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AUTHOR Johnson, Guy, Jr.; Pascarella, Ernest T.
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ABSTRACT

Increasingly higher education is confronted with the task of educating a population of students whose entry aptitudes and skills have grown more heterogeneous. Perhaps nowhere is this diversity of abilities more apparent, and at the same time more difficult to deal with, than in courses in introductory calculus. This paper outlines an experimental course in self-paced calculus at Syracuse University that was designed to allow for different learning styles and learning speeds, and yet permit students to achieve mastery of the content. The development of the self-paced sections of Calculus and Analytic Geometry was the result of a cooperative effort between the Department of Mathematics and the Center for Instructional Development at Syracuse University. Course development was carried out during the summer of 1973 and the preliminary design was pilot tested during the fall semester 1973. (Author)

SELF-PACED CALCULUS: A CASE STUDY*

by

Guy Johnson, Jr.

Department of Mathematics
Syracuse University

and

Ernest T. Pascarella

Center for Instructional Development
Syracuse University

*Presented at the annual convention of the American Association For Higher Education, Chicago, March 12, 1974.

Introduction

Increasingly higher education is confronted with the task of educating a population of students whose entry aptitudes and skills have grown more heterogeneous. Perhaps nowhere is this diversity of abilities more apparent, and at the same time more difficult to deal with, than in courses in introductory calculus. This paper outlines an experimental course in self-paced calculus at Syracuse University which was designed to allow for different learning styles and learning speeds, and yet permit students to achieve mastery of the content.

Course Development

The development of the "self-paced" sections of Mathematics 295 (Calculus and Analytic Geometry) was the result of a cooperative effort between the Department of Mathematics and the Center for Instructional Development at Syracuse University. Course development was carried out during the summer of 1973 and the preliminary design was pilot tested during the fall 1973 semester.

Course Design

Overview

Early in the development process an adaptation of the Keller plan (Keller, 1968) was agreed upon as the basic approach underlying the course design. In

the Keller plan the student works independently and essentially at his own pace to cover a specified amount of course content, usually three credit hours. Occasional lectures are given, as is tutorial assistance when needed. Students move through the course as fast as they are able to demonstrate in independent testing situations a prescribed level of mastery of each unit of material covered. Modifications of the Keller plan have been employed with varying degrees of success in Mathematics (Henderson and Silver, 1972); Engineering (Roth, 1973); and Physics (Green, 1971; Bamberg, 1973). A summary of the Keller plan experience may be found in Kulik, Kulik and Carmichael (1974).

The principal modification at Syracuse was to permit flexibility in the amount of material covered (i.e., variable credit). Although this has been tried in mathematics (Riner, 1972), it does not seem to have been used in connection with a Keller format.

Lectures, Tutorials, and Staffing

Three one-hour periods per week were scheduled for traditional lectures and problem solving sessions. In addition five tutorials of two hours each were arranged. All testing, grading and individual assistance occurred during the tutorial sessions. The staff consisted of three faculty members, three teaching assistants, and one undergraduate tutor. The faculty members and teaching assistants conducted all lectures, while all served as tutors during selected periods.

Instruction, Testing and Credits

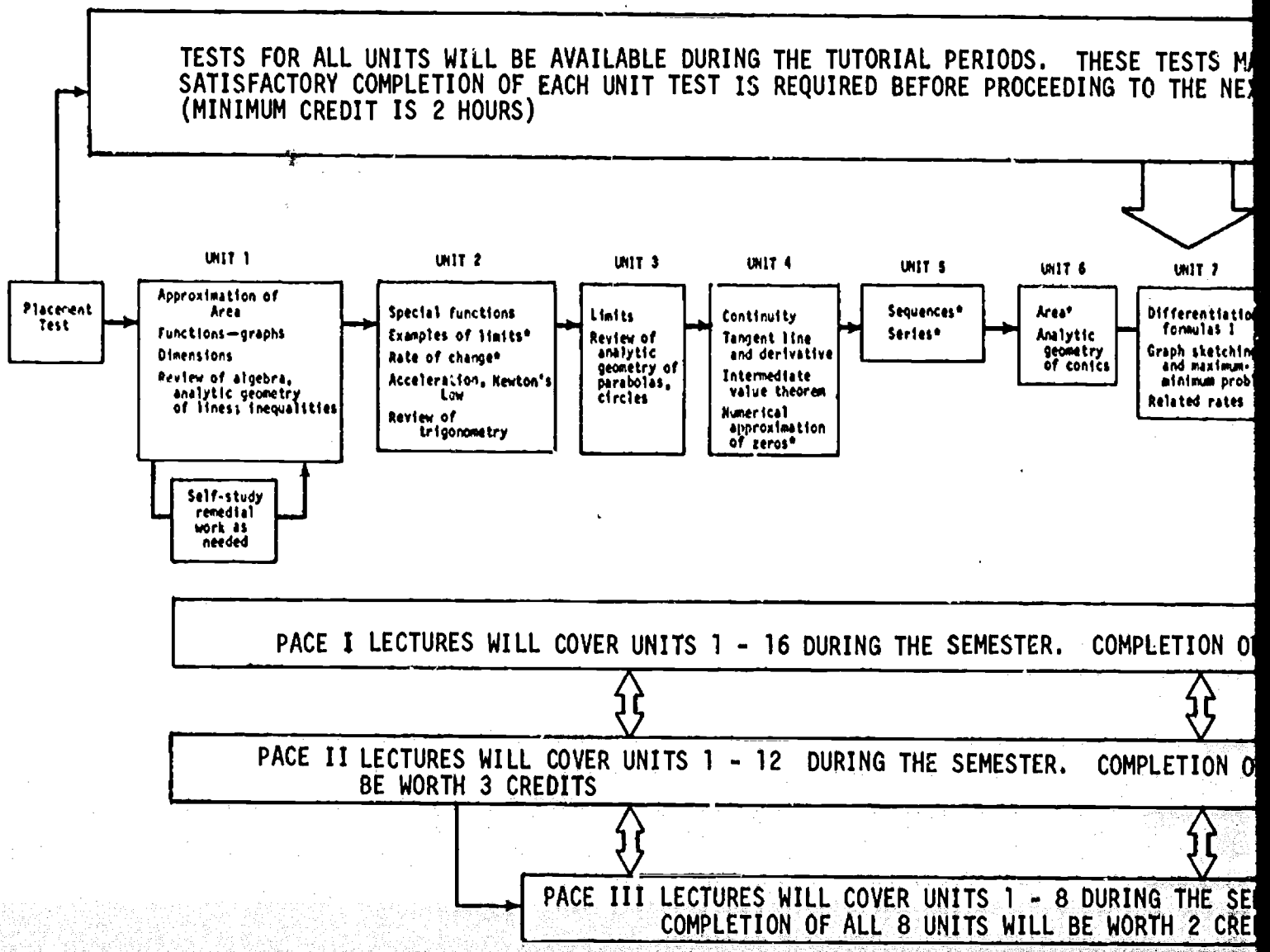
The enclosed "Course Sequence" provides a flow diagram of the course structure. As indicated, the course content was divided into units. It was estimated that one week would be required to learn the material covered in a unit. For each unit a detailed study guide was prepared which included text references, special remarks and supplementary material, recommended problem lists and a sample test.

While it was felt that the study guides were detailed enough to allow a student to work individually or with tutorial help, three sets of lectures and problem solving sessions were given in order to further assist individuals working at different paces. One lecture at the traditional pace covered twelve units during the semester. The other two covered eight and sixteen respectively. Each student could attend the lectures closest to his pace, although attendance was optional.

For each unit of material covered in the course, a set of standard tests was written. When the student felt sufficiently prepared, he could attend a tutorial session and request the test for a specific unit. Immediately after the test was taken the student could watch as the test was graded by his tutor, and the solutions, correct or incorrect, were discussed with him. If the test was completed satisfactorily the student was eligible to take the test for the next unit. Otherwise the student was afforded tutorial assistance and required to take a different form of the test (with no penalty to his grade) until a satisfactory level of achievement was obtained. Only after the test received an "O.K." could the student move to the next unit.

MATH 295 -- FALL 19

(SELF-PACED SECTIONS) COUR

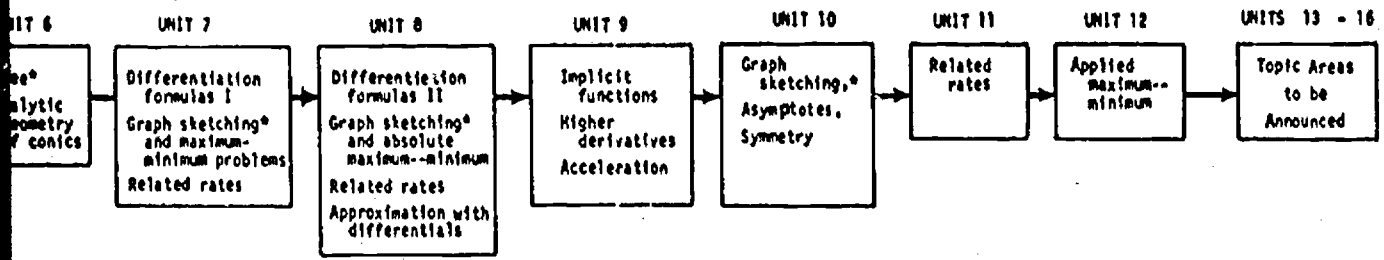


Department of Mathematics
Center for Instructional Development
Syracuse University

5 -- FALL 1973

IONS) COURSE SEQUENCE

THESE TESTS MAY BE TAKEN AT YOUR OWN PACE AS YOU BECOME PREPARED FOR THEM.
EDING TO THE NEXT. YOU WILL RECEIVE 1 CREDIT HOUR FOR EACH 4 UNITS COMPLETED



. COMPLETION OF ALL 16 UNITS WILL BE WORTH 4 CREDITS → 4 CREDITS

. COMPLETION OF ALL 12 UNITS WILL → 3 CREDITS

8 DURING THE SEMESTER.
BE WORTH 2 CREDITS → 2 CREDITS

* To be computed on APL or compared with APL output.

To receive an "O.K." on a unit test, a minimum grade of 85% was required and a good understanding of each problem on the test. Thus one serious mistake forced the student to retake the test. Passing the unit test earned the student a B or C. To obtain an A the student had to complete a number of bonus problems. These were at a somewhat higher level of difficulty than those on the unit tests which were written at a basic knowledge level.

For each four units passed a student earned one credit hour. As a way of encouraging students to work at a steady pace, a minimum of two credits for the semester was required. Completion of twelve units qualified the student for three credits, and if more than twelve units were completed an additional credit hour could be obtained for each additional four units passed. The speed at which an individual progressed through the course, and the number of credit hours he earned, depended upon how fast the unit tests could be satisfactorily completed.

At the end of the semester each student took a final exam which covered course material corresponding to the number of units he completed. The grades on the unit tests (weighted 3/4) and the grade on the final exam (weighted 1/4) comprised his final grade.

Results of the Pilot Test

Two kinds of data were collected during the pilot testing of the course. The first of these was an attempt to obtain an indication of students' reactions to the overall course design as well as such things as the tutorial sessions, the lectures, the study guides, the text books and the sufficiency of student-

faculty interaction. A twenty item questionnaire requiring both structured and open-ended responses was employed to gather this data and was administered during the final week of the course. Table 1 summarizes the percentage of responses to a number of the more salient questions.

The second type of data was a comparison of the achievement of students in the self-paced sections versus students in the traditional sections on a nine-problem final examination. The first five problems were the same for all students regardless of whether they were earning two or more credits. Problems six through nine on the two-credit exam were less advanced, though similar in spirit to the corresponding questions on the three-credit exam. Table 2 shows the means standard deviations and t ratios for a number of comparisons between self-paced sections and a random sample of the same size drawn from the traditional sections.

Conclusions and Future Directions

The percentage responses to the post-course questionnaire shown in Table 1 would suggest a substantially favorable reaction to the self-paced sections by those students enrolled in them. Reactions to particular aspects such as the study guides, tutorials, and the adequacy of student-faculty contact appear to be quite positive, while the lectures and the texts used are less so.

The comparisons on the course final examination suggest a higher level of mastery of the material covered by students enrolled in the self-paced sections than by students enrolled in the traditional sections. This conclusion, however, must be tempered somewhat. Since students were not randomly

TABLE 1

PERCENTAGE RESPONSE FOR SELECTED QUESTIONS FROM MATH 295 POST COURSE QUESTIONNAIRE (N = 50)

% OMITS						
0	1. All things considered, this course was:					
	(a) excellent	22	(c) fair	14		
	(b) good	60	(d) poor	4		
2	2. How do you think the work load required by this course was as compared to the work load required in the "traditionally" offered sections of Math 295?					
	(a) very much heavier	2	(c) about the same	26		
	(b) heavier	34	(d) lighter	14		
			(e) don't know	22		
2	3. How effective were the lectures/problem-solving sessions in this course?					
	(a) extremely effective	12	(c) minimally effective	24		
	(b) moderately effective	52	(d) a waste of time	10		
0	4. How effective were the tutorial sessions in this course?					
	(a) extremely effective	60	(c) minimally effective	10		
	(b) moderately effective	28	(d) a waste of time	2		
0	5. How effective were the study guides in this course?					
	(a) extremely effective	44	(c) minimally effective	8		
	(b) moderately effective	48	(d) a waste of time	0		
0	6. How effective was the primary textbook by Goodman, Analytic Geometry and the Calculus?					
	(a) extremely effective	42	(c) minimally effective	12		
	(b) moderately effective	44	(d) a waste of time	2		
4	7. How effective was the supplementary textbook by Greenspan and Benny, Calculus: An Introduction to Applied Mathematics?					
	(a) extremely effective	10	(c) minimally effective	38		
	(b) moderately effective	30	(d) a waste of time	16		
2	8. Please rate the adequacy of your opportunity to meet directly with faculty during the course.					
	(a) excellent	58	(c) fair	10		
	(b) good	28	(d) poor	2		
0	9. Please rate the overall fairness of the unit tests that you took in this course.					
	(a) very fair; well matched with the materials taught					76
	(b) fair; generally but not always matched with the materials taught					20
	(c) somewhat unfair; frequently tested material I didn't think was taught or required					4
	(d) very unfair; tests had little or no relevance to the material taught					0
2	10. On the whole, how much do you think you learned during the course?					
	(a) a great deal	52	(c) not very much	8		
	(b) some	38	(d) nothing	0		

TABLE 2

MEAN COMPARISONS FOR GROUPS (ITEMS) FOR
MAT 295 FINAL EXAMINATION (FALL 1973)

Group Name		Sample Size	$\bar{X}$	S.D.	$\lvert X_1 - X_2 \rvert$	d.f.	t*	p <
Traditional	(first 5 items)	76	65.43	13.59	5.15	150	2.42	.02
Self-Paced (2 & 3 credits)		76	70.58	12.41				
Self-Paced (3 credits)	(first 5 items)	23	75.86	10.33	7.57	74	2.69	.02
Self-Paced (2 credits)		53	68.29	12.54				
Traditional	(first 5 items)	76	65.43	13.59	2.85	127	1.22	.15
Self-Paced (2 credits)		53	68.29	12.54				

*one tailed test

assigned to the traditional or self-paced sections, the possibility that higher aptitude students may have self-selected themselves into the latter sections could account for some of the observed differences. Future research will investigate the extent to which students enrolling in the self-paced sections are of similar ability to those enrolling in the traditional sections.

Although the course was designed so that students could learn calculus at a pace comfortable for them, one obvious concern from the results of the pilot is that approximately two-thirds of the students in the self-paced sections completed only two credit hours during the semester. This may indicate remaining problems in the course structure which must be addressed in future revisions. It may also evidence a growing diversity in student aptitudes as well as the fact that first semester freshmen need more time than is normally provided to thoroughly master the introductory concepts of calculus. In a word they must first learn how to learn. It will be particularly interesting to observe what proportion of students earning two credits during the fall semester pilot of Mathematics 295 increase the number of credits they earn in the continuation of the self-paced sections (Math 296) this spring.

On the basis of data collected during the pilot a final comment is needed regarding the appropriateness of self-pacing for all students in calculus. When asked in an open-ended question what the best aspects of the course were a large number of students remarked "working at your own pace." Yet when asked what the worst aspects were a rather substantial number mentioned things such as "easy to fall behind," "not enough push" and "worst for students with no discipline." This would suggest that while many students can cope with a minimum of formal course structure and assume a great deal of responsibility for their own learning, a significant number cannot.

Although the addition of a more tightly structured set of deadlines for completing the unit tests may help alleviate this problem, there would seem to be a limit to the amount of structure that can be built into the course without destroying much of the flexibility for which it was designed. Thus, it may well be that for some students the structure provided by the traditional format is more conducive to learning than the flexibility inherent in the self-paced sections. In this sense our experiment in self-paced calculus is not so much an attempt to revise all introductory calculus offerings at Syracuse as it is an attempt to provide an alternative mode of instruction which is workable.

Note: If you wish more detailed information about the course design or the study reported above, contact either author at the following address:

Center for Instructional Development
Syracuse University
115 College Place
Syracuse, N.Y. 13210

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