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David W. Brooks
University of Nebraska at Lincoln

Victor W Day
University of Kansas

J. D. Lewis
Fermi National Accelerator Laboratory (Fermil…

Mark Albanese, David W. Brooks, Victor W. Day, Roger A. Koehler, J. D. Lewis, Robert S. Marianelli, E. P. Rack, and Carol Tomlinson-Keasey
University of Nebraska-Lincoln
Lincoln, 68588

Piagetian Criteria as Predictors of Success in First Year Courses

J. Dudley Herron is to be complimented upon his carefully written article, "Piaget for Chemists" (*1*). Although Piagetian ideas have existed for many years, only now are they becoming appreciated (*2, 3*). Herron makes a point in his article (*1*) that is of great interest to those concerned with problems of student placement. He claims a correlation of 0.8 between performance on a battery of Piagetian tasks and total points earned in one of his chemistry courses at Purdue. This correlation is of a magnitude to be extremely useful if widely and conveniently applicable to student placement.

It is important for the reader to comprehend what is involved when a student performs on a Piagetian task. One such task involves generation of a color by mixing chemical solutions. The student is provided with five colorless, odorless solutions: 1) dilute sulfuric acid, 2) water, 3) dilute hydrogen peroxide, 4) aqueous sodium thiosulfate, 5) aqueous potassium iodide. The person administering the test takes two vessels, one previously filled with water, and the other filled with a mixture of dilute acid and peroxide, and adds a few drops of iodide solution to each. Only the second mixture gives a yellow color. After the demonstration, students are asked to mix the chemicals using solution 5 plus any combination of the other liquids. The objective is to determine which combinations lead to color formation.

Chemists immediately recognize that the color forming reaction requires acid and peroxide, that water will have no effect, and that thiosulfate will prevent the formation of a yellow color.

Typical results of the experiment are described by Inhelder and Piaget (*4*). Also, a demonstration of the application of this task is shown in a film by Robert Karplus (*5*).

Piagetian tasks are lengthy to administer. One is concerned not only with the student's performance, but also with any justification offered on behalf of the problem solving strategy selected. It is almost impossible to conceive of practical circumstances where Piagetian tasks, which always involve manipulation of some concrete objects such as chemical solutions, can be administered to groups of thousands of students. Therefore, experimenters have tried to devise pencil and paper tests which "get at" the same measurable variables (*6*). It is the feeling of many that students perform less well when confronted with the pencil and paper tests than with the manipulative tasks themselves.

Student Results on the Placement Tests

Subscale	Characteristic Measured	Number of Items	F(dfb, dfe)	Percent of *Additional* Variance in Course Grade
1[a]	Arithmetic and Algebra	15	124.8	12.39
2[a]	General (Chemical) Knowledge	25	67.1	6.19
3[a]	Formulas and Nomenclature	10	1.7	0.15
4[a]	Chemical Equations	6	2.4	0.23
5[a]	Algebraic Formulations	6	10.9	0.99
6[a]	Chemical Problems	5	5.93	0.54
7	Reading Comprehension	4	4.01	0.36
8	Interpreting Graphs and Charts	4	1.08	0.10
9	Attitudes	19	1.68	0.15
10	Science and Math Background	3	0.05	0.00
11	Possible Combinations (Piagetian Task)	6	0.04	0.00
12	Identification of Compounds (Piagetian Task)	7	2.95	0.27
				21.4

[a] Toledo Placement Test, Parts 1–6.

Although pencil and paper tests can be evaluated more rapidly than manipulative tasks, they still require that answers be read carefully, that problem solving strategies be evaluated, and that scoring try to reflect the same assessment of the stage of intellectual development as would obtain from observation during manipulative tasks. Such scoring is tedious and expensive.

Because several of us had some experience in preparing and evaluating written Piagetian tasks, we decided to include such tasks as part of a placement test and invest the time and money to determine whether or not we could significantly improve our course placement procedures. (The cost of scoring each student's written responses was about $0.50 per student).

Placement Tests

Registration of students within multi-track general chemistry courses is traditionally accomplished on the basis of recommendations of college admissions officers (using student records, class rank, SAT (ACT) scores, etc.) and/or performance on placement tests.

The Division of Chemical Education has long supported the notion of chemistry placement tests, and the Toledo Chemistry Placement Examination was reissued in 1974. Articles in *this Journal* (*7*)[1] and other journals (*8*) have described the use of placement tests. Many teachers such as John Renner and Glenn Crosby have devoted a great deal of effort to the problem of placement.[2]

[1] A comment by Haffner in reference (*7*) implies that the information developed from SAT scores alone is effective in generating placement recommendations, and that the data gleaned from chemistry and math validation tests offer refinement. Quoting from reference (*7*), p. 160: "It (*sic*, the Academic Composite, a sum of four College Board test scores—math aptitude, math achievement, verbal aptitude, and English composition—plus the prior academic achievement score) is, in itself, a good predictor of overall grade point average and predicts most course grades fairly well." A recent contribution by Pickering (*9*) describes use of SAT scores alone to predict "maximum" course grades.

[2] John Renner of the University of Oklahoma and Glenn Crosby of Washington State University have developed and thoroughly tested instruments which are useful in student placement. Both of these congenial individuals seem most pleased to share their experiences with the academic community at large.

[3] The analyses of the placement test data were performed by Mark Albanese and constituted partial fulfillment of his requirements for the degree of Master of Arts in the Department of Educational Psychology and Measurements. Detailed discussions of the instrument, subjects, course structures, techniques of analysis, reliability of the instrument, and validity of the instrument may be obtained by writing to David W. Brooks at the Department of Chemistry, University of Nebraska—Lincoln, Lincoln, Nebraska 68588.

At the beginning of the Fall Semester, 1974, a placement test in general chemistry was administered to classes at the University of Nebraska–Lincoln. This test consisted of the 1974 "Toledo" test together with other subsections including two pencil-and-paper Piagetian tasks. The results for 885 students are summarized in the table.

Discussion[3]

The purpose of the placement test we developed was to improve upon the placement advice given to entering students by our admissions officers, and to test the notion that scores on written Piagetian tasks would be particularly effective as course grade predictors. We have clearly failed in the first regard, since we are unable to account for more than 21% of the criterion variable (predicted grade).[4]

The impact of the Buckley amendment on this research is that we are unable to conveniently obtain and correlate the data available for each individual student with other data such as ACT score available in personal files. However, it is exceedingly unlikely that most of the variance we account for is not elsewhere accounted for in the admissions data. That is, it is unlikely that we are assessing cognitive skill levels that were not previously assessed using data available to our admissions officers.

It is also noteworthy that our Piagetian tasks account for very little variance in course performance. That is, the specially designed Piagetian tasks did not appear to account for additional variability in criterion score over and above that which was already accounted for in the subscales of the Toledo Chemistry Placement Examination.[5] By way of explanation we might argue that the measures used, while not attempting to specifically tap logical reasoning, do tap these processes. In fact, the authors of the ACT test claim that many of the test items are intended to measure skills which we would interpret as formal operational skills (*10*). Hence, much of the variance accounted for by any Piagetian task should have at least partially been accounted for in the ACT (or SAT) scores.

We still have not accounted for the disparity between Herron's results and those reported herein. Several possible explanations may be offered

1) Pencil and paper Piagetian tasks are not as effective as manipulative Piagetian tasks in assessing the formal operational skills of students.[6] On the other hand, one might expect pencil and paper tests to better reflect the circumstances under which a grade in general chemistry is earned, since most course tests are written. Should results on manipulative Piagetian tasks so effectively predict scores in courses where grades are based upon written tests?
2) Grades in Herron's course at Purdue may be based more on formal operational skills than those in the courses studied at UNL. Although they varied in degree, some of the UNL classes were taught at a high formal operational level. Grades in a course do not necessarily reflect anything about the teaching of the course in terms of formal operational skills required for success. For example, the algebraic formulation subscale (Toledo test, section 5) was not as important in accounting for grade variance of the chemistry majors as it was for students in the other courses we studied. The mean score for chem majors on this subscale was five out of six items correct, while that for students in the regular course was almost one item lower. Thus, the failure of this subscale to account for variance is attributable to the fact that the chemists performed very well and little discrimination was possible. It did not indicate that there was a lesser requirement for algebraic formulation in the chemistry major's course.
3) The original correlation reported by Herron may be spurious, and due to some artifact of sampling. For example, if Herron's students were relatively low performers in formal operations, the result he obtained might be anticipated. When pencil and paper Piagetian tests are administered to groups of students within colleges at UNL, for example, scores for freshmen students in the College of Engineering are significantly higher than those for students in Teachers College (*6*). A small sample in a course section of special and homogeneous student composition might give the results found.[7]

We endorse Herron's suggestions related to the construction of chemistry curricula taking Piaget's stages of intellectual development into account. However, we are as yet unable to translate these ideas in a practical manner for meaningful improvement of the advice we give our students *vis a vis* selection of first year chemistry courses.

[4] Seven course sections were studied and, when examined separately, the percent of variance accounted for ranged from 28.1–42.2%. For the two faculty members teaching two sections each, the percentages of variance in grade accounted for were 29.9/42.2% and 28.1/42.2%. The instrument is a better predictor for students once they know which class they are in—and, one *could* advise students about where their grade opportunity would be maximized. This is because each professor had different exams, different grade weighting schemes, and different grade distributions. When all of the courses are lumped together, the data of the table result.

Reference (*8*) describes the use of the ACS-NSTA Cooperative Examination—High School Chemistry as part of a grade prediction formula. In that study, the test alone accounted for 29% of variance in criterion variable (course grade), and the overall regression equation, including high school average, SAT math, and school of registration, accounted for 41% of variance. The number of lecturing faculty or the number of course sections was not indicated.

When *individual lecture sections* of this study are examined, the best case is 42% of variance accounted for by the 12 subscales of the placement test, with 39% of the variance accounted for in the Toledo Placement Examination. In the worst case, 28% of variance was accounted for with 21.5% of that variance accounted for by the Toledo Placement Examination.

[5] Factor analysis indicated that the Piagetian subscales factored well within themselves, and did not factor with items on the Toledo Examination. Whatever the Piagetian subscales are measuring does not seem to be highly predictive of performance in any of the seven chemistry classes studied.

When the subscales are rearranged and the Piagetian scales placed first, they account for no more than 5.71% of variance. In this case, the variance is confounded with that of the other subscales of the instrument.

Herron (reference (*1*), p. 148) reports a correlation of 0.7 between scores on a "chemistry placement test" and scores on the battery of Piagetian tasks. This is consistent with the notion that whatever placement test he uses gets at some of the same skills as does the battery of Piagetian tasks.

[6] A synergism between manipulative tasks and cognitive learning has been discussed (*11*) and may well play an important role in accounting for the often extreme differences observed between pencil and paper tasks and manipulative Piagetian tasks. These differences are currently under investigation.

[7] When the 19 women in the chemistry major's course of this study were considered separately, fully 88% of the variance in criterion can be accounted for, including 43% from the general knowledge subscale of the Toledo Chemistry Placement Examination and 13.4% from the Piagetian subscales, 11 and 12. Only the variance accounted for by the general knowledge subscale was significant.

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