Are Colleges Concerned with Intellectual Development?

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The assumption is often made by college professors that incoming freshmen students think logically. Using tests designed by the Swiss psychologist Jean Piaget to evaluate logical thought processes, the authors found that 66 of 131 freshmen exhibited characteristics of the concrete operational thinker, while another 32 did not meet the criteria for formal operations. Professors further compound the problem by failing to recognize the kinds of experiences incoming freshmen students must have to move toward more logical thought. McKinnon, using a newly developed inquiry-oriented science course based upon Piagetian criteria, found a highly significant difference between those students who were exposed to the course and like students who were not. The authors concluded that secondary and elementary teachers do not take advantage of inquiry-oriented techniques so necessary to the development of logical thought because college professors do not provide examples of inquiry-oriented teaching.

INTRODUCTION

Are colleges and universities making inadequate evaluations of student ability to think logically? Is the unrest today in many universities caused by student evaluation of problems based upon emotion rather than logic? Do student claims that curriculums are irrelevant, trivial, and inadequate in terms of the magnitude of the problems facing mankind today have substance, or are these students unable to evaluate logically the structure and necessity of those curricula? These questions, together with suspicions voiced by various professors of science about the inability of their freshman students to think logically about the simplest kind of problems, led the authors to question whether or not most college freshmen do think logically. This doubt about the ability of the entering freshman to think logically led to the following hypothesis: The majority of entering college freshmen do not come to college with adequate skills to argue logically about the importance of a given principle when the context in which it is used is slightly altered.

Since these students have been accepted by boards of admission that based their decisions upon high school transcripts and various established entrance examinations such as the American
Table I. A comparison of operational level of 131 students on Piagetian data.

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Total number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal</td>
<td>25</td>
<td>8</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td>Post-concrete</td>
<td>12</td>
<td>20</td>
<td>32</td>
<td>25</td>
</tr>
<tr>
<td>Concrete</td>
<td>16</td>
<td>50</td>
<td>66</td>
<td>50</td>
</tr>
<tr>
<td>Mean Piagetian score</td>
<td>12.82</td>
<td>9.45</td>
<td>Average 10.74</td>
<td></td>
</tr>
</tbody>
</table>

College Test (ACT) and the Scholastic Aptitude Test (SAT), a different means of evaluation was sought. The evaluative system used is one based upon the ability of the student to think critically about problems, the answers to which would be found in his experiential background and could not be derived from memorized data.

**WHEN DO STUDENTS BEGIN TO THINK LOGICALLY?**

The scheme of evaluation of the ability to think logically which was used has been developed and verified by a Swiss psychologist, Jean Piaget, during many years' research with children. There is, however, no indication that his work has been extended to include entering college students, particularly American students. In addition, no work can be found with American children which verifies his conclusions that children begin to think logically between ages 11–15.

Piaget found that children progress through various stages of mental manipulation and that these steps cannot be circumvented. Prior to thinking about abstract ideas, a student must undergo a period of physical manipulation of objects using the basic principles upon which the abstraction to be developed depends. This stage Piaget identifies as the concrete stage of thought. A student may handle concepts quite adequately, but until he has had many manipulative experiences he cannot recognize those concepts in the context of a broader generalization, of which the manipulative experiences and the concepts are simply a subset.

Inhelder and Piaget found that from 11–15 years of age most Swiss children should become formal operational, i.e., capable of abstract logical thought. The concern of this research was whether or not this was true for American college freshmen, i.e., had those students become formal operational?

**A STUDY OF THE ABILITY OF COLLEGE FRESHMEN TO THINK LOGICALLY**

McKinnon studied responses to tasks given 131 members of the freshman class at an Oklahoma university in which students had to think logically about problems of volume conservation, reciprocal implication of two factors, the elimination of a contradiction, the separation of several variables, and the exclusion of irrelevant variables from those relevant to problem solutions. These tasks had initially been developed by Inhelder and Piaget for determining the patterns of thought of children and the ages at which changes in those thought patterns occur.

Table I presents the test results for these 131 students using the foregoing tasks and the criteria specified by Inhelder and Piaget for demonstrating formal operational thought. Each student was graded from 0 through 4 on each of the tasks. Should a student score a total of 14 or more points on the five tasks, he was judged as definitely being at the formal operational stage. To achieve 14 points, he had to score at least 3 points on the

Figure 1. A comparison of ACT score versus Piagetian score for 94 freshman students.
tasks for which 4 points were possible. If a student scored an average of 2 points or less on each of the five tasks, he was judged to be at the concrete stage of operations. Those students who scored more than 10 but less than 14 points were judged to be moving from the concrete stage to the formal stage of thought.

The findings, as shown in Table 1, are that 50% of the entering college students tested were operating completely at Piaget’s concrete level of thought and another 25% had not fully attained the established criteria for formal thought. The average score for all students was 10.74, with the males scoring significantly higher than females. An examination of the performance of the students on the various tasks used follows:

1. Of the college freshmen tested, 17% of them did not conserve quantity (the result of a change of form), while another 10% failed to recognize equivalence of volume. Thus, 27% of those students tested were at the lowest concrete operational state or less.

2. Reciprocal implication involved the student in the problem of reflecting a ball and the necessity to relate incident and reflected angles. This task was second only to the problem of density in the number of failures recorded—64% scored 2 or less.

3. The elimination of a contradiction involved the student in relating weight and volume of floating and sinking objects in a meaningful way. More than ½ of those tested did not relate weight and volume. Typically, they recognized weight only. Seldom was there a proportionality expressed; 67% of the students tested on this task were concrete operational.

4. The separation of variables task gave evidence that 50% of entering college freshmen could not recognize the action of a potential variable and find a way to prove the action of that variable.

5. The task of excluding irrelevant variables showed that 33% of the students tested could not eliminate variables of no consequence in a swinging pendulum, while another 18% could do no more than order the effects of weight.

In the research, a comparison was made of the score obtained by each student on the various Piagetian tasks given him and this score was correlated with his ACT composite score. (See Fig. 1.) A graph of these two scores shows that Pearson product-moment correlations were high for those students scoring at the average ACT composite of 22 or better, but correlations of −0.05 were found for students scoring less than that average. The university where this study was made ranks high in terms of the average ACT scores when compared with all other colleges and universities in Oklahoma and is well above average for all regions of the United States. Almost 75% of that university’s entering freshmen, however, were either partially or completely concrete operational. What evidence exists, therefore, to demonstrate that logical thought can be promoted among all levels of students?

**CAN INQUIRY-ORIENTED COURSES PROMOTE LOGICAL THOUGHT?**

The University of Oklahoma Science Education Center has, for some time, been investigating the effects of inquiry-oriented teaching upon both teachers and pupils. Various new courses in science which utilize the inquiry approach have been evaluated. Porterfield compared teachers of reading who had inquiry educational experiences in science with those who had not. He found that the former tended to use more questions requiring analysis and synthesis and other high-level cognitive thought patterns than did the latter group. Wilson found much the same in a study of 30 classes of elementary children when fifteen of the teachers had been exposed to inquiry experiences in science and fifteen had not. Schmidt found similar results by investigating the teaching in social studies done by teachers who had and had not been involved with inquiry in science. Friot found in a study of seventh, eighth, and ninth grade science that courses placing emphasis upon the inquiry approach allowed students to be able to function at a much higher level of logical thought than those courses in which students did not have that inquiry experience.

Stafford used the development of conservation reasoning in children as an evaluative tool to determine whether or not inquiry-oriented science experiences move first graders toward the acquisition of concrete operational thought. The specific unit he used was Material Objects. Stafford found: “... those first grade children who have experiences with the unit achieved the ability to
Table II. A comparison of the growth in logical thought processes of the experimental and control groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Stage</th>
<th>Pre-test</th>
<th></th>
<th>Post-test</th>
<th></th>
<th>Net. gain</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
<td>Males</td>
<td>Females</td>
<td>Males</td>
</tr>
<tr>
<td>Experimental</td>
<td>Formal</td>
<td>4</td>
<td>11</td>
<td>14</td>
<td>16</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Post-concrete</td>
<td>14</td>
<td>6</td>
<td>17</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Concrete</td>
<td>24</td>
<td>10</td>
<td>11</td>
<td>3</td>
<td>-13</td>
<td>-7</td>
</tr>
<tr>
<td>Control</td>
<td>Formal</td>
<td>4</td>
<td>14</td>
<td>7</td>
<td>17</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Post-concrete</td>
<td>6</td>
<td>6</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Concrete</td>
<td>26</td>
<td>6</td>
<td>18</td>
<td>2</td>
<td>-8</td>
<td>-4</td>
</tr>
</tbody>
</table>

Contrive much more rapidly than did those children who did not have these experiences. Material Objects is an inquiry-centered unit and Stafford concluded: "...children so taught do show more rapid intellectual development than do those children not having such experiences."

Finally, McKinnon, in a study of the effect of an inquiry-centered science course on entry into the formal operational stage of concrete operational freshman college students, found a highly significant difference between those students enrolled in the course and a like group who had not been exposed to the course.

The data of Table I gave evidence of the ability of students to think logically. The data of Table II show the effect of the inquiry-centered course upon freshman students' ability to think logically. A net gain in favor of the experimental group resulted in 15 students moving into the formal stage of thought—compared with six for the control group. The post-concrete gain was, respectively, five and six, with the experimental group showing a net movement of 20 out of this category compared with 12 for the control group, a net gain of more than 50% for the group exposed to the influence of the new science course. The material of the science course did not include references to the tasks which were part of the test instruments; therefore, changes in ability to think logically were caused by added opportunities for inquiry. Another comparison in terms of the mean Piagetian scores for the two groups is shown in Table III.

After obtaining individual pre-test-post-test differences and summing them up for each group, an F ratio of 6.24 was obtained. This value is significant in favor of the test group at the 0.001 level of confidence; therefore, the hypothesis must be accepted that a properly designed course in science for freshman college students does enhance their logical thought patterns by increasing their ability to hypothesize, verify, restructure, synthesize, and predict.

The preceding research gives evidence that students do not think logically. However, research carried out on newly developed courses does give evidence that the logical thought processes can be enhanced. Therefore, who is at fault and what steps must be taken to alleviate the situation?

AN EVALUATION OF EDUCATIONAL RESPONSIBILITY USING THE INQUIRY APPROACH

If students do not think logically when they enter college, who has not discharged his responsibility? The immediate answer to the foregoing question is, the high school. That answer, however, needs to be examined.

Piaget states formal operations begin to emerge around 11 years of age. But Erickson found that 82% of eighth and ninth grade children (ages 13 and 14 years) were still concrete operational. Thus, children probably enter senior high school two to three years behind the age set by Piaget for Piagetian mean scores for both experimental and control groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>69</td>
<td>62</td>
</tr>
<tr>
<td>Post-test</td>
<td>69</td>
<td>62</td>
</tr>
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</table>

1050 / September 1971
entering into formal operation. While some of this age difference might be attributed to differences in the samples of Piaget and Friot, the entire 82% cannot be. The answer to the question of who is responsible for the lag in intellectual development seems to be the elementary school. But that answer, too, needs to be examined.

Begin that examination with another question. Who is teaching in the elementary and secondary schools? Teachers who have been educated in the existing colleges and universities. Those teachers have been subjected to four years of mainly listening experience. They have been lectured to, told to verify, given answers, and told how to teach. Lest you think the foregoing happens entirely in the colleges and/or departments of education, remind yourself that all the content taken by a teacher (which represents a substantially greater number of credit hours than do courses in education) is taken in other colleges and/or departments. Teachers are, in other words, not having the kinds of experiences with inquiry which Piaget says they must have in order to allow logical thought processes to develop. Future teachers are not having learning experiences in college which will permit them to learn the value of inquiry in educating a child. The foregoing rather dogmatic statement was substantiated by Gruber when he found that only 25% of those attending NSF Institutes showed interest in inquiry-oriented science teaching, while Torrance found that only 1.4% of elementary and 8.4% of secondary social studies teachers listed independent and critical thinking as important educational objectives. These statistics suggest that pre-college teachers place little value upon logical thought as an outcome of 12 years of schooling. Considering the paucity of research on implementation of logical thought as an educational objective, these educators' values will not change. The responsibility, then, for the small percentage of high school students attaining formal operations rests in part at the door of the institutions of higher education. They have assumed that their role is to tell. Future teachers, therefore, assume that telling is teaching and when they get their first class, they tell, tell, tell! All the while, very little, if any, intellectual development is going on. If, then, a college student develops logical thought, such development is more by accident than design.

One of the criteria Piaget cites for intellectual development is that of social transmission. Just possibly more intellectual development goes on in dorms, fraternities, sororities, and student hangouts than in the classroom because social transmission occurs in these places and little occurs in classes. To test our assertions, walk down the hall of any building on any campus and stop outside any classroom door and listen to who is talking. In most instances only information is being transmitted by the instructor.

Stafford and Renner hypothesized that "... specialized educational experiences in inquiry-centered science teaching encourage a teacher to become sensitive to children, functionally aware of the purposes of education, and equipped to lead children to learn how to learn in all subject areas." The importance of this hypothesis is in the phrase "... all subject areas," for inquiry methodology is not only the province of science, but all the other disciplines as well. Unfortunately, few other teaching areas have recognized the importance of the inquiry approach.

With the exception of a few new courses in the social science areas, most educators have chosen to ignore the lead taken by science and mathematics in devising new courses from kindergarten through the 12th grade. In many cases, the colleges have failed to use inquiry even when teaching the new curricula. This point was well illustrated by Gruber. Therefore, the blame must, in the last analysis, be placed, at least partially, upon the shoulders of those who teach at the college level and who insist upon ignoring the rapidly accumulating evidence in favor of the inquiry approach.

Renner and Stafford also pointed to the necessity of the teacher becoming "... functionally aware of the purposes of education..." which in far too many cases they are not now. Unless teachers are aware of the primary purpose of education being the development of the learner's intellectual ability, they will not pursue teaching by giving the student opportunities for exploration using all his senses. Rather, they will continue to teach students what the teacher wants them to know and not what the students want to learn.

Finally, the total accumulation of research to date leads to the following hypotheses: (1) The secondary educational experience does not now
promote logical thinking in most students. (2) An abundance of inquiry-oriented courses taught by teachers who are products of college and university professors who practice and profess inquiry must come into being in the secondary schools before an alternative to the first hypothesis can be accepted. Those experiences will have to be developed by many colleges.

Those hypotheses have profound educational implications since a serious problem has been shown to exist and the means for its alleviation have also been shown to be available to the profession. If colleges and universities do not try to solve the problem by assuming the responsibility for the intellectual development of their students, but continue to look at their primary purpose as the transmission of information about the several disciplines, the elementary and secondary schools will continue to fail in their mission of truly educating students. The needed changes, however, can come only through acceptance of inquiry by all of those who teach the teachers.

5 American College Testing Program: College Student Profiles (ACT Publications, Iowa City, Iowa, 1966).
10 Science Curriculum Improvement Study, University of California at Berkeley. (Rand-McNally, Chicago, Ill., 1970.)
12 J. W. McKinnon, Ref. 3, p. 37.

Radiation Field of a Charge Moving on a Straight Line

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A derivation of the radiation field of a charge accelerating on a straight line is presented that makes use of Gauss’ law in a direct manner and does not make use of the concept of lines of force.

We derive the radiation field of an accelerating point charge from the following assumptions: (1) electric effects are transmitted with the velocity c; (2) Gauss’ law holds good in all inertial frames of reference; (3) the electric field of a charge moving uniformly is known.

These are the assumptions made by J. R. Tessman and J. T. Finnel to derive the radiation field of a point charge moving on a straight line. However, we shall not make use of the concept of lines of force, and Gauss’ law shall be used in a most direct way.

Consider the following kinematic sequence on a straight line of a particle with the charge q:

(a) The charge moves with constant velocity \( v_1 \) until \( t = t_0 \). At \( t = t_0 \) we designate its position by \( O \).

(b) The charge moves with constant velocity \( v_2 \) thereafter. We only suppose that \( v_1 , v_2 \) are less than c.