PSI and Piaget

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Each graduate of DePauw University must demonstrate a minimum competency in expository writing, quantitative reasoning, and oral communication. These competencies are demonstrated by satisfactorily completing a course in which one of these skills is emphasized along with the academic content. Such courses are designated as a W course, a Q course, and a S course respectively.

Not all entering freshman students are qualified to enter a W course or for that matter the introductory course in English Composition. Similarly not all students are ready to enter a Q course. These students are placed in a "developmental" writing course and a Q readiness course respectively. Placement is done by means of examinations which are administered during the orientation week in the fall. This paper is concerned with Q readiness. Q placement is ascertained using a Basic Mathematics Test, designed by the mathematics staff. It is an objective test of 50 items. The first 25 items assess Q readiness; it is patterned after the Whimby Analytical Skills Inventory (7). A score greater than 12.5 certifies the students as being Q ready. Items 26-50 which emphasize algebraic skills are used for calculus placement. A score of 15 or more qualifies the student for the beginning calculus course. Table 1 summarizes the percentages of the entering students who are not qualified for W, Q, and calculus courses respectively for the past three years.

TABLE 1. *Competencies of Entering Students*

Academic Year	Class Size	S.A.T. Averages		Not Qualified for in		Percentage
		Verbal	Math	W	Q	Calculus
1981-82	660	517	542	7.6	17.7	37.3
1982-83	676	508	552	7.7	16.7	44.1
1983-84	668	500	557	6.9	15.4	45.8

Students are placed in the Q readiness course, Introduction to Quantitative Reasoning, as the direct result of failing a placement examination over material which should have been mastered during the pre-college years. Traditional methods of instruction associated with teaching quantitative skills did not work initially; consequently, a new approach seemed necessary!

The Personalized System of Instruction, PSI, which is structured within the psychological theory of reinforcement through reward seemed ideally suited to serve as the instructional vehicle for Math 100. PSI seems best adapted for courses that have a structured and highly objective content as opposed to a subjective content. The salient features of PSI as outlined by Keller (3) include:

1. The PSI course is *individually paced*. Each student proceeds at his/her own pace through the course in which the content material is divided into a number of short, easily assimilatable chunks. Each student demonstrates competency in the material of each unit by passing the unit or module test with a perfect score before passing on to the next module. No penalty is assessed if the student fails the quiz.

2. The PSI course is *mastery oriented*. The prime objective is that the student learn the material; hence, s/he must demonstrate competency over each unit before moving onto the next. Negative stimuli to learning are minimized by not imposing a penalty for failure of any quiz nor constraining the student to learn within a set time frame. If the student fails to finish during the semester, s/he can finish during the Winter Term session in January. The industrious student can finish the course well before the end of the semester. During the 1981-82 academic year 16 students finished before Thanksgiving. In the 1982-83 academic year 8 students finished early.

3. The PSI course is *student-proctored*. Throughout the course the students interact directly with undergraduate assistants. These assistants answer questions, administer and grade quizzes which they immediately critique with each student, and decide if the mastery of the particular unit on the part of the student is sufficient to pass him/her along to the next module. Initially module tests were administered from 8:00 to 9:00 a.m. four days per week; presently they are given from 3:00 to 4:30 p.m. four days per week.

4. The PSI course uses *formal study guides to commercial information*. The text, *Arithmetic and Algebra* (5), is almost a programmed tome. The supplementary material for each of the fourteen chapters includes a content summary section which is written to provide greater insight into the academic content of the unit and in certain instances provide additional material. Examples of additional topics which are not included in the next include introduction to mathematical induction, graphing techniques including the ideas of interpolation and extrapolation, number bases, and the compound interest law. A practice module test with answers is an integral feature of each unit supplement.

5. The PSI course provides for *lectures and activities* that are meant for *enrichment and stimulation*. No lecturing is done on mathematical subjects. Student questions are answered on a one-on-one basis by the student assistants, the instructor, or at the Q Reasoning Center in the college library. To provide "enrichment" students meet in small groups once each week with the instructor. The topics treated are math anxiety, how people think, and how to solve word problems. Each will be discussed separately.

To deal with math anxiety the attempt is to make those, who have the problem, realize that it is real and that something can be done about it. The initial emphasis is that the PSI format poses no threat to them and that module tests can be repeated as many times as needed. Two formal sessions are organized for the entire class. One deals with test taking strategies with emphasis directed toward the objective examination. The other focuses on the phenomenon of anxiety with emphasis on recognition and self-diagnosis. Personnel from the counseling service of the University lead these sessions. Finally each student writes his/her math autobiography in which the good and the bad experiences that they have had with math are discussed. Typical comments include:

> ". . . I hated math all through my childhood. I really never knew my multiplication tables. Grammar school mathematics was a disaster. . . ."

> ". . . I also remember being in the slow math groups in the third grade. My best friend was in the higher group. I had to take my math home and finish it over the summer. My parents were always helpful, but I always felt a little ashamed. . . ."

> ". . . In the ninth grade I ran into the meanest teacher I'd ever seen. She made me extremely embarrasssd and ashamed to ask any questions about

numbers. I began to struggle, became frustrated, and hated numbers. . . ."

". . . I started hating math when the teacher started giving fractions. . . . If I could do math I would be the happiest person on earth."

The enrichment exercises on how people think show that different students attack problems at different cognitive levels. Each student takes the Whimby Analytical Skills Inventory and a Piagetian exercise, the Frog Puzzle which measures proportional reasoning ability. These are graded by the instructor—no mark is placed on the papers—returned to the class and discussed during the next period. The author of this paper has given the Frog Puzzle to several classes. Their performances are summarized in Table 2. Over eighty percent of those enrolled in Math 100 tested concrete operation on the Frog Puzzle. The performance on the Whimby Analytical Skills Inventory will be discussed later.

TABLE 2. *Student Performance on the Frog Puzzle*

Class	Number	No Idea Percentage	Concrete Percentage	Transitional Percentage	Formal Percentage
Introductory Chemistry	56	2	41	25	22
Educational Psychology	32	0	63	12	25
Introduction To Quantitative Reasoning					
1981	56	6	73	9	12
1982	55	18	72	3	7
1983	48	21	72	2	5
High School Chemistry Class	12	0	67	8	25

A second exercise within the units was adopted from a Chautauqua Workshop (1), and is an introduction to Piaget's model for cognitive development. The students do four additional Piagetian Puzzles, The Algae Puzzle (combinatorial reasoning), The Islands Puzzle (propositional reasoning), The Ratio Puzzle (proportional reasoning), and The Mealworm Puzzle (propositional and probalistic reasoning), and the read the essay, "Piaget Simplified". They then are given a set of answers to these puzzles given by five other students. As a group they classify these five persons as being concrete operational, transitional operational, or formal operational. The Piaget categories of cognitive development are presented and discussed; in particular the process of self-regulation (6) is emphasized. The idea of the Learning Cycle as developed by Karplus (2) and its implications toward intellectual development is introduced. Finally the theory is put into practice. The group does two Learning Cycles which have been developed by the author, The Chemical Dilemma and An Empirical Approach to Probability. (Copies of these Learning Cycles as well as copies of the Piagetian Puzzles can be obtained by writing the author of this paper.)

The last facet of the enrichment material is a unit on how to solve word Problems. The idea for this unit comes from the paperback book, *Thinking Mathematically*, (4). Following a one period discussion concerning the structure of a solution to a mathematical problem, each section is broken down into groups of four students and problems are solved by committee. Each group presents its solution to an assigned problem to the remainder of the class. Since all groups work on the same problems,

if one group is stuck, the other groups or the instructor provides insight into the solution to the problem.

In this section the performance of the two classes who have completed Introduction to Quantitative Reasoning by Keller Plan pedagogy are presented. All students passed the fourteen modules that were constructed from the textbook material before they were permitted to take the final examination. The final examination consisted of re-administering the Whimby Analytical Skills Inventory and the Basic Mathematics Test, both the Q Placement and the Calculus Placement units. Students were placed in these sections by the Coordinator for the Quantitative Reasoning. Table 3 summarizes the Introduction to Quantitative Reasoning class make up. Notice that the last two SAT-M average is over 100 points less than the average of the freshman class. (Table 1).

TABLE 3. *Compentencies of Keller Section Math 100*

Class	Size	SAT-V average score	SAT-M	Q Placement average score	Calculus Placement
1981-82	62	462	476	10.7	6.8
1982-83	55	462	450	8.8	3.3
1983-84	48	464	415	8.6	4.9

The final performance of the two classes to have completed the Q readiness course using the Keller Plan are presented in Table 4. The performances of the women and

TABLE 4. *Keller Class Performance*

Keller Class Year	All	Women	Men
1981-82			
Number entering	62	40	22
Number withdrawing	8	2	6
		---- average scores ----	
Whimby Inventory	26.2	25.7	27.2
Q Placement			
before	10.7	10.4	11.1
after	16.2	15.6	18.4
Calculus Placement			
	before	6.8 5.5	7.4
after	12.0	11.6	12.1
1982-83			
Number entering	55	34	21
Number withdrawing	12	5	7
		---- average scores ---	
Whimby Inventory	22.3	22.6	21.8
Q Placement			
before	8.8	7.9	10.0
after	18.7	19.0	17.5
Calculus Placement			
before	3.3	3.0	3.6
after	8.3	9.0	7.0

men are compared as well as the class performance as a whole. Of those who withdrew from the course during the semester, six completed it during the Winter Term session in January. Of the 117 students initially placed in the course, 103 completed it. The average increase in the total score of the group on the Basic Mathematics Test was 12.6 points, Q Placement 7.5 points and Calculus Placement 5.1 points. The performance in the course correlates best with the student's initial effort on the Calculus Placement Test. This improvement is presented in Table 5. By not qualified for Q means that the person did not score at least 13 on the first 25 items of the test, and qualified for calculus means that the student scored at least 15 on the remaining 25 items. In only one case did the achievement on the Q Screening Test decrease; achievement on the Calculus Screening decreased in ten cases.

TABLE 5. *Initial Calculus Screening Score and Preformance*

Range	Number	Average Q Screening	Increase Calculus Screening	Number Not Q Qualified	Number Qualified for Calculus
Less than 0	6	8.8	7.7	1	0
0-5	47	7.2	5.5	2	5
5.25-10	31	6.3	5.1	3	13
10.25-15	11	4.6	1.7	2	7

Can the course be classed as a success. In certain instances demonstrated improvement was spectacular. In other cases improvement was at best only tentative. The one thing that did happen during the course was that every student worked problems and at least for a brief time demonstrated a certain competency in arithmetic and algebraic skills. The final question on the Module 14 Test was an anonymous questionnaire that tried to assess the impact of the course on the students. Ninety-five students answered the questionnaire. Sixty-two students preferred the Keller approach to the lecture format, seventy-two acknowledged that their math skills were improved, and forty-three students thought that their math anxiety had been decreased while eight thought that it had increased. Each student had the opportunity to comment about the course and suggest how it might be improved.

The most frequent suggestion was that there be class sessions in which formal lectures treat the mathematical concepts. While the students would feel more secure with this approach, to do this would weaken the most important impact of the Keller Plan, namely, the realization by the individual student that she/he mastered academic material which involved the use of quantitative concepts independently. I feel that the sense of accomplishment of self-learning by the student outweighs any improvement in personal albegraic skills that the student might realize within the lecture format.

Literature Cited

1. Fuller, R. G. and Thornton, M. C., 1978-79. AAAS-NSF CHAUTAUQUA-TYPE SHORT COURSE, The Development of Reasoning through College Science Teaching.
2. Karplus, R. 1977. Science Teaching and the Development of Reasoning. J. Research in Science Teaching, 14, 169-75.
3. Keller, F. S. 1968. Goodbye Teacher. J. Appl. Behavior Analysis, 1, 79-89.

4. Mason, J., Burton, L. and Stacey, K., Thinking Mathematically. Addison Wesley Publishers Ltd., London. 1982.
5. Piaget, J. 1964. Development and Learning. J. Research in Science Teaching, 2, 176-86.
6. Watkins, J. H., Arithmetic and Algebra. Harper and Row, Publishers, Inc., New York, N.Y., 1977.
7. Whimbey, A. and Lochhead, J. Problem Solving and Comprehension. The Franklin Institute Press, Philadelphia, Pa. 1980.

John A. Ricketts is shown in this photo presenting one of his papers during the Science Education Section meeting.