitional formal operational ability and arrive at a more accurate assessment of the subjects' reasoning ability.

The present study was intended not only to test Piaget's 1972 reformulation, but to add to the understanding of the ways in which the context of development and learning is related to the emergence of advanced intellectual abilities.

HYPOTHESES

Piaget's (1972) reformulation asserted that all normal, age appropriate subjects will know how to reason in a hypothetical manner in their areas of specialization. He also maintained that subjects will be hindered in such thinking when faced with unfamiliar content. It was therefore, hypothesized that:

1. Subjects will obtain significantly higher stage level scores on formal reasoning tasks of familiar content than on problems of an unfamiliar content.
 - a. High school subjects trained in carpentry will obtain significantly higher stage level scores on the carpentry task than on the electrical wiring or rod flexibility tasks.
 - b. High school subjects trained in electrical wiring will obtain significantly higher stage level scores on the electrical wiring task than on the carpentry and rod flexibility tasks.

Day (with Danner, 1977; and Stone, 1978) found that use of a series of graduated prompts significantly improved stage level scores on problems requiring formal reasoning. Considered in light of Piaget's (1972) reformulation, it was further hypothesized that:

2. Subjects will require significantly fewer prompts to attain full formal reasoning on problem solving tasks of a familiar content than on problems of an unfamiliar content.
 - a. High school subjects trained in carpentry will require significantly fewer prompts to attain full formal reasoning on the carpentry task than on the electrical wiring task.
 - b. High school subjects trained in electrical wiring will require significantly fewer prompts to attain full formal reasoning on the electrical wiring task than on the carpentry task.

Chapter 2

METHODSubjects:

Sixty male subjects were chosen from two vocational high schools in New York City. Subjects were juniors and seniors and varied in age from 16 to 19 years (mean age = 17.6 years). They were trained in one of two areas of vocational specialization, carpentry and electrical wiring. There were 30 subjects in each vocational specialization. Subjects in the present study were from working class or low income backgrounds.

Measures:

Three reasoning tasks were administered. An adaptation of Inhelder and Piaget's (1958) rod flexibility task was used to assess the subjects' performance on classical Piagetian type problems of formal reasoning. In addition, two experimenter designed tasks which reflected each group of subjects' area of vocational specialization was also used, (i.e. carpentry and electrical wiring). All three tasks required a separation and control of variables

strategy for proper solution. All three tasks contained four possible causal variables, with two dimensions of each variable (with the exception of one dimension on both the rod flexibility and electrical wiring tasks). On each task, subjects were asked to determine the causal variables and to manipulate the apparatus in order to test the causal effect of each hypothesized variables. Each task is described below.

Rod Flexibility Task:

Subjects were presented with six rods, two steel vices attached to a wooden board and two identical lead washers to be used as weights (see Figure 1). The six metal rods varied along three dimensions and presented two aspects of each dimension; rod content (brass and steel); shape (round and square) and diameter ($1/8$ inch and $1/4$ inch). In addition, the rods varied along a fourth dimension, length, depending on the placement of the rod in the vice.¹

1)The original Inhelder and Piaget (1958) rod flexibility task differed from the present adaptation in several respects. The original apparatus used a wooden clamp to suspend the metal rods over a basin of water, to which a clamp was attached. The present study used two vices to hold the metal rods and the tables edge as the point to which the rods may bend. In addition the authors mentioned three aspects along the dimension of cross section and end weights; however it is not clear whether there are two or three aspects along the dimension of thickness, and rod content. The present study offered two aspects along each of the above dimensions.

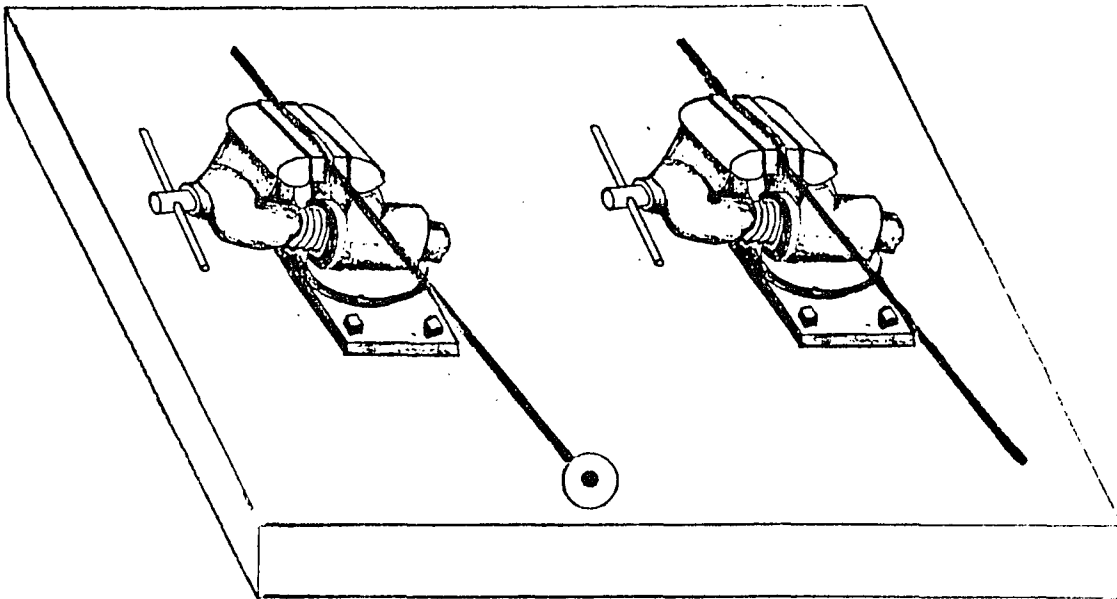


Figure 1. Rod Flexibility Task Apparatus.

The apparatus was demonstrated to each subject by placing a square, 1/8 inch, brass rod into a vice and stating: "When the rods are placed in the vice they will bend, like this one. Some rods will bend more than others. When I place a washer on the end of this rod, it bends enough to touch the table". The subject was asked to: "Tell me what things, or features about these rods will determine whether some rods will bend enough to touch the table when a washer is placed on them, and others will not? That is, what about the rods that will affect how much they will bend?"²

Electrical Wiring Task:

For this task, subjects were shown an electrical apparatus (see Figure 2) consisting of two D cell batteries (A), an on/off switch (B), a diode (C), a small turbine-type universal motor (D), and four binding posts (E-H), all mounted on a 12 x 6 inch board. An extra diode and motor were placed alongside the apparatus and identified to the subject as "spare parts" (not shown). The diode already mounted on the apparatus was connected to two binding posts (G and H) by means of two banana plugs (I and J) attached to wires which extended from either end of the diode. Three wires (colored red, black and green) extended from the

2) Inhelder and Piaget (1958) reported that subjects were "asked to determine whether or not the rod is flexible enough to reach the water level".

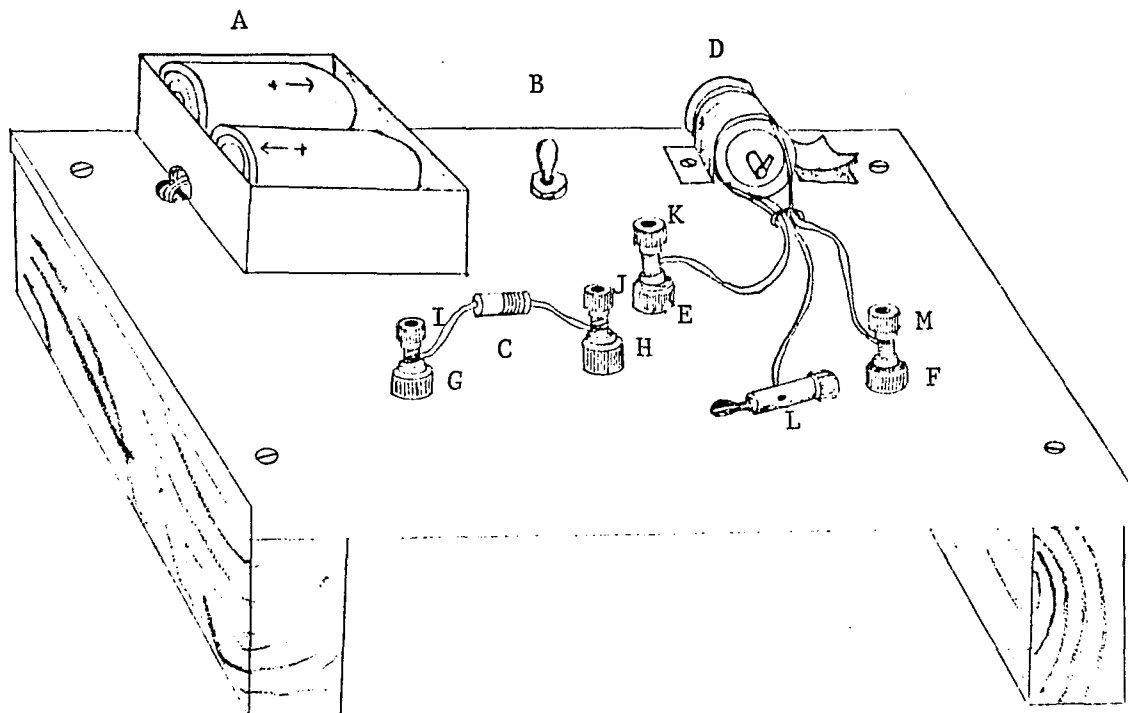


Figure 2. Electrical Wiring Task Apparatus. Shown in this figure are the D cell batteries (A), the on/off switch (B), the diode (C), the turbine-type motor (D), the four binding posts (E-H), and the banana plugs attached to the diode (I and J) and to the motor (K-M).

motor. While there were three banana plugs (K, L, and M) attached to the colored wires extending from the motor, only two of the plugs could be attached to the remaining posts (E and F). The red and black wires were connected to the motor, whereas the green was not. In addition, one of the motors was faulty, although identical in appearance to the working motor. Each diode was marked with a silver band at one end to denote the direction the current flowed through the diode (i.e. left or right). In this task there were, therefore, four possible variables, three of which had two levels each: diode viability (good or faulty); diode position (band pointed left or right) and motor viability (good or faulty). The fourth variable, motor wiring had nine possible conditions, only one of which was correct.

Subjects were instructed as to the functioning of the diode and the removal and replacement of the diode and motor. In addition they were informed that the wiring underneath the display board was correct, as is. They were told: "When all parts of the apparatus are attached correctly, and the switch is thrown, the motor will run. Right now something is wrong with some part of the apparatus which you are to find and correct." Subjects were then asked: "What about the parts, or the arrangement of the parts that prevents the apparatus from operating. In other words, what is causing this problem?" If a subject suggested battery inviability, or switching the location of the diode or motor, he was instructed that these features were correct in the present position.

Wall Brace Task:

The apparatus for this task (See Figure 3) consisted of a 29 inch x 28 inch x 4 inch trough filled with sand (A); an 18 inch x 24 inch x 4 inch free standing wall (B) placed atop the sand; three sets of wall braces (only one set is shown, item (C)); three set of stakes (only one set is shown), item (D); and a supply of 3 inch nails. Each of the braces and stakes was constructed to vary along two dimensions with two levels of each dimension; brace length (20 inches and 24 inches); brace thickness (1 inch and 2 inches); stake length 6 1/2 inches and 10 inches) and stake thickness (1 inches and 2 inches). Braces could be attached to the free standing wall by placing nails through the predrilled holes in the wall which could be aligned with matching holes at the top of each brace. The stakes could be pressed or hammered into the sand. A tilt guage (E) was attached to the side of the wooden trough to indicate the relative tilt of the wall.

The experimenter demonstrated the placement and removal of the braces and stakes and then stated: "When pushed lightly from behind, the wall will tilt forward. Sometimes with the same light push the wall will tilt enough to enter the red area shown on this gauge. The subject was then asked: "What things or features about this equipment will determine whether the wall will tilt enough to enter the red area when pushed lightly, and at other times will not?"

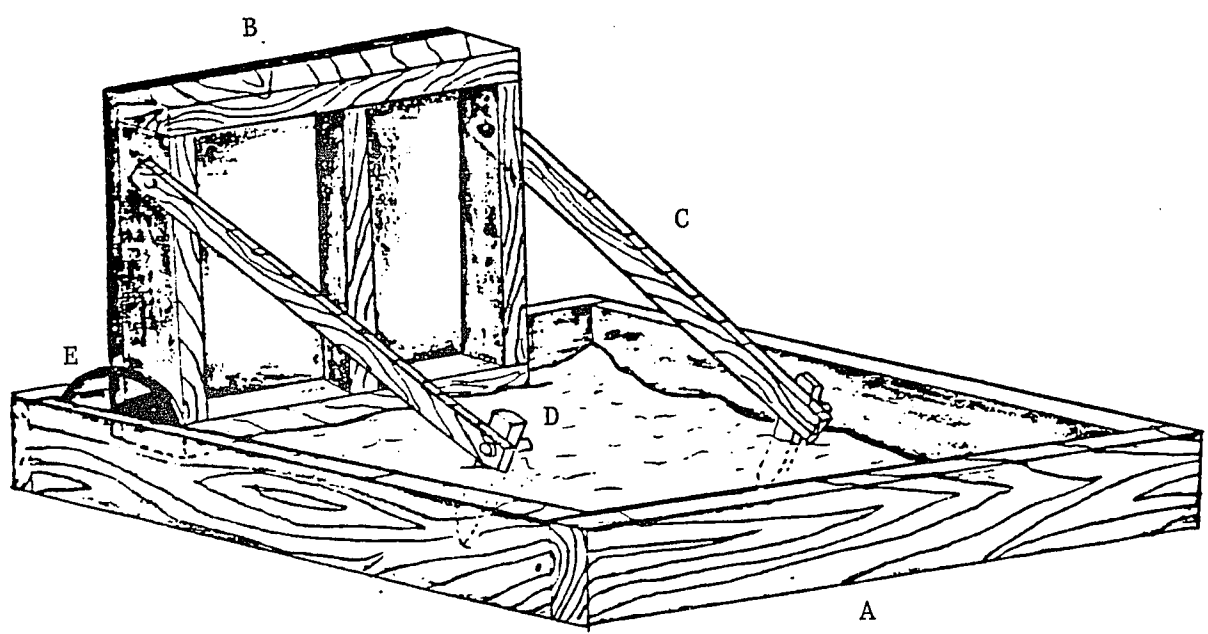


Figure 3. Wall Brace Task Apparatus. Shown in this figure are the sand trough (A), a free standing wall (B), one of three sets of braces (C), one of three sets of stakes (D), and the tilt guage (E).

After each of the task problems had been stated the subject was encouraged to generate a list of possible independent variables. He was then asked to demonstrate proofs for each hypothesized variable. The experimenter then stated: "Now how would you prove that your hunches are right? Show me how you would prove for sure that (the experimenter states the independent variable) has an effect?"

Procedure:

Each subject was seen individually on two separate occasions. At the start of the first session each subject was brought to the experimenter's room and told the following:

"I am doing a study on how people solve problems and would like you to help me. I would like to hear how someone trained in a skill or trade goes about solving problems that may or may not be familiar to their skill or trade. This is not a test. I am not interested in the correctness or incorrectness of your answers, but in how you go about proving your hunches in solving a problem. Therefore, please think out loud. Your responses at this and any later session will be kept confidential and be used only for the purposes of this study. Before we begin there are some questions I would like to ask you."

The subject was then given an introductory interview. This interview was to ascertain how much formal instruction and practical experience the subject had in his chosen vocational specialization and the alternate vocational field. The subject was asked the following:

"How many courses have you had in (technical major)? ... What were they?... Do you have any work experience in this field?... What kind?... How many courses have you had in (alternate field)?... What were they? (If any)... Do you have any work experience in this field?... What kind?(If any)... Have you taken any physics courses?... How many?... Have you ever taken a course in Strength of Materials?"

"Okay. In this session and the next I will show you a model of a wall, an electrical circuit and some metal rods and will ask you to solve a problem with each of these things. If you don't understand the problem, or have any other questions, please ask. Remember to think out loud as you reason. Ready?"

After this introductory interview, task administration was begun. Each subject was initially administered the rod flexibility task. Then one of the two specialized vocational tasks was presented. Depending on the subject's response, administration of the vocational task could involve two phases, an open ended phase and a prompt phase. In phase one, the open ended administration, if the subject did not spontaneously evidence full, formal reasoning during this part of the task administration, he immediately entered phase two. In phase two, prompt administration, the subject was presented with a series of prompts which gradually explicated the isolation and control of variables strategy. When the subject successfully demonstrated the required formal reasoning strategy, or when all six prompts had been administered, task administration was concluded.

Following completion of the vocationally specialized task the subject was again interviewed. This closing interview was to ascertain what was familiar, or unfamiliar about the vocational problem solving task presented that day. The subject was asked the following:

"How did you find doing, or working on this last task?... Was it hard or easy?... Why?... Was the task familiar to you in any way? That is, is this the kind of problem that you are used to solving? ... (If the answer was yes) How? In what way? ... How was the problem unfamiliar, or new to you?"

This concluded the first session.

During the second session the vocationally specialized problem solving task not presented during the first session was administered according to the two phase procedure outlined above.

The order of presentation of the two vocational tasks was counterbalanced. At the initial session half of the subjects were administered a vocational task of a content familiar to their area of vocational specialization and half were presented with a problem of an unfamiliar content. The presentation of the vocationally specialized tasks was randomly alternated. After the presentation of the remaining vocational task the second session concluded with the administration of the closing interview described above.

Task Administration

Administration procedures for the Piagetian type, rod flexibility task and the vocationally specialized tasks varied. All tasks were initially presented in an open ended manner as described in phase one below.

Phase 1: Open Ended Administration:

The problem solving question was posed. The subject was encouraged to generate a list of possible variables. He was then asked to test each variable. Using a scoring sheet containing an abbreviated listing of each independent variable and their respective conditions, the experimenter recorded all direct responses to questions and any remarks made by the subject that might assist in stage categorization, e.g. statements concerning the subject's intention to control variables. The experimenter provided no feedback as to the correctness or incorrectness of each test. After the subject had made a comparison, the experimenter encouraged the subject to proceed to his next hypothesized variable where necessary.

Forced Comparison: After the subject had tested each of his variables he was presented with a forced comparison. The experimenter demonstrated a confounded proof and stated: "I recently did this task with another student. He showed me this comparison in order to prove that (e.g) rod shape has an effect. Is this a good test?... Why?..." This comparison is similar in format to the Stone and Day (1978) "good test argument and was used to force the subject to think about the validity of a proof. The experimenter recorded the subject's response and rationale, concluding phase one of the task administration.

Administration of the rod flexibility task ended at this point, irrespective of the level of reasoning

demonstrated by the subject. For the two vocational tasks, however, if the subject failed to evidence full formal reasoning during the open ended administration, he immediately proceeded to phase two of the task administration.

Phase 2: Prompt Administration:

The experimenter introduced this phase by stating:

"Okay. Now I'm going to give you a series of clues to try and get you to answer this problem in a particular way. After each clue you will have a chance to try the problem again. If you are correct, the remaining clues will not be given and the task will be over. If your solution is not the one desired the next clue will be presented.

The subject was given an opportunity to demonstrate the desired reasoning strategy immediately before any prompts were begun. The subject was asked: "Before we begin these clues, would you like to try and prove what effect each of the factors had on ...(the dependent variable)?" Immediately after each prompt was given a standard exit question followed: "Based on this clue can you now prove what effect each of the factors has on ... (the experimenter stated the dependent variable)?" The six prompts listed below were the result of an adaption of the Danner Day (1977) prompt series and a task analysis.

Prompts:

1. Listing of Variables: The experimenter named all the relevant variables for the task.

2. Need for a Comparison: The subject was told: "When testing for the effects of a factor like (e.g.) brace thickness, you must make a comparison. First see the effect of (e.g.) brace thickness in one position, change, and then look to see if there is any change in (e.g.) the sturdiness of the wall."

3. Recognition of a Confounded Variable: The subject was instructed to consider an experimenter presented proof for brace thickness or diode viability. The proof was confounded. The subject was told: "When two or more things change at the same time, as in this comparison, you can't tell which thing is really causing any change you might find. Here brace thickness and stake thickness, or diode and diode position are both changing at the same time and therefore you can't tell which one is really causing any change that might occur."

4. Deconfounding Variables: The experimenter now modelled an unconfounded proof for brace thickness or diode viability and stated: "To get rid of the effects of an unwanted factor, you must keep that factor the same, or unchanged in the comparison, and only change the factor you are testing. For example, here you must keep (e.g.) stake thickness / the position of the diode the same, or unchanged

while making the comparison and only change (e.g.) brace thickness / diode.

5. Rule Statement: The subject was instructed to consider another confounded, experimenter proof. The subject was told: "To test the affects of any one factor, you must keep the other factor unchanged and only change the factor you are testing. For example, to test for the affects of (e.g.) stake height you must keep the other three factors unchanged (they are listed), and only change the factor you are testing, like this." The experimenter unconfounds the modelled test.

6. Demonstration of All Proofs: The experimenter asked the subject to watch while she demonstrated all four proofs. The subject was then asked to repeat them.

Scoring

Subjects received two types of scores: stage level scores and prompt scores.

Stage Level Criteria:

Stage level scores were based on the subject's performance on each of the three reasoning tasks during the open ended administration. Subjects were assigned one of four possible substage levels according to criteria outlined in Inhelder and Piaget (1958). Substage categories are defined below.

Substage IIA: Subjects at this substage understand compensation and multiplication between variables. However, subjects offer single instance proofs for the independent variable and fail to make spontaneous comparisons.

Substage IIB: Subjects at this substage make comparisons. However, when comparisons are made, any pair of stimulus items that differ along the independent variable is considered adequate for comparison. Tests are not ordered, but proceed in a trial and error fashion. Subjects do not generalize knowledge of specific variables to other task variables. Subjects do not isolate and control variables.

Substage IIIA: Subjects spontaneously set up experimental comparisons. Subjects indicate a mild awareness of the need to control variables. Subjects may state an intention to hold one or more variables constant or may voice dissatisfaction with a test but cannot accurately state why. Still, subjects cannot successfully separate and control variables.

Substage IIIB: Subjects spontaneously set up experimental comparisons. Proofs become rigorous and subjects can now successfully separate and control variables.

Prompt Criteria:

This score indicated the point at which the subject exited from the prompt series. The subject exited when he had performed minimally three out of four unconfounded proofs and correctly answered the forced comparison for that task.

Scores ranged from 0 to 7. A "0" indicated the subject attained criterion level before any prompts were administered. Subjects who evidenced full formal reasoning during the open ended administration, and those who evidenced similiar performance immediately after the general introduction to the prompt series received prompt scores of "0". Scores from 1 to 6 corresponded to the six prompts and exits and indicated the point at which the procedure was terminated by the subject. A score of 7 indicated that the subject was not able to attain criterion level.

Subjects received two prompt scores, one for each of the vocationally specialized tasks.

PILOT DATA

Ten female and five male subjects were used to test the validity of the experimenter designed instruments. Pilot subjects ranged in age from 12 to 40 years. Academic and vocational specializations varied widely. Subjects were primarily students attending public junior high (n=4, ages 12 to 13 years), private primary (n=2, ages 11 to 12 years), and specialized public high schools (n=4, ages 15 to 17 years). In addition, five adults whose occupations included nurse, office worker, and policy analyst were used. None of the pilot population had any experience with, or training in electrical wiring or carpentry.

Results of the open ended administration of the three formal reasoning tasks were as follows: twelve of the fifteen subjects were consistent in their scores across the three reasoning tasks. Of these subjects, four consistently evidenced full formal reasoning, three consistently evidenced early formal reasoning, and five consistently evidenced early concrete reasoning across all three tasks. Change in stage level scores was demonstrated by three subjects. One initially performed at stage IIIB on the rod flexibility task and IIIA on the two specialized tasks. Another subject initially evidenced IIB level reasoning on the rod flexibility task, but achieved full formal reasoning on the two specialized tasks. The third subject evidenced

consistent improvement in her stage level scores across each of the three tasks. This subject initially demonstrated concrete operational (IIB) reasoning on the rod flexibility task, early formal (IIIA) reasoning on the carpentry task, and full formal operational (IIIB) reasoning on the electrical wiring task.

Prompt analysis indicated that neither of the specialized tasks required a greater number of prompts to achieve full formal reasoning. Of the ten subjects to whom the prompt series was administered, two subjects required more prompts on the carpentry task and three subjects required more prompts on the electrical wiring task. Of the remaining five subjects, all required the full prompt series and none demonstrated full formal reasoning.

These findings indicated that the three instruments were of approximate operational difficulty and that the experimenter designed tasks appeared to tap the same reasoning strategy or process required by Inhelder and Piaget's rod flexibility task. However, of the original 15 pilot subjects, four evidenced ceiling effects and five evidenced floor effects. It is therefore recommended that these findings be taken with caution.

Chapter 3

RESULTS

The results of the current study are presented in three sections: a report of preliminary tests involving procedural issues; a description of results of stage level analyses; and a presentation of results of the prompt analyses.

Methodological Tests

Interscorer Reliability. Interscorer reliability was assessed for the stage level analyses of the three reasoning tasks. After careful review of the stage level criterion used in the current study, a research associate scored twenty randomly selected student protocols. Half were protocols of carpentry students and half were protocols of electrical wiring students. The second scorer was not aware of the previous stage level ratings assigned by the original experimenter. Agreement in the stage level assignments between the two scorers was defined as the number of response agreements divided by the total number of responses. Results of this reliability check were as follows: .90 for the rod flexibility task, .90 for the carpentry task, and .80 for the electrical wiring task. In those instances where scorers disagreed on a particular stage assignment, the difference was never more than one substage in either direction.

Task Order Effects. The order of administration of the two vocational tasks was counterbalanced. After initial administration of the rod flexibility task, half the subjects in each vocational population were administered the carpentry task while the remaining half were administered the electrical wiring task. At the second, and final session, the vocational task not administered during the previous session was presented. An ANOVA indicated neither a significant main effect for order, nor a significant interaction between order and task.

Stage Level Analyses

The main stage level hypothesis (hypothesis 1) predicted that subjects trained in a vocation would obtain significantly higher stage level scores on reasoning tasks which used materials familiar to their area of specialization. This hypothesis was not confirmed by analyses of the data. Specifically, it was predicted that high school students trained in carpentry would obtain significantly higher stage level scores on the carpentry task than on the less familiar electrical wiring and rod flexibility tasks (hypothesis 1a). Carpentry students mean stage level scores for the three reasoning tasks are shown in Table 1. A 2 x 3, repeated measures analysis of variance was performed on the task by subject condition data with repeated measures on the task variable. Results, shown in

Table 2, revealed a significant difference between students' mean stage levels on the three tasks, $F(2,58) = 5.072$, $p < .01$. However, a Newman Keuls post hoc test of significance, (Table 3), indicated that these mean stage level differences were not in the predicted direction. Carpentry students' mean stage level on the carpentry task (mean = 2.33) was significantly lower than on the electrical wiring (mean = 2.73) and rod flexibility tasks (mean = 2.80), $p > .05$. Mean stage level scores on the latter two tasks did not significantly differ from each other.

Hypothesis 1b predicted that high school students trained in electrical wiring would obtain significantly higher stage level scores on the electrical wiring task than on the carpentry or rod flexibility tasks. Wiring students mean stage level scores in response to the three reasoning tasks are shown in Table 1. Results of a 2 x 3, repeated measures analyses of variance was performed on the task by subject condition data with repeated measures on the task variable (Table 4) and revealed a significant difference between these mean stage levels $F(2,58) = 7.120$, $p < .002$. A Newman Keuls post hoc test of significance (Table 5) again indicated that these differences were not in the predicted direction. Electrical wiring students' mean stage level on

Table 1

Experimental and Pilot Subjects'
 Mean Stage Level Scores and Standard Deviations
 on the Three Reasoning Tasks

Subject Condition	Tasks					
	Rod Flex		Carpentry		Elec Wiring	
	Task	(S.D.)	Task	(S.D.)	Task	(S.D.)
Carpentry	2.80	(.96)	2.33	(.94)	2.73	(1.05)
Elec.Wiring	2.70	(.95)	2.10	(.71)	2.73	(1.01)
Pilot Pop.	2.6	(1.25)	2.66	(1.29)	2.72	(1.33)

Table 2
Repeated Measures ANOVA
of Mean Stage Level Scores
for Carpentry Students

Variables	SS	df	MS	F	p
Tasks (T)	5.756	2	2.898	5.072	.01
Subjects(S)	47.122	29	1.625		ns
T x S	32.922	58	.567		
Total	85.789	89	.964		

Table 3

Newman Keuls Post Hoc Test of Significance
of Carpentry Students'
Mean Stage Level Scores

Tasks	Diff	Critical Value
1-2	.57	.4*
1-3	.07	.48
2-3	-.50	.4*

* $p < .05$

Table 4
 Repeated Measures ANOVA
 of Mean Stage Level Scores
 for Electrical Wiring Students

Variables	SS	df	MS	F	p
Tasks (T)	7.622	2	3.811	7.120	.002
Subjects(S)	39.822	29	1.373		ns
T x S	31.044	58	.535		
Total	78.488	89	.882		

Table 5

Newman Keuls Post Host Test for Significance
of Electrical Wiring Students'
Mean Stage Level Scores

Tasks	Diff	Critical Value
1-2	.60	.39*
1-3	-.03	.47
2-3	-.63	.39*

* $p < .05$

the electrical wiring task (mean = 2.73) did not significantly differ from their mean stage on the rod flexibility task (mean = 2.70). A significant difference was obtained, however, between these two mean stage levels and the mean stage level on the carpentry task (mean = 2.10). Electrical wiring students' mean stage level on the carpentry task was significantly lower than their mean scores on the electrical wiring and rod flexibility task ($p < .05$).

In summary, mean stage level on the carpentry task was significantly lower than on the electrical wiring and rod flexibility tasks for both vocational populations. Also, subjects' mean stage level on the latter two tasks did not significantly differ, with wiring students scoring slightly better on the wiring task and carpentry students scoring slightly better on the rod flexibility task.

Also shown in Table 1, are a nonvocationally-trained pilot population's mean stage level scores for the three reasoning tasks. Demographic differences in age range, sex, education, and vocational training between the pilot and the experimental populations prevented statistical comparison. Pilot data appear here for later speculative comparison and to suggest future research possibilities.

The relationship between stage level and task condition was further explored using log linear analyses. Subjects' unanticipated high performance on the rod flexibility task strongly suggested the need for an investigation of this relationship. Log linear analysis was chosen for its ability to examine relationships between categorical variables and its ability to provide a parsimonious description of these relationships. Similar to analysis of variance, log linear analysis attempts to use main effects and variable interactions to account for cell frequency differences. By initially postulating all possible combinations of effects and interactions, and then systematically eliminating those which prove non significant, this analysis arrives at the smallest number of parameters needed to account for the observed cell frequencies. Specifically, possible models, or statements of the expected cell frequencies as a function of the task variables and their relationship to each other were fit to the observed data. To determine how well a model "fit", or explained the data, the extent to which frequencies expected under the model approximated the frequencies actually observed was calculated. An acceptable model was one whose expected cell frequencies did not significantly differ from the observed data. Consequently, an hypothesis of association was sought and probability statistics of committing a Type I error above $p = .10$ were regarded as a good "fit" of the data. When two or more models produced

acceptable probability statistics and differed from each other in only one term or parameter, a comparison of the difference between two models' likelihood chi square statistics (L^2) and degrees of freedom (df) determined if the additional parameter had explanatory significance. If no significant additional information was provided, the model containing the extra term was rejected due to lack of parsimony.

All possible main effect and bivariate models for the task variable were fit to the two subject samples' stage level data. The frequency distributions on which these analyses were based appear in Table 6. The likelihood ratio chi squares and probability levels for these models appear in Table 7 for the carpentry students and in Table 9 for the wiring students. In these tables the task variables are R for the rod flexibility task, C for the carpentry task and W for the wiring task. Initially, four substage levels were used in these analyses: IIA, IIB, IIIA, and IIIB, (see page 38 of the methodology section for the defining characteristics of each stage). However, to minimize the number of cells with observed frequencies equal to zero, a two stage delineation was used: substages IIA and IIB were collapsed and labelled "concrete operational", and substages IIIA and IIIB were collapsed and labelled "formal operational".

For the carpentry population's stage level data, only Model 9 produced an acceptable probability statistic. This model indicated explanatory importance of the two bivariate

Table 6

Grouped Frequency Distributions
of Carpentry and Wiring Populations'
Stage Level Data

Carpentry Task					
		Concrete Operational	Formal Operational		
Rod Flex	Electrical Wiring Task				
Task	Concrete	Formal	Concrete	Formal	
Carpentry Students					
Concrete	8	1	0	2	
Formal	4	8	3	4	
Electrical Wiring Students					
Concrete	10	5	0	0	
Formal	2	6	2	5	

Table 7
 Log Linear Analysis
 of Carpentry Students'
 Stage Level Data

Model	Degrees of Freedom	Likelihood Chi Sq. (L^2)	Probability Level
1. R,C,W	4	10.27	.0361
2. R,C,RC	4	8.14	.0864
3. R,W,RW	4	8.99	.0613
4. C,W,CW	4	8.99	.0613
5. R,C,W,CW	3	7.09	.0690
6. R,C,W,RW	3	7.09	.0690
7. R,C,W,RC	3	8.14	.0431
8. R,C,W,RC,RW	2	4.97	.0834
9. R,C,W,RW,CW	2	3.92	.1411
10. R,C,W,RC,CW	2	4.97	.0834
11. R,C,W,RC,RW,CW	1	2.91	.0879

Task Variable Code: R = Rod Flexibility Task
 C = Carpentry Task
 W = Electrical Wiring Task

Table 8
Lambda and Standardized Lambda Statistics
for Model 9 of
Carpentry Students' Stage Level Data

Model Parameter	Lambda	Standardized Lambda
R	-0.265	-1.414
C	0.265	1.414
W	0.0	0.018
R W	0.324	1.728
C W	0.324	1.728

interactions RW and CW; i.e., between carpentry students' stage levels on the rod flexibility and electrical wiring tasks (RW), and between their stage levels on the two vocational tasks (CW). However, examination of Model 9's standard error ratios, shown in Table 8, indicated that neither of these bivariate interactions was significant (i.e. for neither did the absolute value exceed 1.96). This lack of significance may be attributed in part to the small sample size of the current population. Therefore, although Model 9 was selected as best fitting carpentry students' stage level data, no significant interactions were found to exist between stage levels on the rod flexibility and the vocational tasks or between stage levels on the two vocational tasks, although these two interactions approached significance.

A somewhat different picture emerged from the results of the log linear analyses of stage level scores for the electrical wiring population. Examination of the probability levels shown in Table 9 indicated that five models produced acceptable probability statistics, viz., Models 2, 7, 8, 10, and 11. Comparisons of the likelihood ratio chi square statistics between Models 2 and 7 revealed that the ability of Model 2 to account for the data patterns was not statistically improved by the inclusion of parameters for the main effect of stage level on the wiring task ($L_2^2 - L_7^2 = .11$, $df = 1$, $p > .05$). Similarly, there was no statistical improvement in Model 2 by the addition of Model 10's interaction for stage level on the two vocational

tasks, ($L2^2-L10^2= 1.06$, $df = 2$, $p>.05$). As a result, Models 7 and 10 were rejected. Model 11 was also rejected for lack of parsimony. Comparisons involving Model 8 produced conflicting statistics. The simultaneous inclusion of the C by R and the R by W bivariate interactions significantly improved Model 8's explanatory ability over Model 1, which contained only parameters for the R, C, and W main effects, ($L1^2-L8^2= 12.53$, $df = 2$, $p<.01$). Model 7, which contained parameters for the three main effects plus the R by C interaction, also fit worse than Model 8 ($L7^2-L8^2= 4.35$, $df = 1$, $p<.05$). However, addition of the W main effect and the R by W interaction in Model 8 did not significantly improve its explanatory ability over Model 2, ($L2^2-L8^2= 4.46$, $df = 2$, $p>.05$). That is, while the R by W interaction did provide additional information, the addition of the main effect for W did not. Lambda and standardized lambda statistics for Models 2 and 8 are shown in Table 10. For Model 2, the standardized lambda for the C main effect and the R by C bivariate interaction were significant. For Model 8, only the standardized lambda value for the R by W interaction proved significant. Because Model 2 produced parameter estimates of greater explanatory significance, this model was chosen as best fitting the data and Model 8 was rejected. However, had the sample size been larger, Model 8 may have proved the more accurate model. Model 2

Table 9
 Log Linear Analysis
 of Electrical Wiring Students'
 Stage Level Data

Model	Degrees of Freedom	Likelihood Chi Sq.	Probability Levels
1. R,C,W	4	12.65	.0131
2. R,C,RC	4	4.58	.3328
3. R,W,RW	4	16.14	.0028
4. C,W,CW	4	11.71	.0197
5. R,C,W,CW	3	11.71	.0085
6. R,C,W,RW	3	8.31	.0401
7. R,C,W,RC	3	4.47	.2154
8. R,C,W,RC,RW	2	0.12	.9413
9. R,C,W,RW,CW	2	7.36	.0252
10. R,C,W,RC,CW	2	3.52	.1717
11. R,C,W,RC,RW,CW	1	0.12	.7280

Task Variable Code: R = Rod Flexibility Task
 C = Carpentry Task
 W = Electrical Wiring Task

Table 10
 Lambda and Standardized Lambda Statistics
 for Two Selected Models of
 Electrical Wiring Students' Stage Level Data

Model Parameter	Lambda	Standardized Lambda
Model 2		
R	-0.375	-1.320
C	0.723	2.536
R C	0.664	2.330
Model 8		
R	-0.352	-0.058
C	0.723	0.058
W	-0.067	-0.366
R C	0.664	0.134
R W	0.370	2.015

indicated that for wiring students, there was a significant main effect for stage level on the carpentry task and a significant bivariate interaction between stage levels on the rod flexibility and carpentry tasks. This interaction indicated that operational performance on the rod flexibility task was correlated with operational performance on the carpentry task, i.e., subjects who demonstrated concrete or formal operativity on one task tended to demonstrate similar operativity on the other.

Prompt Analyses

The main prompt hypothesis (hypothesis 2) predicted that subjects would require fewer prompts to attain full formal reasoning on tasks of a familiar content than on tasks of a less familiar content. This hypothesis was partially confirmed by statistical analyses of the prompt data. These analyses did not support hypothesis 2a for the carpentry students but did support hypothesis 2b for the electrical wiring students. The mean number of prompts required by carpentry students to exit the carpentry and electrical wiring tasks were 3.57 and 2.87, respectively. A t test found no significant difference between these two prompt means. The mean number of prompts required by electrical wiring students to demonstrate full formal reasoning on the carpentry and electrical wiring tasks was 4.13 and 2.60, respectively. A t test revealed a

significant difference between these two prompt means, $t(29) = 4.01$, $p < .01$. Therefore, contrary to prompt hypothesis 2a, high school students trained in carpentry did not require fewer prompts to demonstrate full formal reasoning on the familiar task than on the less familiar task. No significant difference was found between their two prompt means. However, consistent with hypothesis 2b, high school students trained in electrical wiring required significantly fewer prompts to demonstrate full formal reasoning on the familiar task than on the less familiar task.

The relationship between task, stage level, and prompt number was also explored using log linear analyses. Possible models, or statements of the expected cell frequencies as a function of stage level on the rod flexibility task or the particular vocational task under investigation (and their relationship to each other) were fit to the observed prompt score data. The frequency distribution of subjects' prompt scores from which these analyses were calculated appear in Tables 11 and 12. Results of these analyses appear in Tables 13 through 16.

In these log linear analyses, stage level and prompt variable codes were used. The stage level variable codes employed were R for the rod flexibility task, C for the carpentry task, and W for the electrical wiring stage.

Table 11
 Grouped Frequency Distributions
 of Carpentry Students'
 Prompt Scores
 on the Carpentry and Wiring Tasks

Prompt Group	Rod Flexibility Task			
	Concrete Operational		Formal Operational	
	Concrete	Formal	Concrete	Formal
	Carpentry Task			
4 or more	7	1	4	2
3 or fewer	2	1	6	7
	Electrical Wiring Task			
4 or more	7	1	3	2
3 or fewer	1	2	4	10

Table 12
 Grouped Frequency Distributions
 of Electrical Wiring Students'
 Prompt Scores
 on the Carpentry and Wiring Tasks

Prompt Group	Rod Flexibility Task			
	Concrete Operational		Formal Operational	
	Concrete	Formal	Concrete	Formal
Carpentry Task				
4 or more	14	0	3	3
3 or fewer	1	0	5	4
Electrical Wiring Task				
4 or more	10	1	2	1
3 or fewer	0	4	2	10

Prompt variable codes were labelled K for scores on the carpentry task, and L for scores on the electrical wiring task. For these analyses both the variables of stage level and prompt number were dichotomized to minimize the number of cells with observed frequencies equal to zero. As in the log linear analyses of stage level data, substages IIA and IIB were collapsed and labelled "concrete operational", while substages IIIA and IIIB were also collapsed and labelled "formal operational". The seven prompt categories, each corresponding to the number of prompts needed by the subject to demonstrate full formal reasoning, were dichotomized as follows: scores between zero and three were collapsed and labelled "low scores", and scores between four and seven were collapsed and labelled "high scores". This particular prompt division was based on the point in the prompt series where the isolation and control of variables strategy was revealed to the subject. No direct statement or explanation of the control of variables strategy was given in prompts zero to three. The strategy was first given with prompt four, and repeated with an explanatory demonstration with each successive prompt.

The probability statistics for models fitted to the prompt score data patterns of carpentry students on the carpentry task (Table 13) revealed that all but one of the p values were above the suggested minimum range. Comparisons between models indicated that Model 3 provided the best and

Table 13

Log Linear Statistics
for Carpentry Students'
Prompt Data

Models	Degrees of Freedom	Likelihood Chi Sq(L ²)	Probability Levels
Carpentry Task			
1. R,C	5	7.72	.1722
2. R,C,K	4	7.60	.1072
3. R,K,KR	4	5.27	.2607
4. R,C,RC	4	5.60	.2312
5. K,C,KC	4	7.22	.1248
6. R,C,K,KR	3	3.37	.3380
7. R,C,K,RC	3	5.48	.1398
8. R,C,K,KC	3	5.32	.1499
9. R,C,K,KR,RC	2	1.25	.5363
10. R,C,K,KR,KC	2	1.08	.5815
11. R,C,K,RC,KC	2	3.19	.2024
12. R,C,K,RC,KR,KC	1	.05	.8254
Electrical Wiring Task			
1. R,W	5	13.21	.0200
2. R,W,L	4	12.74	.0126
3. R,L,LR	4	7.26	.1230
4. R,W,RW	4	10.04	.0398
5. L,W,LW	4	8.60	.0718
6. R,W,L,LR	3	7.26	.0642
7. R,W,L,RW	3	9.57	.0226
8. R,W,L,LW	3	6.70	.0819
9. R,W,L,RL,RW	2	4.08	.1301
10. R,W,L,RL,LW	2	1.22	.5440
11. R,W,L,RW,LW	2	3.53	.1713
12. R,W,L,RW,RL,LW	1	.31	.5769

Stage Level Code: R = Rod Flexibility Task Stage Level
 C = Carpentry Task Stage Level
 W = Wiring Task Stage Level

Prompt Code: K = Prompts on Carpentry Task
 L = Prompts on Wiring Task

most parsimonious fit of the data ($L3^2 - L6^2 = 1.80$, $df = 1$, $p > .05$; $L3^2 - L10^2 = 4.19$, $df = 2$, $p > .05$). Examination of the lambda and standardized lambda values for the model (Table 14) indicated that the K by R bivariate interaction was of primary explanatory significance. That is, the number of prompts needed by carpentry students to demonstrate full formal reasoning on the carpentry task was related to the stage level of these students on the rod flexibility task. Students who initially evidenced concrete operational performance in response to the open ended administration of the rod flexibility task were more likely to require four or more prompts, than three or fewer prompts to demonstrate full formal reasoning on the carpentry task. Conversely, students who evidenced formal operational performance in response to the rod flexibility task were more like to require three or fewer prompts, than four or more prompts to demonstrate formal operational reasoning on the carpentry task.

Models fit to the prompt score data patterns of carpentry students on the electrical wiring task appear in Table 13. Five models had p values above .10. These were models 3, 9, 10, 11, and 12. Comparisons between Models 3, 9, and 10 indicated that Model 10 provided the best fit for the data and was the most parsimonious ($L3^2 - L9^2 = 3.26$, $df = 2$, $p > .05$; $L3^2 - L10^2 = 6.04$, $df = 2$, $p < .05$). Models 3 and 9 were consequently rejected. Model 11 was rejected for its inability to provide significant additional information

Table 14

Lambda and Standardized Lambda Statistics
of Selected Models
for Carpentry Students
Prompt Score Data

Model Parameter	Lambda	Standardized Lambda
Carpentry Task - Model 3		
K	-.029	-0.153
R	-.250	-1.320
R K	-.376	-1.983
Electrical Wiring Task - Model 10		
L	.051	0.245
R	-.229	-1.188
W	.060	0.312
R L	-.432	-2.240
W L	-.446	-2.335

beyond that supplied by Model 8, an insignificant model. Model 12 was also rejected because it lacked parsimony. Model 10 was therefore chosen since it best fit the prompt score data patterns and was most parsimonious. The lambda and standardized lambda values for Model 10 (Table 14) indicated that both the RL and LW bivariate interactions were of significant explanatory value. That is, the number of prompts required by carpentry students to demonstrate full formal reasoning on the electrical wiring task was related to their stage level scores on both the rod flexibility task and the electrical wiring task. Students who were concrete operational on the rod flexibility and wiring task were more likely to require four or more prompts, than three or fewer prompts to exit the latter task, while students who were formal operational on the two tasks were more likely to require three or fewer prompts.

Results of the log linear analyses of the prompt scores for electrical wiring students on the two vocational tasks appear in Tables 15 and 16. For models fit to the data patterns on the carpentry task, only two models, 9 and 12, produced acceptable probability statistics. A comparison of the likelihood ratio chi squares and degrees of freedom of these models led to the acceptance of Model 9 as best fitting the data ($L_9^2 - L_{12}^2 = .02$, $df = 1$, $p > .05$). The lambda and standardized lambda values for the model (Table 16) indicated the explanatory significance of the main effect for C, and the two bivariate interactions RK and RC. This

Table 15
 Log Linear Statistics
 for Electrical Wiring Students'
 Prompt Data

Model	Degrees of Freedom	Likelihood Chi Sq(L ²)	Probability Levels
Carpentry Task			
1. R,C	5	20.98	.0008
2. R,C,K	4	18.00	.0012
3. R,K,RK	4	17.03	.0019
4. R,C,RC	4	12.80	.0123
5. K,C,KC	4	15.86	.0032
6. R,C,K,KR	3	9.20	.0268
7. R,C,K,RC	3	9.81	.0202
8. R,C,K,KC	3	15.86	.0012
9. R,C,K,RK,RC	2	1.01	.6023
10. R,C,K,RK,KC	2	7.06	.0293
11. R,C,K,RC,KC	2	7.68	.0215
12. R,C,K,RC,RK,KC	1	.99	.3206
Electrical Wiring Task			
1. R,W	5	24.69	.0002
2. R,W,L	4	24.57	.0001
3. R,L,RL	4	16.82	.0021
4. R,W,RW	4	20.34	.0004
5. L,W,LW	4	9.22	.0559
6. R,W,L,RL	3	16.70	.0008
7. R,W,L,RW	3	20.23	.0002
8. R,W,L,LW	3	9.22	.0265
9. R,W,L,RL,RW	2	12.36	.0021
10. R,W,L,RL,LW	2	1.35	.5095
11. R,W,L,RW,LW	2	4.87	.0875
12. R,W,L,RW,RL,LW	1	1.17	.2785

Stage Level Code: R = Rod Flexibility Task Stage Level
 C = Carpentry Task Stage Level
 W = Wiring Task Stage Level

Prompt Code: K = Carpentry Task Prompt Score
 L = Wiring Task Prompt Score

Table 16

Lambda and Standardized Lambda Statistics
of Selected Models
for Electrical Wiring Students
Prompt Score Data

Model Parameter	Lambda	Standardized Lambda
Carpentry Task - Model		
K	-.414	-1.843
R	-.588	-1.837
C	.723	2.536
R K	-.593	-2.636
R C	.664	2.330
Electrical Wiring Task - Model 10		
L	.053	0.216
R	.036	0.183
W	.036	0.159
R L	-.514	-2.629
W L	-.769	-3.417

model indicated that a complex relationship existed among the number of prompts needed by electrical students to exit the carpentry task and stage level on both the carpentry and rod flexibility tasks. Stage level on the rod flexibility task was correlated with stage level on the carpentry task. That is, the subjects who demonstrated concrete or formal operativity on the rod flexibility task had a tendency to be ranked, or ordered respective to each other, in a similar manner on the carpentry task (RC). However, the number of prompts needed by these subjects to exit the carpentry task was more closely related to these same subjects' stage level on the rod flexibility task. Subjects who evidenced concrete operational performance on the rod flexibility task were more likely to require four or more prompts, than three or fewer prompts to exit the carpentry task, while subjects who evidenced formal operational performance on the rod flexibility task were likely to require three or fewer prompts to exit the task.

Two models, 10 and 12, produced acceptable probability levels for models fitted to the prompt score patterns of wiring students on the wiring task. Comparison of the likelihood ratio chi squares and degrees of freedom of these two models led to the acceptance of Model 10 as the most parsimonious and best fitting the data ($L_{10}^2 - L_{12}^2 = .18$, $df = 1$, $p > .05$). The standardized lambdas of this model, shown in Table 16, indicated explanatory significance in the R by L and the W by L interactions. That is, the number of prompts required by electrical students to demonstrate full formal

reasoning on the electrical wiring task was related to the students' stage level scores on both the rod flexibility and electrical wiring tasks. Students who demonstrated concrete operational performance on the rod flexibility and/or the electrical wiring tasks were more likely to require four or more prompts than three or fewer prompts to exit the wiring task, while those who performed at the formal level on the two tasks were more likely to require three or fewer prompts.

Chapter 4

DISCUSSION

The present study investigated the relationship between task familiarity and problem solving. Task familiarity was operationalized by employing materials typically encountered in subjects' areas of vocational training and/or specialization and required an isolation and control of variables strategy for solution. For each of two vocational high school populations (one majoring in carpentry, the other in electrical wiring), an experimenter designed reasoning task was constructed. Subjects' stage level reasoning was assessed in response to the two vocational tasks and the Inhelder and Piaget (1958) rod flexibility task.

It was hypothesized that problem solving would be facilitated by tasks which employed materials familiar to the subjects' areas of vocational training. More specifically, it was hypothesized that subjects would perform at their maximum operational level and would require fewer prompts or clues to problem solution on the familiar task than on less familiar or unfamiliar tasks.

Results of the investigation indicated that task familiarity did not unequivocally facilitate operational performance and prompt utilization. Task familiarity was found to have both facilitative and inhibitory effects on formal operational performance. Moreover, the number of

prompts needed by subjects to demonstrate formal reasoning on the two vocational tasks was influenced by task familiarity and by subjects' operational ability. Subjects trained in carpentry performed significantly poorer on the hypothesized familiar carpentry task than on the other two reasoning tasks. Also, carpentry students required more prompts to solve the carpentry task than the wiring task. Their prompt utilization pattern was inversely correlated to their operational level on the rod flexibility task (the task on which they achieved their highest mean stage level score). Subjects majoring in electrical wiring performed significantly better on the hypothesized familiar wiring task than on the unfamiliar carpentry task. However, performance on the former task was not significantly different from performance on the rod flexibility task. Wiring students required significantly fewer prompts to solve the wiring task than the carpentry task but their prompt pattern was correlated to operational levels on both the wiring and the rod flexibility tasks.

Discussion of the above findings is organized in three sections: 1) the relationship between task familiarity and operational level, 2) the relationship between task familiarity and prompt number, and 3) conclusions and recommendations for future research.

Task Familiarity and Operational Level

Piaget's concept of task familiarity proved more complex to operationalize and control than initially perceived. A major problem the current study encountered was Piaget's lack of clarity in defining this concept. Piaget did not distinguish between familiarity of task content (i.e., the materials used in the study) and familiarity of strategy (i.e., the reasoning process desired for problem solution). The 1972 modification (Piaget, 1972) did not specifically refer to familiarity of task content or to familiarity of reasoning strategy. Piaget stated that it was likely that certain groups, such as apprentice carpenters, knew how to reason in a hypothetical manner within their speciality. That is to say, they could dissociate the variables involved, relate terms in a combinatorial manner, and reason with propositions involving negation and reciprocities. On the one hand, this statement could mean that a task of familiar content alone could and would elicit these formal strategies from the vocationally trained subject. On the other hand, it could mean that the experimental situation must not only be framed in terms and materials commonly encountered in the field, but require a sequence of steps for solution typically employed in the trade and used with those materials as well. Previous work by Piaget (1968) introduced the concept of "resistance of objects" to explain horizontal decalage. In addition, Flavell (1963) described how task contents differ in the

extent to which they inhibit application of cognitive structures. The present study assumed that it was familiarity of task content alone to which Piaget's 1972 modification referred. This assumption led to complications in interpreting subjects' stage level performance on the two vocational tasks.

Another problem encountered was in the implementation and control of task familiarity in the subject population. In New York City vocational high schools, first year students are required to take a full year of "exploratory" courses. That is, for two semesters, students receive courses in each of the vocational specializations offered at their respective trade schools. All subjects in the present study received training in other area specializations regardless of major. This curriculum requirement made it virtually impossible to obtain a high school population with no formal training with the unfamiliar vocational area. Consequently, carpentry students used in the present study received a full semester of instruction in electrical wiring, and conversely, wiring students received a full semester of carpentry instruction. Discussion of the results of the present study is in light of these considerations.

Rod Flexibility Task

Piaget's (1972) modification to his theory of cognitive development asserted that a primary reason other researchers investigating formal operations were unable to replicate its

relative incidence in their respective subject populations was due to a mismatch between subjects and tasks. Piaget offered, by way of illustration, that carpenters and mechanics may not be able to evidence formal operations in response to the classical Inhelder and Piaget (1958) measures, but if given tasks that were familiar to their areas of training, they will evidence formal reasoning.

In accordance with the 1972 modification the current study assumed that the Inhelder and Piaget rod flexibility task was an inappropriate and unfamiliar task for the current population. It was also assumed, due to the subjects' previous training in both vocational areas, that the Inhelder and Piaget task would be the least familiar of the three experimental tasks and subjects would perform their poorest on this task.

In response to the rod flexibility task, vocationally-trained, inner-city high school students' incidences of formal operational reasoning was comparable to their best performance on the two vocational tasks. Almost fifty-seven percent (56.6 percent) of all subjects used in the present study obtained scores indicative of formal operational reasoning (IIIA and IIIB) on the rod flexibility task. When performance criteria was restricted to full formal reasoning (IIIB), 27 percent of all subjects obtained scores at this level. No significant improvement above these scores was found when subjects were presented with reasoning tasks which required the same formal strategy for solution and employed materials familiar to their specific

area of vocational training. Moreover, these rates were comparable to the majority of Western studies employing some combination of the Inhelder and Piaget (1958) reasoning tasks. Previous researchers (Jackson, 1963; Dulit, 1972; Lee, 1971; and Tomlinsen-Keasey, 1972) also found that approximately 50 percent of the subjects they tested performed at the combined early and advanced formal levels, while the incidence of full formal reasoning seldom exceeded 30 percent of the subjects tested.

The present findings are of significance for three reasons: 1) the demographic nature of the present subject population, 2) the appropriateness of the Inhelder and Piaget task as an assessment tool for this population and 3) the failure of the familiar tasks to significantly improve subjects' stage level reasoning.

Subjects in the current study differed from subjects in previous research on formal operational reasoning in two regards: racial and socio-economic background, and educational training. Previous research (Dulit, 1972; Kuhn and Angelev, 1976; Kuhn and Brannock, 1977) typically used subjects who were predominantly white and from the lower-middle to upper-middle classes. In addition, these studies used subjects whose school experience was academic in nature. In several studies (Tomlinsen-Keasey, 1972; Diamond et al, 1977; Kuhn, Ho and Adams, 1979) college trained subjects were used. In contrast, the present study used subjects who were predominantly Black and Hispanic, and who were from working and lower working classes. In

addition, the subjects' current school experience stressed vocational training. Although subjects' vocational training included a physics and a Strength of Materials course, reports from classroom teachers indicated that these curricula were very basic and practical in nature. Despite these differences between the previous and present subject samples, the latter group demonstrated formal reasoning in proportions consistent with previous studies.

Inhelder and Piaget's (1958) rod flexibility task proved an appropriate assessment tool of the vocationally-trained, high school subjects' operational ability. Mean stage level on this task was comparable to the subjects' best mean stage level on the two vocational tasks. Carpentry students evidenced their highest mean stage level on this task. Subjects' performance may have been due, in part, to the familiar nature of the rod flexibility task for a vocationally trained population. Previous researchers disagree on whether the rod flexibility task differs from the other Inhelder and Piaget (1958) problem solving tasks in its familiarity to a vocationally trained population. Ribaupierre and Pascual-Leone (1979) made no distinction between Inhelder and Piaget's 15 problem solving tasks and found that in eight out of nine of the tasks the performance of subjects engaged in "non academic" curricula did not differ from subjects engaged in "academic" curricula. However, Uzan (1978) found that vocationally trained subjects performed significantly better on those tasks which he categorized as within the "physical domain"

than on those which he categorized as within the "logical domain". Uzan placed the rod flexibility task within the physical domain.

The present subject sample may have been an appropriate population for another reason. Piaget's (1972) modification stated that the 1958 formal reasoning tasks were most appropriate for subjects who were still in school and who had taken courses in the physical sciences. The present subject sample met both of these criteria. Although Piaget may not have considered the present sample a typical "school" population and therefore inappropriate for the administration of the rod flexibility task, the present findings would deny this assertion and extend the nature of the "school" population to include vocationally trained populations.

No significant improvement in vocational subjects' stage level reasoning was achieved by the provision of tasks of a content specific to their area of vocational specialization. This finding is understandable if the rod flexibility task was not only an appropriate tool for operational assessment of the current vocational sample, but a familiar task as well. Subjects' performance on this task would then be at or near their cognitive ceiling and operational performance should not be significantly improved by task familiarity.

Vocational Tasks

The results of the rod flexibility task did not explain the subjects' pattern of performance on the two vocational tasks. Regardless of subject major, both populations performed similarly on the two tasks. Both carpentry and electrical wiring students performed significantly better on the electrical wiring task than on the carpentry task. A key to understanding these results lies in the distinction between content versus strategy familiarity.

The effects of content familiarity are not unidirectional. Content familiarity can have both facilitative and inhibitory effects on problem solving depending upon the interaction of content familiarity with strategy familiarity. According to learning theorists, problem solving is facilitated when learning in one situation aids learning or problem solving in a new situation. Birch and Rabinowitz (1968) called this process reproductive thinking. Ellis (1965) termed it positive transfer and stated that it applied when two learning or problem solving activities contained identical elements (contents); required similar responses or techniques (schemes); or employed similar principles. According to Pascual-Leone's (1978, 1979) neo-Piagetian Theory of Constructive Operators, problem solving is facilitated when previously learned schemes and strategies compatible with the present problem solving situation are activated by the new task situation.

Content familiarity can also inhibit problem solving. When ones previous experience with the task materials is very different from the strategies required by the present problem to be solved, problem solving is impaired. Learning and neoPiagetian information processing theorists were also familiar with this process. Birch and Rabinowitz (1968) stated that past experience may become a hindrance and an obstacle to problem solving if the problem solver is "chained to the past". Duncker (1945), writing on functional fixedness, found that previous utilization of an object in a manner dissimilar to its use in a present problem solving context affected subsequent problem solving. He stated that previous experience with objects made them less available as instruments in the new situation. Ellis (1972) called this effect negative transfer and stated that it resulted when different responses were associated with the same or similar stimuli in two separate learning situations. According to Pascual-Leone's (1969) theory in cases of this nature, operative schemes are boosted which are inappropriate for the present problem solving task. These inappropriate schemes are then applied to the task, and, as a consequence, inhibit or delay the application of correct schemes.

What appears to be important in determining whether preutilization will facilitate or inhibit current task performance is the nature of the preutilization experience. If the previous experience with problem solving materials involved the employment of strategies or schemes which are

the same or are similar to the current task demands, problem solving is facilitated. If previous experience with materials involved the employment of schemes which are different from those desired in the present problem solving situation, an inhibitory effect occurs. Both facilitative and inhibitory effects of previous experience were in evidence in the subjects' response to the two vocational tasks.

The Electrical Wiring Task: Electrical wiring and carpentry students obtained the same mean stage level scores in response to the electrical wiring task. For both populations, no significant difference was found between mean scores on this task and the rod flexibility task.

Previous training in electrical wiring had differential facilitative and inhibitory effects for the two subject samples. Exploratory training facilitated problem solving for both populations while advanced training might have inhibited the performance of some students trained in electrical wiring. Students' exploratory courses in electrical wiring exposed both populations to all parts of the experimental apparatus save one, the diode. This course also equipped both populations with a rudimentary strategy for use with these materials. In the two schools from which students were drawn, this strategy was variously called "trouble shooting", or, "the process of elimination", and was similar to the isolation and control of variables strategy required by the experimental task. This training

therefore provided not only content familiarity but strategy familiarity as well. The operational schemes that were associated with, or elicited by these previously experienced materials were appropriate and useful to the current problem solving situation. As a result, positive transfer (Ellis, 1972) occurred and problem solving was facilitated.

Advanced training in electrical wiring might have led to differences between wiring and carpentry students in their problem solving approaches. Differences were primarily evidenced in preexperimental discussion and preparation, and in the use of experimental shortcuts. Before wiring students began to manipulate the apparatus, many asked pointed questions about the equipment. Typical questions were: "What does the blue band on the diode mean?", "Why are there three wires coming from the motor when you only need two?". Although all subjects were told that the underlying circuitry was "correct" during the initial task administration, approximately two thirds of the wiring students picked up and examined the underlying circuitry. Some correlated the under wires with the specific electrical parts on top of the apparatus (i.e., diode, motor, switch, and batteries) while others merely inspected the under wires and commented that "Everything seems to be okay". Similarly, about half of the wiring students inspected the wires emanating from the motor. Several tried to gently tug on the wires to see if one was not directly connected to the motor. Carpentry students seldom evidenced the above forms of pre-experimental questioning and preparation. Typically,

carpentry students asked the following sorts of questions: "What did you say the diode does?", "Aren't there too many wires coming from the motor?", and "Are the batteries good?". Only two carpentry students inspected the wires under the apparatus and of these, one commented that he wasn't sure what he was looking for. Carpentry students never closely inspected the motor or the attached wires before experimentation.

The greatest difference that emerged between the two populations was in the use of shortcuts to problem solving. To test the viability of the motor, about one third of the electrical wiring students initially attempted the same solution: Students would hold the motor in one hand and attach two of the three wires extending from the motor directly to the positive and negative poles of the battery. They were thus able to quickly test the viability of the motor, ascertain which two of the three wires were live, and effectively bypass a test of the viability of the diode "until later". Carpentry students never used shortcuts.

Differences between subject populations in their problem solving approaches were poorly, or even negatively reflected in the stage level scoring system. Few provisions were made for rating the content of subjects' discussions. Comments were scrutinized only for references to intentions to control variables. Subjects were allowed to inspect the apparatus, but were instructed not to pull on the wires extending from the motor. Although manipulation of the apparatus in this manner did not effect subjects' stage

level scores, use of wiring shortcuts could result in depressed scores. When subjects used a shortcut to test the motor, they often switched the wires that they touched to the battery poles. This confused scoring because, for a test of motor viability, subjects should have switched motors and held wire position constant. With this shortcut, the motor was often held constant while wire position was changed. This was scored as a confounded test. Initial use of shortcuts was not scored. However, subjects were requested not to use this procedure and to solve the problem as if they had no knowledge of it. Some subjects calmly accepted the directive and proceeded to another test. Other subjects protested that the shortcut was standard procedure within the field. Still others appeared disconcerted and hesitant to proceed. This latter group appeared to no longer know what was being asked of them nor what to do next.

In summary, previous training in electrical wiring had differing affects on the two subject populations. Carpentry students were aided in solving the experimental wiring task by their exploratory course. Although carpentry students' previous training was less recent than that of electrical wiring students, this training led to familiarity with the task materials. More importantly, it gave these students a specific strategy or problem solving approach for use with these materials that was appropriate for the current experimental situation. Conversely, students majoring in electrical wiring were both aided and impeded in solving the

wiring task by their previous training in the field. Training in electrical wiring received early in their vocational instruction facilitated solution to the experimental task by electrical wiring students. However, advanced training at times diverged from a strict application of the isolation and control of variables strategy. When this occurred in the form of problem solving shortcuts, use of advanced wiring strategies retarded solution to the experimental task and may even have depressed subjects' stage level scores.

Carpentry Task: Both subject populations obtained their lowest mean stage level scores in response to the carpentry task. These scores were significantly lower than mean scores on the other two reasoning tasks. Two possible factors could account for these results: 1)the task was inherently more difficult than the other two reasoning tasks, and 2)previous experience with the task materials inhibited task performance. Each of these possibilities is discussed below.

1)Task Difficulty: For a pilot sample, untrained in carpentry and electrical wiring, stage level performance on the carpentry task was comparable with performance on the other two reasoning tasks. A pilot study was conducted with 15 male and female subjects with no previous experience or training in electrical wiring or carpentry. Analysis of the pilot data found no significant difference between mean stage levels on the three tasks (see Table 1, page 49).

With one exception, all subjects who initially demonstrated formal reasoning (IIIA or IIIB) on the rod flexibility task (n=8) continued to evidence some level of formal operational reasoning in response to the two vocational tasks. Of the seven subjects who performed at the concrete level, five scored at the early concrete level (IIA) and two at the late concrete level (IIB). Subjects in the former group continued to evidence IIA level reasoning across all three tasks. Of the two subjects in the latter group (IIB level reasoners), one evidenced full formal reasoning on the two vocational tasks, and the other evidenced increasingly higher stage level scores across the two tasks.

Therefore, it appeared that with a nonvocational population, untrained in the areas of carpentry and electrical wiring, the three reasoning tasks were of comparable difficulty. For the pilot population the carpentry task was not inherently more difficult nor did it lead to consistently poorer stage level performance. However, because of ceiling and floor effects evidenced in nine of the fifteen pilot subjects and to wide variation between the pilot and experimental populations, caution is recommended in comparing these findings with those of the experimental population.

For the two subject populations, the carpentry task may have become a more difficult task as a result of their vocational training. Through their instruction, vocationally-trained subjects may have acquired perceptual and behavioral schemes that interfered with, or were

incompatible with operational schemes demanded by the experimental situation, thus rendering the task more difficult. This possibility is discussed below.

2)The Effects of Previous Training: Both populations received training in carpentry, but differed in the amount of familiarity that previous training provided. Exploratory training in carpentry focused neither on the materials nor practices used in building construction (the field from which the experimental task took its content). This training focused instead on the principles, materials and practice of cabinetry. Students in exploratory carpentry learned how to read plans for and construct simple cabinets and other small pieces of furniture. When interviewed, electrical students stated that although they had a general knowledge of the materials employed in the carpentry task, they had never used these materials nor received instruction in their use in or outside of school. However, carpentry students had both instruction and experience with the materials employed in the carpentry task with one exception - the stakes. This training was provided in their advanced courses. As a result, electrical wiring students were relatively unfamiliar with the materials used in the carpentry task, while carpentry students had both instruction and experience with these materials. However, exploratory training may have provided a perceptual scheme for the general practice of carpentry. This perceptual scheme was furthered in advanced carpentry courses in

building construction. In particular, instruction in these principles appeared to affect the manner in which vocationally trained subjects perceived and manipulated the experimental apparatus.

Training in carpentry provided subjects with perceptual and/or operational schemes for use with carpentry materials which interfered with performance on the experimental task. The demands of the carpentry task required students to perceive the task variables as isolated entities capable of independent manipulation and influence. Subjects were required to hold three variables constant while changing a fourth. Vocationally trained subjects used in the present study had difficulty perceiving the four variables in the carpentry task as separate and independent entities. The four variables (brace length, brace thickness, stake length, stake thickness) were regularly perceived by the students as interconnected units. That is, subjects matched the long fat braces with the long fat stakes, the long thin braces with long thin stakes, and the short fat braces with short fat stakes. This constituted a kind of "goodness of fit" between these units. When initially demonstrating a test for one variable (e.g. brace thickness), many subjects would change the other variable (e.g. stake thickness) in conformity with this perceived interconnectedness.

Interviews with subjects and their instructors indicated that the perceptual approach to the task used by subjects was a product of their vocational instruction and practice in the field. Electrical wiring students said that

they were taught in their exploratory courses "to match things". This matching appeared to refer to a perceptual match or balance. Carpentry students stated that the matched braces and stakes "go together". The most revealing comment came from a carpentry instructor. After observing a student performing the task, he commented that while he understood the solution to the problem, the required tests of variables were "not how students of carpentry were taught to use the materials".

Wiring students performance on the carpentry task was therefore influenced by two factors: the relative novelty of the task materials and subjects' previous training in carpentry. To the extent that the task was novel, students attempted to apply a general problem solving strategy. Where the task was familiar, students applied a specific carpentry scheme. Although wiring students' performance on the carpentry task was significantly poorer than their performance on the rod flexibility task, log linear analyses indicated a correlation between the two sets of scores. This would indicate that formal and concrete reasoners on the rod flexibility task maintained their relative positions although their scores were displaced downward. This displacement resulted from students' attempts to apply previously acquired perceptual schemes toward the task materials that were incompatible with the task demands. In combination, these factors functioned to depress wiring students scores. Of 14 wiring students who obtained lower scores on the carpentry task than on the rod flexibility

task, nine regressed by only one substage, four regressed by two substages, and one regressed three substages.

Carpentry students performance was more sharply affected by their previous training in the field. Advanced training not only provided them with exposure to the task materials, but with perceptual and behavioral schemes for use with these materials. These schemes were incompatible with the current problem situation. Not only did this previous experience lead carpentry majors to link variables, but it handicapped them in another way. Several carpentry majors were found to have problems functioning within the task structure. Occasionally, certain constant factors such as sand were considered to be variables by the subjects. In these cases, subjects said that changes in the consistency of the sand would effect not only the length of the stakes, but whether a stake or some other type of securing device should be used. These subjects had to be specifically instructed to regard this factor as a constant. The combined inhibitory effects of previous training led to sharply depressed stage level scores. Of 15 carpentry students who obtained lower scores on the carpentry task than on the rod flexibility task, seven regressed more than two substages. Of the seven, four regressed three substages to demonstrate early concrete level reasoning on this task. What is most revealing is that all four had previously demonstrated full formal reasoning on the rod flexibility task.

However, the inhibitory effects of previous training in carpentry were not universal. Five carpentry students improved their stage level scores from those on the rod flexibility task. Only one wiring student showed improvement on this task.

In summary, vocationally trained subjects' performance on the carpentry task was very complex. Whether advanced or exploratory, previous training in carpentry appeared to have other than facilitative effects. Although exploratory training in carpentry did not directly expose vocational subjects to the materials used in the current study, it provided them with perceptual and behavioral schemes which were incompatible with the demands of the experimental task. Wiring students were predisposed by their training to match variables thereby inhibiting the use of the desired separation and control of variables strategy. Carpentry students' advanced training provided them not only with exposure to the experimental materials, but provided them with a perceptual and behavioral scheme for use with these materials. These schemes were also incompatible with the task demands. The carpentry students also matched variables. Moreover, some carpentry students found it difficult to perceive the task situation as intended (i.e., to accept some variables as constants). As a result, overall performance by both subject populations was depressed relative to their performance on the two tasks.

Results for the subject populations on the two vocational tasks indicated that problem solving, even at the

formal level, was not dissociated from task content. Problem solving approaches were primarily specific rather than general. In support of Pascual Leone's Theory of Constructive Operators, it appeared that the figurative aspects of the task situation boosted operative schemes that were applied to the current situation. Subjects attempted to apply specific knowledge (perceptual and behavioral schemes) learned in previously similar situations. Students applied wiring strategies on the wiring task and carpentry strategies and perceptual schemes to the carpentry task. It was "trouble shooting" or "the process of elimination" and not a general isolation and control of variables strategy that was applied on the wiring task. Students attempted to match variables on the carpentry task in accordance with their previous training in the field. Use of these previously learned schemes outweighed the use of more appropriate, general schemes of which the subjects were capable. As a consequence of the need to deactivate (Pascual-Leone, 1979) inappropriately applied figurative and operative schemes, the carpentry task was more difficult than the other two reasoning tasks for the current vocational population.

Task Familiarity and Prompt Utilization

The present study also hypothesized that task familiarity would affect the number of prompts or clues needed for problem solution. Specifically, it was hypothesized that subjects would require significantly fewer prompts to attain full formal reasoning on problem solving tasks of a familiar content than on problems of an unfamiliar content. This hypothesis was only partially confirmed by the data. Electrical wiring students required significantly fewer prompts to demonstrate full formal operational reasoning on the wiring task than on the carpentry task. However, there was no significant difference in the number of prompts required by carpentry students to exit the two vocational tasks. Findings indicated that the number of prompts required to evidence full formal reasoning on the two vocational tasks was influenced not only by task familiarity, but by subjects' operational level as well.

The effect of task familiarity was qualified by the interaction between content and strategy familiarity. The number of prompts required by subjects decreased when content familiarity facilitated task performance, i.e., when previously learned schemes did not inhibit the elicitation of the desired strategy. This occurred for both populations on the wiring task and as a result, their mean prompt numbers were nearly identical. However, content familiarity did not decrease the number of prompts when previously

learned strategies or perceptual schemes inhibited the elicitation of the desired strategy. Under these circumstances, more prompts were needed to 1) eliminate the inappropriate scheme and 2) to either inform students of the appropriateness of the previously demonstrated separation and control of variables strategy or instruct them in the use of this strategy if not previously demonstrated. These processes can probably occur both simultaneously and sequentially. For both populations, the number of prompts required on the carpentry task was greater than that required on the wiring task. The difference between mean number of prompts on the carpentry and wiring tasks was not significant for the carpentry population but was significant for the wiring population. For the former population, it appeared that once the inappropriate scheme was eliminated the familiar materials provided by this task had a facilitative effect. However, for the wiring students, once this first step was accomplished, the relative novelty of the task materials further inhibited their performance. Therefore, familiarity with task content may decrease the number of prompts subjects require to demonstrate full formal reasoning. However, this effect is not automatic, but qualified by the positive and negative effects of strategy familiarity.

Prompt utilization was also found to be related to subjects' operational stage on the rod flexibility and electrical wiring tasks. These were the two tasks on which subjects typically demonstrated their most advanced

reasoning. Subjects who were concrete operational on one or both of these tasks typically required four or more prompts for problem solution. Subjects who were formal operational on one or both of these tasks typically required three or fewer prompts for problem solution. To the extent that performance on these tasks was indicative of subjects' operational ability, prompt number was related to subjects' level of operativity.

A previous study on the effects of prompts and problem solving also found that prompt number was more related to internal organismic factors than task factors. Danner and Day (1977) found that the mean number of prompts subjects needed to demonstrate formal operativity on two of the Inhelder and Piaget (1958) tasks decreased with subjects' age and operational ability. They asserted that older subjects (age 13) had formal ability that could be elicited by the prompts or instructional series. Danner and Day concluded that the differential value of instruction was dependent upon what knowledge subjects brought to the task.

The present study differed from the Danner and Day (1977) study in several respects. In the Danner and Day study, prompts were administered only to those subjects who performed at the concrete operational level. In the current study, prompts were administered to subjects who performed at the concrete and early formal operational levels. All three tasks in the Danner and Day study were formal tasks and were not specifically relevant to the subjects' areas of interest or training. In the present study, in addition to

the Inhelder and Piaget rod flexibility task, reasoning tasks which were familiar to subjects' areas of vocational training were included. In the former study, formal operational ability was partially assumed to be present by virtue of subjects' age. In the current study, operational ability was demonstrated rather than assumed. Nonetheless, like the Danner and Day study, the current study found that the differential ability of subjects to benefit from prompts was related to the differential abilities subjects brought to the experimental situation.

Like the Danner and Day (1977) study, the present study also indicated that the prompt series was unable to train formal operational reasoning in a significant number of subjects who had not previously demonstrated this ability. Of the 26 subjects who evidenced concrete operational performance (IIA or IIB' on the rod flexibility task, 18 continued to evidence concrete operational performance across the two vocational tasks. Of five subjects who evidenced early concrete operational performance (IIA) across all three tasks, all required four or more prompts on the two vocational tasks. Of the seven subjects who evidenced late concrete operational performance across all three tasks, five required four or more prompts. The initial prompt series was inadequate to induce spontaneous formal operational reasoning on the second vocational task and these subjects subsequently required varying degrees of restatement and demonstration of the desired strategy. Therefore, it appeared that for most of these students, the

formal strategy was not present as a latent strategy or competence that could be "elicited" nor was the initial prompt series able to induce formal reasoning during the open-ended administration of the second vocational task.

The current study did provide some heuristic evidence that subjects can learn to apply general problem solving strategies across content domains. This evidence was provided by individual subjects' response to the prompt series. After the start of the prompt series for the second vocational task, several subjects realized that it was the same series of prompts except for the illustrative examples. They correctly surmised that they were to "change only one thing at a time" on the current task.

However, the results of the present study cannot determine the extent to which improvement in operational level and a decrease in the use of prompts across tasks was a function of task familiarity or prompt effects. Of the original 26 subjects who performed at the concrete operational level on the rod flexibility task, eight evidenced formal operational reasoning (IIIA or IIIB) on either one or both of the vocational tasks. All of these subjects had evidenced late concrete operational performance on the rod flexibility task. These subjects may have been in a transitional state of cognitive readiness and the prompt series functioned to precipitate a cognitive reorganization akin to Vygotsky's (1978) "zone of proximal

development". However, this is speculative and the improvement might also have been a result of task familiarity.

Conclusions

The results of the present study reiterate the influence of task and organismic factors on formal operational performance and the use of prompts. Task familiarity proved a complex concept involving an interaction between content and strategy familiarity. Previous experience with task content may have both facilitative and inhibitory effects on problem solving. Facilitative effects were achieved when tasks of familiar content also required reasoning strategies that were consistent with subjects' previous experience with these materials. When the experimental task required strategies that were inconsistent or contradictory to strategies learned for use with these materials, reasoning was inhibited.

Organismic and task factors affected prompt performance and indicated that subjects differentially benefit from prompts. The number of prompts required to demonstrate full formal reasoning was both related to the subjects' most advanced level of operational performance and to the facilitative and inhibitory effects of task and strategy familiarity. How much subjects benefitted was primarily dependent upon the nature of the subjects' existing knowledge (i.e., what was previously learned) and their operational ability.

The Inhelder and Piaget (1958) rod flexibility task was also found to be an appropriate assessment tool of cognitive

ability for the vocationally trained high school students used in the present study. Its appropriateness may be due, in part, to subjects' vocational training rendering this task a familiar one. Subjects' performance on the rod flexibility task was found to be consistent with their most advanced performance on the two vocational tasks and with previous research using subjects whose education was more academically oriented. The current research would extend the applicability of this task to vocationally trained populations.

Formal operations was not found to be dissociated from the content of thought. Findings indicated that learning and problem solving strategies acquired in one subject domain were not spontaneously abstracted and transferred to another domain. For subjects who received prompts on both vocational tasks, there were few who realized that except for the illustrative examples, the two prompt series were identical. With regard to problem solving, individuals were found to apply particular strategies to particular tasks and strategies learned for use with a particular set of materials were typically elicited by those materials whether appropriate or inappropriate to the present problem solving situation.

There are two educational implications of the above findings. First, teachers cannot assume that a problem solving process learned with one set of materials, or in one subject domain, will be spontaneously abstracted and transferred to another set of materials or subject domain.

Strategy transfer must be taught. Therefore, problem solving approaches that are applicable across domains must be extracted as general schemes and their use demonstrated across domains. Otherwise, this knowledge will remain content bound. Extending this notion, the second educational implication is that classroom instruction should become more process oriented. Currently, classroom instruction tends to focus on the products of education (e.g. efficiently performing a particular task or responding to tests). As a consequence, constructive thinking is too often replaced by reproductive thinking. Students apply a rigid sequence of steps to problem solving tasks rather than constructing solutions. Although reproductive thinking is both time and cost efficient, students are often unable to generate alternative problem solving approaches when learned sequences fail to produce the desired results. However, this is not to say that content instruction should be totally replaced by courses in logic or problem solving. Rather, a balance must be achieved whereby specific content knowledge and broad problem solving approaches are disseminated.

The findings of the present study also have implications for future research. Contrary to Inhelder and Piaget's (1958) stage description, formal operational performance does not appear to be dissociated from the contents of thought, nor to spontaneously evolve toward increasing abstraction. Rather, Piaget's (1972) assertion, that manifestations of formal operations are frequently

domain and content specific, appears more accurate. If, as suggested by Flavell and Wohlwill (1969), the original Inhelder and Piaget (1958) stage description is more accurately regarded as a structural model of intellectual ability, future research should continue to investigate factors affecting formal operational performance. The findings of the present study would strongly suggest the need to further explore the influence of content and strategy familiarity. In addition, research exploring the relative incidence of formal operations among a population of skilled practitioners of a trade is needed. However, future research exploring the increasing specificity of formal thought must be responsive to the unique manifestations of advanced thinking within a particular field. Rigid application of presently existing stage level criteria and scoring systems may be inappropriate or insensitive to the unique characteristics of advanced thinking within a field. Findings of the present study suggests that future researchers take a more emic approach when constructing stage level and scoring criteria. Researchers should study how skilled craftspeople or practitioners of a trade solve problems within their field. An understanding of how these techniques diverge from a rigid definition of formal thinking should be used to modify existing scoring systems. Only then can research which seeks to accurately assess stage level thinking in skilled individuals be accurately conducted.

The present study concludes that task familiarity is not unequivocally facilitative. Task familiarity may have both facilitative and inhibitory affects based on the nature of subjects' previous experience with the task materials. This previous experience may even interfere with the elicitation of formal strategies in subjects who have previously demonstrated formal operations. From these findings it must be concluded that nothing is inevitable about the application of a formal strategy.

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