AN ABSTRACT OF THE THESIS OF

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Title Formal Reasoning Thought Among American and Chinese College Students

Abstract Approved: John C Schwenn

This research involved an analysis of the results of the formal reasoning total scores and eight subtest scores obtained from the Arlin Test of Formal Reasoning (ATFR). American and Chinese college students' ATFR scores were compared. The purposes of the present study are threefold: one, to examine the cross-cultural differences; two, to examine the effect of gender differences; and three, to examine the effect that major field has on formal reasoning ability.

The data were obtained from two groups. The first group included 44 American college students (17 males and 27 females, 14 of whom were science majors and 39 of whom were non-science majors). The mean age of the American group was 21.9 years. The second sample included 50 Chinese college students (24 males and 26 females, 22 of whom were science majors and 28 of whom were non-science majors). The mean age of the Chinese group was 24.3 years. All the subjects were given the ATFR.

Results obtained from the ATFR indicated that about the same proportion of students from the two cultures functioned at each cognitive level, namely the high concrete,

transitional, low formal, and high formal levels. None of the subjects performed at the concrete level. In addition, the present study indicated a significant difference that favors science majors, a difference indicated by both total scores and the "informs of conservation beyond direct verification" subtest. For the probabilistic reasoning, no significance was found among Americans; however, the male Chinese science majors surpassed the female Chinese science majors. In the "frames of reference" subtest, female non-science majors scored significantly lower than female science majors and male non-science majors. No significance was found among scores in the other five subtests.

The fact that science majors scored significantly higher than non-science majors suggests that the aptitude or learning interest in science or technology may be closely associated with the development of formal reasoning. In addition, because of the discrepancy between the Chinese males and females, it is conjectured that Chinese society and the educational system have not focused equitably on science training for females. Further, the higher scores of the science majors raises a question of scientific bias in the ATFR. Because of the suspected bias, it is suggested that further investigation be conducted to analyze the correlation between individuals' aptitude test scores and their ATFR scores.

FORMAL OPERATIONAL THOUGHT AMONG AMERICAN AND CHINESE COLLEGE STUDENTS

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CHAPTER 1

INTRODUCTION

During the past several decades, cognitive development has been gaining enormous attention among developmental psychologists and educators. The study of cognition is the understanding of the knowledge a person possesses, the organization of this knowledge, and the process for using this knowledge in the everyday activities of attention, learning, memory, comprehension, and problem-solving (Small, 1990).

Numerous studies have been based on Jean Piaget's comprehensive and coherent stage theory of cognitive development. Piaget assumes that cognitive structures pass through four major qualitative stages from birth to adulthood according the following order: sensorimotor, preparations, concrete operations, and formal operations. According to Inhelder and Piaget (1958), the first stage of cognitive development, sensorimotor stage, covers the period from birth to about age two. The child learns to coordinate perceptual and motor functions and to utilize certain elementary schemata for dealing with external objects. The child knows objects exist even when they are out of sight. The preoperational stage extends from the beginning of organized symbolic behavior, such as language, until about age six. During this stage, the child comes to represent the external world through the medium of symbols. Between 7 and 11 years of age, a logic of reversible actions (as adding and subtracting) is established. The child is now in the stage of concrete operations, characterized by the "formation of a certain number of stable and coherent structures, such as classification system, the construction of natural numbers, the concept of measurement of line and surfaces, projective relations (perspectives), certain general types of causality, etc." (p. 4, Piaget, 1972). These operations are "concrete" which means in using them the child still reasons in terms of objects (classes, relations, numbers) and not in terms of hypotheses that can be thought out before knowing whether they are true or false.

The present study focuses on the fourth stage, formal operations. Piaget (1972) assumed formal operational reasoning begin at 11 or 12 years of age and to be established by about age 15. In other words, the previous stage, concrete operations ends at the beginning of adolescence; thus adolescents are able to reason hypothetically and independently on concrete states of affairs, providing the essence of the logic of cultured adults and the basis for elementary scientific thought.

However, the rate of cognitive development may vary from individual to individual, especially from one culture to another. Piaget (1972) acknowledged the role of both innate structure and the environment in the development of cognition. In addition to maturation, experiences such as education or social interactions emphasizing science, math or logic are crucial factors in enabling an individual to attain formal operational thought.

To explain why formal structures do not appear in all children 14 to 15 years of age, Piaget (1972) formulated a hypothesis that it could be due to the diversification of aptitudes with age, and proposed that only individuals having the talent of logic, mathematics, and physics would manage to construct such formal structure, whereas literary, artistic and practical individuals would be incapable of doing so. If individuals tend to reason in the logic related to their specialties, then the performance on formal reasoning test of people whose aptitudes are in non-science fields may appear poor. The interventions Paget used for assessing formal reasoning are fundamentally logic, physics and mathematics which were taught in elementary and junior high school. This knowledge may be forgotten by people who are literary, artistic and practical.

Statement of problem

Of Piaget's stages, the concrete operational stage has been studied most often, both nationally and cross-culturally, whereas the formal operational stage has not received much attention (Mwamwenda & Mwamwenda, 1989). Evidence has been gained to support Piaget's (1972) statement that culture and education are crucial factors on formal operational development. Cultural or educational condition can accelerate or retard it. Kuhn and Angelev (1976) reported that exercising of the cognitive functions in question is sufficient to promote their development toward a more advanced structure. In the study of formal operations among African and Canadian college students, Mwamwenda and Mwamwenda (1989) demonstrated that the environment in terms of the education received, the various activities in which children were engaged, as well as the level of independent thinking they acquire would facilitate the acquisition of formal operations. Furthermore, there is ample evidence to show that non-western children perform less well on Piagetian tasks and that such a difference is attributed to cultural differences in child-rearing practice (Dasen, 1977).

Douglas and Wong (1977), Goodnow (1962), Goodnow and Bethon (1966), and Hsi and Lim (1977) compared Chinese and Americans and demonstrated cultural differences on cognitive tasks in favor of American subjects. If the negative educational methodology, such as directive teaching, lack of interpersonal interaction and experimentation, and not allowing much argumentation (Upton, 1989) hinders the attainment of formal operational thinking of the non-western students, their reasoning level or problem solving ability would be lower than the western students. However, there are also studies that indicated contradictory demonstrations and warrant further cross-cultural investigation. Lawson (1990) reported that Japanese students outperformed the North Carolina American students on scientific reasoning tasks. Li & Shallcross (1992) indicated more Chinese than American subjects solved the nine-dot problem that required the subjects to apply the knowledge of spatial relationships and strategies for problem solving. Stevenson et al. (1985) found the Chinese and Japanese surpassed the American subjects on the mathematics test, but found no significant difference among the three cultures on cognitive tasks. The major purpose of the present study is to examine the cultural/educational effect on formal reasoning between American and Chinese college students.

Furthermore, formal operational thinking is more likely to be demonstrated in certain domains than in others, depending upon an individual's intellectual endowments, experiences, talents and interests (Berger,1988). Piaget (1972) believed that the aptitudes of individuals differentiate progressively with age. Piaget stated "different children also vary in terms of the areas of functioning to which they apply formal operations, according to their aptitude and their professional specializations" (p. 1).

Significant correlation (*r*= .58) between the learning interests in science and the development of formal operations in the ninth grade subjects has been reported by

Shemesh (1990). However, Timm & Gross (1990) reported no significant difference between business and education majors on the Arlin Test of Formal Reasoning (ATFR) level. Additionally, no significant differences were obtained between science education majors and non-science education majors. The study also indicated that ATFR level and majoring in science education were not related.

Literature Review

Recent studies show that reasoning ability correlates highly to school success. Niaz and Lawson (1985) demonstrated that formal operational reasoning was required to balance even simple, one-step chemical equations. In another study, Niaz (1987) suggested that formal operational reasoning was a requirement for students to succeed in introductory science courses at the college and university level. Schonberger (1981), in the research of solving mathematics problems among two-year college students, stated that "since problem solving involves broad transfer of algebra skills as well as putting them into new combinations, students who were at the formal level when they learned the skills are more likely to be successful problem solvers" (p. 9).

Research reported by Bitner (1988) indicated that five formal operational modes in the Group Assessment of Logical Thinking (GALT) (proportional reasoning, controlling variable, probabilistic reasoning, correlational reasoning, combinatorial logic), were significant predictors of mathematics, language arts, and social studies achievement. Gipson and Abraham (cited in Helgeson, 1985) in the study of the relationship between formal operational thought and conceptual difficulties in genetic problem-solving demonstrated that formal operational-level students had significantly more success in proportional reasoning, combinatorial reasoning, and probabilistic reasoning areas than did the transitional level students, and transitional level students had significantly more success than did concrete-operational students.

Logan (1991) in a study of ATFR and Classroom Multiple-Choice (CMC) tests, reported that college students who appeared in formal reasoning levels scored significantly higher on CMC test in introductory psychology classes than the concrete level students do. Similar results were reported in a study of traditional and non-traditional students (Timm & Gross, 1990). The study indicated older non-traditional students with higher order cognitive skills had greater potential for academic success.

Shemesh (1990) in his study of gender-related differences in reasoning skills and learning interests of junior high school students gave another explanation for the narrow participation of girls in high school courses of science and technology (Schonberger, 1981). Shemesh assessed 229 seventh, eighth, and ninth grade students' formal reasoning skills by a videotaped group test (VTGT). This test was based on 12 videotaped simple experiments and demonstrations, consisting of the following subscales: conservation of weight and displaced volume, control of variables, proportional reasoning, probabilistic reasoning, combinatorial analysis, and recognizing correlations. At the end of each demonstration, students were asked to answer questions and justify their solutions. Students were also asked to write down two subject fields in which they were most interested. Results showed that cognitive levels and learning interests were significantly related for ninth grade students, indicating that learning interests in science and technology are closely associated with development of formal reasoning. It was also indicated that boys mastered the quantitative formal operations earlier (at seventh grade) and to a greater extent than girls.

Review of Cross-Cultural Research

Positive correlations between cognitive ability and academic achievement have been obtained in many studies. Conversely, certain types of schooling and educational experiences could facilitate cognitive development. Shemesh and Lazarowitz (1985) stated "while age and gender are features of the first aspect, schooling which includes type of school, subject matter, instructional method, classroom environment, etc., is one of the important factors of the second aspect" (p. 3). On the other hand, lack of schooling might hinder the development of formal reasoning ability. Evidence of this hindrance has been shown in both national and cross-cultural studies of cultural/educational factors.

A study of immigrant children gave more evidence of cultural and educational effects of thinking ability. Ghuman (1975), in his comparative study of Punjabi and English boys, assessed the influences of British education on the thinking processes of British Punjabi boys by comparison with control groups in Punjab and England. Matched samples of 140 boys from three communities, indigenous Punjabi, immigrant Punjabi and English were equally assigned into two age groups (age 9 years-9 months to 10 years-11 months and age 11-years to 12-years.) All subjects were given tests of conservation of weight and area, Vygotsky Block, Raven Progressive Matrices, Equivalent test and Wechsler Block Design to assess their abilities to form concepts. In addition, the samples in England were tested on Draw-a-Man and Conservation of Volume tests. The home-background of the British Punjabi was determined by personal interviews. The Punjabi schools, by and large, were poorly equipped and the curricula were often narrow and rigid. Teaching relied on information and facts through the most formal method and avoided questions, discussion, and debates. Ghuman's hypothesis was the British environment and schooling would improve the mental abilities of the immigrant children. The inference drawn from the results is that the British Punjabi groups did not differ significantly from the English group but were significantly different from both indigenous Punjabi age groups. The Punjabis who had full schooling in England showed a similar pattern of abilities to that of their English schoolmates; their performance was primarily due to their school-based educational experiences. Thus the results of the study were encouraging to those educators who stressed the important role of school in the intellectual development of children, and lent support to the point of view that certain types of education experiences exceed others in facilitating children's cognitive development. Children from traditional societies are capable of developing the mental abilities which are valued by contemporary western society.

In studying the patterns of intellectual differences of Black, Hispanic and White children, Taylor and Richards (1991) used the Wechsler Intelligence Scale for Children-Revised (WISC-R) to examine 100 Black, 100 Hispanic and 100 White children selected randomly from a sample pool of 700 children from 13 Florida counties. Results of the Multivariate analysis of variance indicated that the effect of ethnic status was significant. When overall IQ was held constant, Black children performed better on verbal tasks, Hispanic children performed better on visual-spatial tasks, and White children performed better on tasks requiring abstract thinking and knowledge of facts.

Scribner (cited in Duran, 1987) cited studies of formal reasoning among non-schooled persons residing in Central Asia, West Africa and Mexico. These studies found that individuals who had little formal schooling had difficulties in interpreting formal reasoning problems. Those individuals often refused to interpret problems as meaningful, because the problems referred to persons, objects or events that were not a part of their everyday life. The main point raised by Scribner was that learning to reason in ways induced by education amounts to learning mental schemata for performing thinking under certain circumstances.

Mwamwenda and Mwamwenda (1989) reported a significant cultural effect on formal operational thought in a comparative study of African and Canadian college students. The sample was drawn from two distinct cultural groups, Canadian and South African (Xhosa) college students. The Canadian sample included 30 college students, whose average age was 22.4 years. The South African sample included 48 students with an average age of 20.7 years. The two groups of subjects were administered a 10 minute, two-question, formal operational test requiring propositional and proportional reasoning.

The analysis of the performance of the two groups showed that 100% of the Canadians passed propositional reasoning, whereas only 84% of South Africans passed. In proportional reasoning, 60% of the Canadians passed compared to 29% of South Africans. These data provided further confirmation of the view that was reported in previous studies (Lawson, 1985; Piaget, 1972) that formal operations are susceptible to cultural differences. South African educational environment, in comparison to Canadian's, was less favorable to formal operational thought. In South Africa, many science teachers were unqualified, and the laboratories and equipment were inadequate. Further, students, teachers, and parents interacted very little. These interactions were considered as vital in promoting formal operational thought (Lawson, 1985). Knowledge of science has been reported to be essential for successful performance on formal operational concepts.

One of the cognitive styles, field dependence-independence has been indicated as an important factor associated with mathematics and reasoning abilities. Field dependence-independence refers to the relative ability to separate an object from its background. The concept of field dependence-independence can best be explained by an instrument that measures this ability. The Rod and Frame Test consists of a straight rod attached to a square frame. The subject sits in a darkened room facing the apparatus. The experimenter then tilts the rod or the frame or both at various angles. The subject is asked to adjust the rod until it appears to him vertical with the ground. Those who are able to adjust the rod without reference to the frame are field independent while those who tend to adjust the rod in relation to the square frame are field dependent. The field dependence-independence variable has been investigated in many cross-cultural studies. Studies showed that Mexican-Americans were more field dependent than Anglos (Hsi & Lim, 1977). It was suggested that ethnic minority group students in the United States possess a field dependent cognitive and learning style while Anglo students possess a field independent cognitive and learning style. In fact, there was no evidence that the Asian-Americans were more field dependent than the Anglo-Americans. Besides, Chinese-Americans and Japanese-Americans were shown to be about equal to or surpass the Anglos on mathematics and reasoning abilities.

Lawson and Bealer (1984) attempted to test the hypothesis that cultural diversity contributed to the development of formal operational reasoning. The areas from which participants were selected varied in the extent to which they were culturally diverse. Three hundred seventy students were selected from suburban culturally homogeneous areas; 420 students were selected from suburban culturally heterogeneous areas; and 391 rural community students were selected. The age range of the subjects was from 10 to 18, and from grades 6, 8, 10 and 12. The students were enrolled in required courses in elementary, junior and senior high schools in their own communities. A five-item pencil and paper test was given to determine the ability of propositional, probabilistic and correctional reasoning. The results showed that the suburban-heterogeneous sample performed at a substantially higher level than the other samples at all grades on proportional reasoning and correlational reasoning items. On the probabilistic reasoning items, performance at the tenth grade was also in favor of the suburban-heterogeneous sample. The findings support the hypothesis that cultural diversity influences the development of formal reasoning.

Lawson (1985) indicated that training studies showed that young children can indeed be taught to solve formal tasks at an early age and that limits on performance may be largely related to lack of experiences rather than cognition structural deficiencies. Kuhn and Angelev (1976) conducted an experimental study on the development of formal operational thought. The major purpose was to test the hypothesis that preadolescent subjects would begin to develop formal operations if they were given opportunities to confront situations requiring formal thought over a period of time. Ninety-one fourth and fifth graders took part in a 15-week intervention program, confronting problems requiring formal operational thought. Subjects showed progress toward formal operations on the pendulum, chemical and verbal problems on both immediate and four-month posttests. Subjects initially at concrete operational stage progressed predominantly to the transitional stage, and those initially at a transitional stage progressed predominantly to the formal stage. Results also indicated that the density of exposure to the problems (once per two weeks, once per week and twice per two weeks) was related to the amount of progress. An additional group of subjects who were also given explicit demonstration of formal operational situations to the problems showed no more advancement than subjects given exposure alone. The results supported the main hypothesis that "exercise" of the cognitive function in question was sufficient to promote their development toward a more advanced structure. Furthermore, school type communities did contribute to the variance on formal reasoning test performance.

In Shemesh and Lazarowitz's (1985) study, Israeli subjects were chosen from two urban schools, with low and middle socio-economic backgrounds, and from Kibbutzim, Israel, and small villages (rural schools). Students' formal reasoning skills were measured by a video-taped group test demonstration. While no differences were found between the two urban school students, significant differences were found between the Kibbutzim school students and urban school students. The Kibbutzim students obtained a higher rate of cognitive development. Shemesh and Lazarowitz (1985) stated the following:

(a) Kibbutzim education is less formal with more extra-curricular activities than provided for urban school students.

(b) In the Kibbutzim elementary schools, students are more autonomous, since they experienced new instructional methods, such as hands-on activities, learning centers, individual projects and social interactions. Some of these activities were found to promote students' cognitive development (p. 9).

Lawson and Snitgen (1982) investigated whether the inquiry-based instruction that included specific provision for instruction in the control of variables, proportional, correctional, probabilistic and combinatorial reasoning produced measurable gains in their use by students in solving novel problems. A sample of 72 students with a mean age of 22.7 years enrolled in a one-semester Biology Science for the Elementary School Teachers course. Subjects were given tests of formal reasoning in the beginning, during and at the end of the semester. The course was taught as an inquiry-based hands-on course in which a series of laboratory investigations formed the major mode of instruction. Aspects of formal reasoning were introduced during discussions at specific points in the course only when needed by the investigations. After the introduction of a reasoning pattern, such as proportional reasoning, subjects were given additional information about its use and were given problems requiring its application in reasoning modules. The reasoning patterns were then reinforced by their subsequent use in later investigation and by the inclusion of problems on examinations that required their use. Results showed the inquiry-based classroom instruction produced measurable advancement in the use of formal reasoning before the Piaget's development stage.

The studies reviewed support the idea that the environment or educational experiences that provide the opportunity to experience the situation requiring formal reasoning thought would facilitate the development of reasoning ability. Consequently, the development of cognitive abilities would affect the academic achievement of in school. Also, Western cultural and educational milieu seemed to be superior to Non-Western schooling in the development of cognitive abilities. However, there were still some uncertainties in this area. Some cross-cultural studies on student academic achievement of Non-Western and Western countries showed Oriental children have superiority in science and mathematics achievement. The high level of academic success of Asian-American children is a well-known feature of American society (Douglas & Wong, 1977). Many hypotheses have been drawn, including the possibilities that the cognitive abilities of these children exceed those of American children. Additionally, Lawson (1990) reported the results of a comparison between Japanese and North Carolina students on reasoning abilities showed the Japanese students outperformed the North Carolina students on all reasoning tasks.

Comparison between American and Chinese

Goodnow (1962) and Goodnow and Bethon (1966) presented Piaget's conservation and combination tasks to Hong Kong, European and American boys. They found that Chinese boys with no schooling did as well as European schoolboys on tasks for conservation of weight, column, and surface. In contrast, the unschooled Chinese boys were markedly poorer on the task of combinatorial reasoning which demonstrated solving the problem "in the head" rather than by action.

In another cross-cultural study of American and Chinese of formal operations, Douglas and Wong (1977) demonstrated a cultural difference in favor of American subjects. In that study, 60 Hong Kong Chinese and 60 American adolescents, aged 13 to 15 were given three Piagetian tasks of formal operations in order to assess cultural, sex, and age differences. The three tasks are color-combinations which measure the ability to utilize combinatorial rules; the role of the invisible magnet assessed the ability to note relevant variables; the projection of shadows assessed the use of inversion and reciprocity as one single process. Analysis of variance on individual scores indicated cultural effect was significant. The American subjects scored significantly higher than Chinese with Chinese girls scoring the lowest. In Chinese culture, the male has played the dominant role with females encouraged to yield to authority and not exhibit for assertive, questioning behavior. The authors of this research stated "an aptitude for the hypothesis testing and experimentation of formal thought requires an active searching mode of behavior, characteristics which the Hong Kong culture may not encourage in females" (p. 692).

Youniss and Dean (1974) found that the urban children performed better than rural subjects on the combination task. This finding was similar to Goodnow's (1966) study with uneducated and educated Chinese children in Hong Kong. Both results suggested that rural and uneducated children may not be encouraged to take the initiative in thinking and may not be rewarded for generating new manipulations. These studies gave support to one of Piaget's assumptions that the acquisition of formal operations depended in part on educational/cultural factors which fostered a particular aptitude for such thinking.

Research found that people were more field dependent if they lived in more traditional societies or a community stressing social conformity to family, religious and political authority (Hsi & Lim, 1977). Chiu (cited in Hsi & Lim, 1977) compared Chinese subjects in rural Taiwan with rural United States subjects. He identified Chinese child-rearing and societal characteristics as similar to the field dependent socialization cluster and American practices as similar to the field independent cluster.

Contrasting the findings that cultural difference favors Americans, Lawson (1990) reported a surprising discovery that Japanese students outperformed the North Carolina American students on scientific reasoning tasks. In a discussion to explore the possible causes of this cultural difference, a group of international psychologists found that the application of Japanese philosophy and methodology in science education, such as hands-on activities, was attributed as the major factor of Japanese superiority in reasoning skills.

Li and Shallcross (1992) demonstrated that more Chinese subjects broke the assumption boundary and solved the nine-dot problem. It was indicated that in the formal operational stage, thought is no longer bound and one is developmentally ready for the nine-dot problem. In addition to the factor that Chinese subjects spent a longer time on the problem, they reported that chinese students may have more training and exercise in skills for solving mathematic problems than American children. This training may provide the students with knowledge of straight lines, shapes and spatial relationships as well as strategies for representing and attacking the problem and monitor the problem solving process.

Stevenson and others (1985) studied the cognitive performance and achievement of Japanese, Chinese and American children, and found that Chinese children surpassed the Japanese and Americans in reading scores; both Chinese and Japanese children obtained higher scores in mathematics than the Americans. Contrarily, the prediction of achievement scores from the cognitive tasks showed only few differential effects among the three cultures. The author stated that "the results suggest that the high achievement of Chinese and Japanese Children cannot be attributed to higher intellectual ability, but must be related to their experiences at home and at school" (p. 734).

Factors of Reasoning

The other purposes of this study are to examine the relation between reasoning and two influencing factors: gender and major. These issues are still controversial.

Significant gender related differences were found by Shemesh and Lazarowitz (1985). Four hundred and eleven students participated in this study. The students' formal reasoning skills and the level of formal tasks performance were measured by a Video-Taped Group Test (VTGT) demonstration. VTGT assesses six formal reasoning skills: (a) conservation and volume displacement, (b) proportional reasoning, (c) control of variables, (d) combinatorial analysis, (e) probabilistic reasoning, and (f) correlational reasoning. The results indicated that boys surpassed girls in VTGT performance in all tested grades. The difference between boys and girls seemed to increase with age. Boys showed formal reasoning patterns earlier than girls.

In the study of gender difference in solving mathematics problems among two-year college students, Schonberger (1981) examined the related factors of solving algebra problems that included formal reasoning ability. Seventy-five subjects were from two-year programs at the University of Maine at Orono who finished a developmental Algebra course taught by the author. All participants in the study took a teacher-constructed final exam: a multiple choice test of algebraic concepts and skills and a free response test of problem solving. Besides the mathematics measures, the students took several paper and pencil tests to provide the following measures: visual spatial ability, cognitive style, abstract reasoning ability, learning style, and Piagetian developmental level. The Piagetian test is a fifteen-item multiple choice test based on Piaget's balance tasks and designed to measure developmental level of reasoning about proportions.

The analysis of data indicated a significant difference in favor of males on algebraic problem-solving, spatial-relations, and the Piagetian developmental level. Females had a more independent learning style than males. The test of Piagetian developmental level indicated gender differences in problem-solving, especially the items at the level of formal reasoning.

Similarly, in Bitner's (1988) study of logical and critical abilities of sixth through twelfth grade students, there was a significant gender difference in favor of males on probabilistic reasoning on the Group Assessment of Logical Thinking (GALT). But the results did not indicate significant gender difference in logical and critical thinking abilities for total scores on the GALT and the other tests used in this study, namely, the Ross Test of Higher Cognitive Processes and the Watson-Glaser Critical Thinking Appraisal.

Primeau (1989) reported a significant difference of performance on the Arlin Test of Formal Reasoning. Analysis of variance for the eight subtests found that the gender difference exist on three subtests: multiplicative compensations (volume), proportional reasoning, and frames of reference.

Peterson (1986) also found gender divergence on spatial ability and proportional reasoning ability among his 335 secondary school subjects. The assessments in his study included spatial ability (Primary Mental Abilities: Space Relations subtest), fluent production (Differential Aptitude Test: Clerical Speed and Accuracy subtest), and formal operations (Linn's equilibrium in a balance test of proportional reasoning). Performance in all three areas increased over time for both girls and boys; however, boys scored higher in spatial ability and formal reasoning and girls in fluent production.

However, the sex difference was not found in Linn and Pulos' (1983) study. Linn and Pulos used 778 students in the seventh, ninth and eleventh grades to examine the role of aptitude and experiences in gender differences in scientific reasoning. The results indicated that males were only more successful than females in the proportional reasoning. On the other three formal measures: controlling variables, permutations and combinations, males and females performed equally well.

In two other studies, Linn and Swiney (1981) and Linn (1982) established an aptitude model based on Horn and Cattell's (1966) fluid and crystallized abilities and then determined whether formal reasoning measures a unique ability in the model and the relation between formal reasoning and the aptitude model. The results of both studies found that formal reasoning did not measure a unique dimension different from the aptitude model. The results of Linn and Swiney's (1981) study indicated that formal reasoning overlapped substantially (88%) with general crystallized, general fluid visualization, and familiar field. However, such high correlation was not found in Linn and Pulos' (1983) study.

<u>Purpose of this study</u>

The first purpose of this study was to examine the difference between American and Chinese college students concerning formal reasoning ability as well as to examine the proportion of students of two cultures that were functioning at formal operational stage. It was hypothesized that the American college students would score significantly higher on the ATFR than Chinese students.

The second purpose of this study was to examine the relationships between gender and cognitive abilities. Significant gender related differences, generally in favor of males were found by Bitner (1988), Douglas and Wong (1977), Schonberger (1981), Shemesh (1990), and Shemesh and Lazarowitz (1985), Douglas and Wong (1977). Such difference were not reported by Linn and Pulos (1983), Peterson (1986), and Saarni (1973). The gender issue is still controversial and warrants further investigation. It was hypothesized in this study that males would score higher than females.

As stated earlier, boys tend to develop formal operations earlier and to a greater extent than girls, and subsequently have the tendency of majoring in science in college (Shemesh, 1990). Shemesh and Lazarowitz (1985) reported gender-related preferences of science subject matter by junior high school students. Among ninth graders, the majority of the boys preferred mathematics and technology, while the majority of the girls preferred arts and humanities. Based on similar interest, Lawson and Bealer (1984) found differences between formal and concrete reasoners in respect to their science learning choice. In contrast, the similar findings in the students' cognitive abilities across academic majors were indicated in other research (Timm & Gross, 1990). The choice of major apparently was related to personal interest rather than to reasoning abilities. Linn and Pulos (1983) reported low correlation between the aptitudes measures and the formal reasoning measures. These conflicting results warrant a further examination of the cognitive abilities across majors. An additional objective of this study is to investigate the difference between science majors and non-science majors formal reasoning abilities. It was hypothesized that the science majors would score higher on Arlin Test of Formal Reasoning.

CHAPTER 2

METHOD

Subjects

The sample population for this study included 94 college students from American and Chinese groups. The American group consisted of 44 college students [ranging in age from 18 to 30 with a mean of 21.9 years, (*SD* = 3.12)] who were enrolled at two midwestern universities. The American subjects included 14 science majors (pharmacy, chemistry, physics, engineering, biology, geology, psychology, computer science, etc.) and 30 non-science majors (performing art, mass communication, history, geography, education, business, accounting, music, English, etc.).

The Chinese group included 50 college students, 22 science majors, and 28 non-science majors, all enrolled in the same universities as the American subjects. The Chinese students' age ranged from 19 to 30 years, with a mean of 24.3 years, (*SD* = 2.82). The Chinese subjects all had completed their high school education in Taiwan. To prevent the American cultural effect, the Chinese subjects chosen had stayed in the United States no less than 6 months but no more than 2 years and 10 months.

Design

Three independent variables, namely culture, gender, and academic major, were used in the present study. Since formal reasoning ability is a developmental ability, age was used as a covariate. Nine 2 (culture: American and Chinese) x 2 (gender: male and female) x 2 (major: science and non-science) analyses of covariance (ANCOVA) were conducted to determine the difference of ATFR total scores and the subtest scores.

Instruments

The Arlin Test of Formal Reasoning (ATFR) was used to measure formal reasoning ability. The ATFR was designed for large group administrations to obtain a general assessment of cognitive development levels (from concrete to formal operations). It was designed for middle school, high school, and adult levels. The ATFR consists of a total of 32 items organized into eight subtests. Each subtest represents one of the following eight concepts: (1) multiplicative compensation, (2) correlations, (3) probability, (4) proportions, (5) combination reasoning, (6) forms of conservation beyond direct verification, (7) mechanical equilibrium, and (8) the coordination of two or more systems of reference. All items are presented in a 4-response, multiple-choice format with each subtest composing four items.

A multi-trait, multi-method validity study (Arlin, 1984) indicated that this objective test is a valid and reliable measure of formal operations. The two methods employed were the paper and pencil version of the ATFR and the cross-validation of the instrument by individual clinical interviews with a random sample of the same subjects. Test-retest reliability coefficients were on the order of .76 to .89, depending on the version of the test and the time period between testings. A significant positive correlation (r= .56) was indicated between the ATFR and the Gorham Proverbs Test (Primeau, 1989). A range of correlation coefficients from .80 to .90 between the ATFR and Shayer's Reasoning Tasks was reported by Shayer (cited in Arlin, 1984). The readability is the United States sixth-grade level, which should not be a problem for the Chinese college students, all of whom had successfully completed coursework at the American university level.

Procedure

The Chinese subjects were selected first. Name lists with addresses and telephone numbers of 100 Chinese college students were provided by the presidents of Taiwanese student associations. Fifty students were randomly selected from the name list and contacted for testing. Most of the subjects were tested at the same time, and all subjects were tested under the same testing conditions.

The American subjects were selected from two general courses offered in the same universities. The Arlin test was given to each subject in groups according to the specific directions provided in the test manual by the same examiner.

Before the test, all subjects were requested to complete an information sheet requesting their age, gender, and major. Additionally, the Chinese subjects were asked to provide the highest TOEFL reading score they obtained and the length of time they have been in the United States.

Scoring

According to the ATFR manual instruction for scoring, one point was awarded for each correct response. The total raw score was used to determine the students' overall cognitive level, and one of the five levels was assigned to each individual. The levels are based on Inhelder and Paget's (1958) description of performance by subjects on their formal reasoning tasks. The five levels are: concrete (0-7 points), high concrete (8-14 points), transitional (15-17 points), low formal (18-24 points), and high formal (25-32 points).

CHAPTER 3

RESULTS

The total score of every student in this study was assigned to one of the five cognition levels according to the classifications in the ATFR manual. The numbers of students at each level were converted into percentages for two cultures. A 2 x 4 Chi square was used to determine the difference of the proportion of each cognitive level between two cultures.

Table 1 reports the percentage of students in each culture who scored at each of the four levels.

The Chi-square analysis found that the two cultures do not significantly differ. $X^2_{(3)} = 5.74$, $p > .05$ with respect to their frequency of each cognitive reasoning level.

Table 1

Numbers and Percentages of Students at the ATFR Cognitive Level

	American		Chinese	
Level	N	percentage	N	percentage
High Concrete	9	20.5	9	18.0
Transitional	6	13.6	15	30.0
Low Formal	23	52.3	16	32.0
High Formal	6	13.6	10	20.0

(N: American = 44; Chinese = 50)

A *t*-test was used to examine the difference of age of two cultures, and a significant difference was found, $t = 15.52$, $p < .001$; therefore, age was used as a covariate in the analysis of covariance. To discover the effects of culture, gender, and major on the total scores, a 2 x 2 x 2 analysis of covariance (ANCOVA) was conducted. The results are presented in Table 2.

The results showed that only the major main effect was significant, $F(1, 85) = 5.83$, $p < .05$. The science majors ($M = 21.23$) scored significantly higher than the non-science majors ($M = 18.06$).

Table 2

<u>ANCOVA Table for Total Scores</u>

Source	SS	DF	MS	F
Culture	4.94	1	4.94	.21
Gender	3.59	1	43.59	1.89
Major	134.18	1	134.18	5.83 *
Culture x Gender	2.74	1	2.74	.12
Culture x Major	55.06	1	55.06	2.39
Gender x Major	18.44	1	18.44	.80
Culture x Gender x Major	11.37	1	11.37	.49
Covariate	43.50	1	43.50	1.89
Error	1955.18	85	23.00	

* $p < .05$

Eight 2 x 2 x 2 ANCOVAs were conducted to analyze the effect of the three independent variables for the eight subtests. The results showed no main effect or interactions for five of the eight subtests. Those subtests are: multiplicative compensation (volume conservation); correlation; combination; proportional reasoning; and mechanical equilibrium.

For probabilistic reasoning, the culture x gender x major interaction was significant, $F(1, 85) = 6.43$, $p < .05$. The results of ANCOVA for probabilistic reasoning are presented in Table 3. Separate 2 (gender) x 2 (major) ANOVAs were performed on the American and Chinese subtest data. No significance was found among the Americans; however, the male Chinese science majors ($M = 3.5$) scored significantly higher than female Chinese science majors ($M = 2.25$).

Table 3

ANCOVA Table for Probabilistic Reasoning

Source	SS	DF	MS	F
Culture	3.57	1	3.57	3.92
Gender	.87	1	.87	.96
Major	.12	1	.12	.13
Culture x Gender	3.02	1	3.02	3.33
Culture x Major	1.27	1	1.27	1.39
Gender x Major	.11	1	.11	.12
Culture x Gender x Major	5.84	1	5.84	6.43 *
Covariate	.41	1	.41	.45
Error	77.25	85	.91	

* $p < .05$

In the "informs of conservation beyond direct verification" subtest, the major main effect was significant, $F(1, 85) = 17.32$, $p < .001$ as was the culture x gender x major interaction, $F(1, 85) = 4.43$, $p < .05$. The results of ANCOVA for this subtest are presented in Table 4. Separate 2 x 2 ANOVA were used on the American and Chinese subtest data. No significance was found among the Americans, while the major main effect was significant among the Chinese in favor of the science majors ($M = 2.55$) over the non-science majors ($M = 1.00$).

Table 4

ANCOVA Table for Subtest Informs of Conservation beyond Direct Verification

Source	SS	DF	MS	F
Culture	.00	1	.00	.00
Gender	2.02	1	2.02	1.53
Major	22.85	1	22.85	17.32 **
Culture x Gender	1.65	1	1.65	1.25
Culture x Major	4.27	1	4.27	3.24
Gender x Major	.02	1	.02	.01
Culture x Gender x Major	5.84	1	5.84	4.43 *
Covariate	.03	1	.03	.02
Error	112.12	85	1.32	

* $p < .05$
** $p < .001$

In the subtest "the coordination of two or more systems or frames of reference", the gender x major interaction was significant, $F(1, 85) = 5.95$, $p < .05$, with female non-science majors (M =1.45) scored significantly lower than female science majors (M = 2.40) and male non-science majors (M = 2.40). The results of ANCOVA are presented in Table 5.

Table 5

ANCOVA Table for Subtest Frames of Reference

Source	SS	FD	MS	F
Culture	1.74	1	1.74	1.27
Gender	1.30	1	1.30	.94
Major	2.64	1	2.64	1.92
Culture x Gender	.02	1	.02	.01
Culture X Major	1.51	1	1.51	1.10
Gender x Major	8.19	1	8.19	5.95 *
Culture x Gender x Major	5.22	1	5.22	3.79
Covariate	1.75	1	1.75	1.27
Error	116.94	85	1.38	

* $p < .05$

CHAPTER 4

DISCUSSION

The results of this study of formal operations demonstrated that cultural main effect was not significant either on the total scores or the subtest scores. The Chi-square result showed that about the same proportion of students of the two cultures were functioning at each cognitive level. A significant percentage of students in both cultures failed to reason formally, 34% for the American group and 48% for the Chinese group.

However, the significant main effect in regard to academic major was found for science majors for the total scores. This result supports Piaget's (1972) statement that the acquisition of formal operations depends in part on educational factors that foster a particular aptitude for such thinking. Although Arlin (1984) had tried to present the test concepts in non-science and non-mathematics terms and examples, the ATFR items are basically logic, physics, and mathematics that are taught in junior high and high school in both Taiwan and the United States. This knowledge is emphasized in the college of science and technology, but may have been forgotten by students who majored in liberal arts, education, and business. Therefore, the performance on formal reasoning tests of non-science majors is poorer than that of science majors.

The difference among majors may be more pronounced among Chinese students. In Taiwan, the curriculum of the high school is divided into two specializations: (1) social studies and (2) science. The major courses for social studies are geography, history, and social studies mathematics, while the major courses for science students are chemistry, biology, physics, and science studies mathematics. The science graduates would have stronger preparation in the areas of mathematics and science (AACRAO, 1967). After taking the college entrance examination, social studies graduates go to one of the colleges of art, literature, business, or law. Contrarily, science graduates go to one of the colleges of science, technology, medicine, or agriculture. Most of the science major subjects in this study are engineering, computer science, and physics, while most of the non-science major subjects are business, mass communication, and education. The findings of this study imply that aptitude or learning interest in science or technology are closely associated with development of formal reasoning.

Furthermore, the significant culture x gender x major interaction on probabilistic reasoning and "forms of conservation beyond direct verification" subtest and the gender x major interaction on "frames of reference" subtest seemed to indicate that the female non-science majors performed the lowest among all students, while the male science majors performed the best. In both western and non-western society, males are encouraged to develop interests or aptitude in hard sciences, such as engineering, physics, and chemistry, while the females receive less encouragement in developing the ability in the same fields. Since the aptitude and the interest in science may associate with the development of formal reasoning, the author suggests that society and the educational system should focus more equitably on science training with respect to gender.

Furthermore, the significant difference between science and non-science majors raises a question of bias. Although Primeau (1989) indicated significant correlations between scores on the ATFR and the Gorham proverbs test, and though Timm and Gross (1990) indicated no difference between business and education majors on the scores of the ATFR, neither demonstrated the non-scientific bias of the ATFR. Thus, a further study of the relationship between the individuals' scientific aptitude and the ATFR scores is suggested.

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