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The Relation Between Formal Operational Reasoning and Academic Course Selection and Performance Among College Freshmen and Sophomores*

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The significance of Inhelder and Piaget's (1958) construct of "formal operations" depends in part on establishing the extent to which formal operations have real-world relevance beyond the narrow domain of assessment situations in which Inhelder and Piaget studied them. The present research investigates this question by examining the effect of exhibiting a concrete versus formal operational level of reasoning in an isolation of variables task on academic program selection and performance of beginning college students over a two-year period. Students who reasoned at the concrete operational level did not differ from students matched on ACT scores who reasoned at a formal operational level with respect to either number of college credits obtained or overall grade point average. When courses were broken down into three categories, however, "formals" took significantly more science/math courses and received significantly higher grades in them. No differences were found in the other two categories: liberal arts/social sciences or activities/vocational courses. A further study of beginning college students already enrolled in science/math courses confirmed that very few concrete operational reasoners were present in these courses, suggesting that a process of self-selection is in operation.

Inhelder and Piaget's (1958) stage of formal operations has received considerable attention as the only comprehensive theoretical formulation of major cognitive changes occurring subsequent to childhood. At the most abstract level, formal operations can be characterized as operations on operations, or, in other words,

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the organization of classes or relations into higher-order classes or relations Earlier in development, with the attainment of first-order, "concrete" operations an individual acquires the competence to organize a set of elements into a logica class on the basis of their possession of the common attribute x; and similarly t organize another set of elements into a class on the basis of their possession of th common attribute y. With the attainment of formal operations, the individual ma also go on to infer that there exists a relationship (of, say, implication) between th class of elements defined by the attribute x, and the class of elements defined b the attribute y. Such relationships are not derivable directly from the concrete el ments. They must be constructed, based on the results of the first-order operatio of classification; hence the term "operations on operations."

More specifically, Inhelder and Piaget (1958) cite a number of striking new behavioral strategies, most notably isolation of variables and systematic com bination, that they believe mark the emergence of the formal operational structur which is described in complex, formal, logical terms. Inhelder and Piaget "theory" of formal operations remains unconfirmed, and indeed it remai unresolved exactly what kinds of evidence would be required to confirm it. Th underlying logical model has been criticized by a number of writers (see, for e ample, Ennis, 1975), on the grounds of both its internal coherence and its conne tion to the psychological phenomena it is purported to underlie. At the level empirical observation, replication studies have confirmed that reasoning strat gies such as isolation of variables and systematic combination, as assessed Inhelder and Piaget's (1958) tasks, do not appear before adolescenc Intercorrelations among these tasks, however, range only from low to modera leading some to question whether the various reasoning strategies form t "structured whole" that Inhelder and Piaget claim (though, it must be adde there remains theoretical controversy as to whether this criterion is an appropri one). (See Keating, 1979; Kuhn, 1979; or Neimark, 1975, for reviews of the search literature pertaining to formal operations.)

A further, and we would argue critical, problem is that formal operatio reasoning strategies have been defined and assessed almost exclusively in the n row domain of physics problems in which Inhelder and Piaget originally inve gated them. Thus, it remains unestablished what broader, real-world relevar these reasoning strategies have beyond these specific assessment problems. I intuitively compelling to believe that the presence or absence of a for operational reasoning strategy such as isolation of variables has important im cations for an individual's real-world, everyday functioning (and indeed, it is this reason, it would seem, that interest in Inhelder and Piaget's work on for operations remains strong). Yet, there has been little investigation of such im cations, and what research exists is largely correlational in nature. For example cross-cultural work, it has been shown that performance on concrete and for operational tasks varies as a function of schooling, and rural versus urban envir ment (e.g., Laurendeau-Bendavid, 1977; Kelly, 1977). Dasen (1977) in an in

ductory chapter in the same volume concludes: "What is lacking (and that is true of all Piagetian psychology, not only of the formal stage, and not only cross-cultural) are studies demonstrating the presence of operational thinking in culturally relevant, real-life situations" (p. 7).

The ultimate significance of Inhelder and Piaget's "formal operations" construct, we would claim, is dependent on the establishment of the extent and nature of this real-world relevance. It is as a contribution towards this objective that the present work is intended.

We undertook this initial investigation in one of the most readily obvious real-world contexts in which we would expect formal operational reasoning to play a role: achievement in college-level academic coursework. Do college students who do not exhibit reasoning at a formal operational level in fact show inferior performance relative to those reasoning at that level?

Findings from a number of studies support the conclusion that formal operational reasoning is not a universal attainment, even among a college population, though methodological problems preclude any precise numerical estimates (see the references cited earlier for reviews of the literature). These findings have provided the incentive for "Piaget-based" educational programs at the college level. These programs are based on the assumption that beginning college-level students do not uniformly reason at a formal operational level and that intervention efforts directed towards the facilitation of formal reasoning are essential for the successful college performance of some significant proportion of students. (See the Project ADAPT manual, Note 1, for a description of such a program and a review of other such programs.) Research of the nature to be reported in the present paper, in our view, constitutes essential groundwork for these increasingly popular educational programs. In what ways, if any, is formal operational reasoning in fact implicated in college performance?

Because, as indicated earlier, it is not clearly established to what extent different formal operational reasoning strategies are part of a unified whole, we regarded it as inappropriate to attempt to assess students on some global index of "formal reasoning ability." Instead, we selected one specific formal reasoning strategy as the focus of attention. This strategy, isolation of variables, is one of two strategies Inhelder and Piaget (1958) specify as the major behavioral hallmarks indicating the emergence of formal operations. It is also the strategy in our view having the greatest face validity with respect to a role in the performance of college-level coursework. Furthermore, we narrowed our attention to the form of isolation of variables reasoning studied by Kuhn and Brannock (1977), in which the subject is asked to make inferences regarding the effects of variables based on a set of multi-variable "natural experiments." It is in this form, Kuhn and Brannock (1977) argue, that isolation of variables reasoning most often occurs in real-life reasoning contexts. Thus, no claim can be made that we have investigated the relevance of formal operational reasoning in general (if such a construct is indeed valid) with respect to college-level academic performance. If,

however, competence in the particular formal reasoning strategy we have chos for investigation is found to have an impact on academic performance, some ir tial evidence of the sort we are seeking will have been obtained, and further inve tigation of the issue will be warranted.

STUDY I

Method

SUBJECTS

Subjects were 64 college freshmen, half of whom scored at the concr operational level on the isolation of variables problems used in the present stu (hereinafter referred to as "concretes"), and half of whom scored at the for operational level (hereinafter referred to as "formals"). The selection criteria described in more detail below. The two groups of 32 subjects were each co prised of 23 females and 9 males.

PROCEDURE

Two problems, which were in written form, were administered to an init pool of 474 students—191 males and 283 females—enrolled in introductory p chology courses at a midwestern state university. The problems differed in cont but were identical in form to the plant problem described by Kuhn and Brann (1977). Group written administration was justified on the basis that underestimates true competence and leads to "false negatives"—assessing a s ject as lacking a formal operational level of competency who in fact possesses This works against rejecting the null hypothesis of no difference on dependent v iable measures between students designated "concrete" and those designa "formal."

The two problems were identical to the plant problem in requiring the s ject to detect the single variable (of several present) that consistently covaried v an outcome. The first problem dealt with a milkman who either did or did not liver milk. The conditions that varied were whether the day was sunny or r whether the dog barked or not, and whether it was a Monday or a Thursday. ' second problem dealt with Susan's tennis playing strategies. She either turned racket to the left or to the right, she turned her wrist either inward or outward, she used either type A or type B tennis balls. The outcome was hitting eith good or a bad serve over the net.

Responses to each problem were scored in terms of Kuhn and Brann (1977) scoring system, which contains five levels: Level 0 - completely conc operational; Level 1 - predominantly concrete operational but with some emer formal reasoning; Levels 2 and 3 - transitional; Level 4 - fully formal operatio

In order to be classified as "concrete," a student had to score at either Level 0 or Level 1 on the two problems. To be classed as "formal," a student had to score at Level 4 on both problems or Level 3 on one problem and Level 4 on the other.

In selecting subjects to constitute the "concrete" and "formal" groups, we felt it essential to use a matching procedure that would enable us to discount the hypothesis that the assessment measures used to select subjects had served simply as alternative measures of "general mental ability," and accordingly that the ability to reason at a formal operational level played no specific role in differentiating the two groups. ACT (American College Testing) scores were used as the basis for matching "concrete" and "formal" subjects with respect to general mental ability. ACT scores were available for 265 of the 474 students in the initial pool. With the students' permission, these scores were obtained for the 265 students. The remaining students were dropped from consideration as potential subjects. Before doing so, it was ascertained that there were no differences in performance on the isolation of variables tasks between the group of students for whom ACT scores were available and the group for whom they were not. (Neither were there significant sex differences either for the 265 potential subjects or the total pool of 474.)

Of the 265 potential subjects, 45 met the criterion for classification as "concrete" (28 females and 17 males). Of the same group, 135 met the criterion for classification as "formal" (99 females and 36 males). Of the "concretes," 32 were able to be matched with a student from the "formal" group who was of the same sex and whose ACT score was within one point of the "concrete" subject's ACT score. The total sample of subjects thus consisted of 32 matched pairs, or 64 subjects. The mean ACT score of the "concrete" subjects was 16.0 (SD = 3.4). The mean ACT score of the "formal" subjects was 16.1 (SD = 3.2).

With subjects' permission, copies of college transcripts of these 64 subjects were obtained at the end of their sophomore year. Of the 32 "concrete" subjects, two had voluntarily left school before the end of the sophomore year because of academic problems, five had left to seek employment or for other reasons (e.g., marriage), and two transferred to other colleges. Of the 32 "formal" subjects, none had left school by the end of the sophomore year for academic reasons, seven left to seek employment or for other reasons, and three transferred to other colleges. Only one subject, in the "concrete" group, was terminated by the university, based on poor academic performance.

Results

The two groups of subjects were compared first of all with respect to the total number of college credits taken during the two years. (Note that the measure in this case is one of credits *attempted,* rather than credits *earned* so as to keep the measure independent of performance in courses, which is considered separately.) The mean number was 52.4 for "concretes" and 57.0 for "formals." Mean dif-

ference score over matched pairs was 4.7 credits (or about 1.2 courses), which d not differ significantly from zero, t (31) = .97, *ns*.

A further comparison of the two groups was made with respect to cumul tive grade point average over the four semesters (or over the number of semeste completed for those students who dropped out). Mean cumulative GPA was 2. (of a possible 4.00) among the "concretes" and 2.20 among the "formals." T mean difference score over the matched pairs was .11, which did not differ signi cantly from zero, t (31) = .69, *ns*.

Further analyses were performed, based on the division of coursework ir three categories: (a) natural science or mathematics; (b) liberal arts and social s ences; and (c) activities and vocational. The last category (exemplified by su courses as Physical Fitness, University Choir, Food Selection and Preparatic and Office Machines) was a sizable one, as the university offered a large numl and variety of vocational programs.

Among the "concretes," 16 of the 32 completed no courses in t science/math category. (A course was said to be completed even if an F was t grade earned.) The remaining 16 completed one course in this category. Amc the "formals," 5 completed no courses, 8 completed one course, and 19 co pleted two or more courses in the science/math category. Mean number science/math credits completed by "concretes" was 4.0, and by "formals" 9 Mean difference score over matched pairs was 5.81 credits (or about 1.5 course which differed significantly from zero, t (31) = 3.35, $p < .001$.

In the liberal arts/social sciences category, mean number of credits was 3 for "concretes" and 38.3 for "formals." In the activities/vocational catego mean number of credits was 10.8 for "concretes" and 9.0 for "formals." Dif ence scores over matched pairs in both cases were not significantly different fr zero.

Cumulative grade point average was examined within each of the th course categories. In each category, included in the analysis were only those p for whom both the "concrete" and "formal" member of the pair had taken sc credits in that category. Because only 50% of the "concretes" took science/math courses, the analyses for that category were based on only 13 pa while analyses for the liberal arts/social science category were based on 32 pa and for the activities/vocational category on 30 pairs.

In the science/math category, the mean GPA of "concretes" was 1.62 of "formals" was 2.40. The mean difference score over matched pairs was . which was significantly different from zero, t (12) = 2.44, $p < .025$. In qua tive terms, course grades among "concretes" in math/science courses were as lows: 3% of the final grades were A's, 8% were B's, 42% were C's, 25% v D's, 17% were F's, and 5% were withdrawals. Among "formals" math/science courses, 11% of grades were A's, 24% were B's, 27% were 18% were D's, 10% were F's, and 10% were withdrawals.

In the liberal arts/social sciences category, the mean GPA of "concretes" was 2.08, and of "formals" 2.18. In the activities/vocational category, mean GPA of "concretes" was 2.83, and of "formals" 3.04. In both cases, difference scores over matched pairs were not significantly different from zero.

STUDY II

Since it was only in the category of science/math courses that any differences were found between subjects designated as "concrete" and those designated as "formal" on the isolation of variables tasks we used, a second study was undertaken, designed to investigate more specifically the performance of students enrolled in science and mathematics courses.

To keep the ability level of students similar in both studies, subjects were 182 college students enrolled in introductory or remedial level mathematics or natural science courses sampled from three different colleges or universities in the Northeast. Students from this population were similar in scholastic aptitude to the population drawn from in Study I, as indicated by the range of ACT or SAT scores in the respective student bodies. Barron's Profiles of American Colleges (1974) lists all the colleges used as being part of the same category, "covering colleges that enroll students with median test scores from the upper 400's (above 450) to about 550 on the SAT, or from 20 to 23 on the ACT" (p. xviii).

In this sample, there were 18 males and 162 females: 35% were freshmen, 39% sophomores, 12% juniors, 10% seniors, and 4% unclassified. Subjects were from four different classes: an introductory physics class for nonmajors, a remedial algebra class, a first-year college algebra class, and an introductory chemistry class.

In order to maximize the accuracy of assessment, after subjects were screened using the previously described written problems, low scoring subjects were interviewed individually using a version of the Kuhn and Brannock (1977) plant problem. Again, this problem involved a common, everyday situation—doing laundry. The outcome was a cloth coming out clean or dirty; the potential causal variables were powdered or liquid soap, Type A or Type B bleach, and blue vs. white laundry booster. The intent, similar to that in Study I, was to compare the academic performance of students reasoning at a "concrete" level to that of students scoring at a "formal" level.

Results

Results were quite striking and contrary to expectation. Of the 182 students, only one scored at Level 0 and none at Level 1. The remainder were at least transitional or fully formal with regard to the isolation of variables strategy as assessed

by the laundry problem. This proportion of roughly .5% is significantly different from the 12% of a general college population (as opposed to those enrolled in science/math courses) who were classified as "concrete" in Study I ($X^2 = 19.31$, $p < .001$), or the 6% reported by Kuhn, Ho, and Adams (1979), based on individual administration of the plant problem to students in introductory psychology classes.

Discussion

At the broadest level, results of these two studies support the thesis that the measured presence or absence of a formal operational reasoning strategy, as represented here by the Kuhn and Brannock (1977) isolation of variables task, affects performance in a real-world context. The present studies also suggest that such effects may be selectively concentrated in math/science, rather than generalized academic performance.

The significant effects in Study I were limited to coursework in the math/science category. The effects included not just academic performance (as indexed by GPA), but also number of courses enrolled in. These findings suggest the likelihood of the operation of a self-selection process on the part of students reasoning at a concrete level, with respect to math/science coursework. This likelihood is supported by the fact that only 16 of the 32 "concrete" subjects in Study I had enrolled in *any* math/science courses during their first two years. In contrast, only four "formals" enrolled in no math/science courses and one "formal" dropped her only such course. This finding was made more striking by two facts. First, as mentioned earlier, the true competence of some of the "concrete" subjects may have been underestimated due to the group administration procedure and written form of assessment. They may actually have had the capacity to reason at a formal level, under improved assessment circumstances. In addition, this finding is based on an assessment of performance on just one measure of formal operational reasoning. Presumably, if subjects had had to qualify as "concretes" or "formals" on several measures, this would have reduced potential classification errors further. Nevertheless, the group of 32 subjects labelled as "concrete" both took significantly fewer math/science courses, relative to their matched "formal" counterparts, and performed significantly more poorly in the courses they did take.

The existence of a self-selection process is further supported by the results of Study II. When students in lowest level math/science courses were carefully assessed on an individual basis, only a very small percentage showed reasoning at a concrete operational level. This would suggest that by the end of high school, college-bound students have acquired some self-knowledge of a sort that leads some of them away from enrolling in math/science courses in their beginning college years. Such a strategy on the part of these students may in fact be an effec-

tive one. The formal reasoning deficits of the "concrete" group in Study I did not lead them to drop out of college any more frequently than their "formal" counterparts, nor were their overall GPA's or numbers of courses taken significantly different from those of the "formals."

These students did differ, however, in the kinds of coursework they enrolled in, i.e., they tended to avoid courses in the fields of mathematics or natural sciences. Such a tendency, of course, has some extremely important implications, both in terms of limiting these students' own personal options and in terms of a broader loss to society. Thus, the results of the present research point to the importance of our being concerned about the development of formal operational reasoning strategies (or the lack thereof) during the high school years. Investigation of this area must begin, in our view, with very broad, thorough investigation of the particular senses and contexts in which middle and older adolescents in fact lack the ability to reason at a formal operational level—an objective which the present study did not encompass. (See Kuhn, Ho, & Adams, 1979.)

Finally, a few words should be said regarding what, if anything, the present study reveals about the role of formal operational reasoning strategies in college level coursework. It should be emphasized that what we are able to say about this relationship is severely limited by the limitations intrinsic to our main dependent variable, GPA. It is not necessary to go into a discussion here of all the variables that contribute to determining a student's college course grades. It is sufficient to say that GPA is at best an imprecise, global measure of student achievement. It is also, as we have all come to accept, only somewhat related to a student's comprehension or mastery of course material. Thus, we would not wish to suggest, based on the present results, that formal operational reasoning strategies are irrelevant for the understanding of concepts in social science or liberal arts fields. The more correct interpretation, we believe, is that formal operational strategies (or, at least, the particular strategy investigated in the present study) are evidently not necessary or facilitative with respect to the types of competencies students are required to exhibit to earn satisfactory grades in introductory level college courses in these fields.

To achieve any deeper understanding of the role of formal operational reasoning in academic work at the college level, it is necessary to look more closely at the nature of this work itself. In future research in this area, our objective is to follow beginning college students who show various patterns of initial reasoning competency through a number of their beginning college courses, in order to identify the particular concept areas or activities in which they encounter success or failure.

REFERENCE NOTES

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