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Computer-Assisted Instruction in Logic at Stanford*

Since 1972, the introductory logic course at Stanford has been taught during the regular academic year entirely as a computer-assisted-instruction (CAI) course. Various aspects of the course have been described in a number of publications (Goldberg and Suppes, 1972, 1976; Larsen et al., 1978; Suppes, 1975; Suppes et al., 1977).

Basic data on course enrollment are given in Table 1. As can be seen,

Table 1

Enrollment in CAI Logic Course

Academic Year	Fall	Winter	Spring
1972-73			41
1973-74	53	57	59
1974-75	82	63	62
1975-76	50	66	88
1976-77	58	64	95
1977-78	74	73	92
1978-79	67	83	93
1979-80	73	78	98

the enrollment is large, especially for a university that has about 6,000 undergraduate students. The size of the enrollment is due to the fact that the course satisfies a number of different requirements in the university's rather arcane distribution system, which I shall not attempt to describe here.

In content the course is a more or less standard introductory course although it would be regarded as more difficult than the average as reflected in introductory textbooks. In many universities and colleges the course would probably be a second course in logic in the curriculum offerings of departments of philosophy. Twenty-nine lessons form the core of the course. Basic data about these 29 lessons are given in Table 2. These data include the number of exercises in each lesson, the mean time to complete the lesson, and the cumulative time to complete the course. The cumulative times are shown in parentheses after the times for the individual lessons. The data shown in the table are for the autumn quarter of 1976-77 but are typical of the current course and the data collected in the intervening years.

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Table 2

Mean Time and Cumulative Mean Time for a Representative Quarter

Lesson	No. of exercises	Student's time in hours	Content
401	19	0.59 (.59)	Introduction to logic
402	18	1.12 (1.71)	Semantics for sentential logic (truth tables).
403	14	0.76 (2.47)	Syntax of sentential logic, parentheses
404	14	1.17 (3.64)	Derivations,rules of inference,validity
405	19	4.07 (7.71)	Working premises, dependencies, and conditional proof
406	16	1.83 (9.54)	Further rules of inference
407	12	2.37 (11.91)	New and derived rules of inference
408	21	14.38 (26.29)	Further rules and indirect proof procedure
409	24	2.37 (28.66)	Validity, counterexample, tautology
410	13	0.71 (29.37)	Integer arithmetic
411	7	0.61 (29.98)	Two rules about equality
412	7	0.59 (30.57)	More rules about equality
413	7	0.44 (31.01)	The replace equals rules
414	7	0.97 (31.98)	Practice using equality in integer arithmetic
415	11	1.99 (33.97)	The commutative axiom for integer arithmetic
416	4	0.99 (34.96)	The associative axiom
417	7	2.00 (36.96)	Two axioms and a definition for commutative groups
418	8	1.50 (38.46)	Theorems 1-3 for commutative groups
419	8	1.54 (40.00)	Theorems 4-7 for commutative groups
420	12	1.51 (41.52)	Noncommutative groups
421	8	0.44 (41.96)	Finding axioms exercises
422	14	1.20 (43.16)	Symbolizing sentential arguments
423	28	2.78 (45.94)	Symbolizing English sentences in predicate logic
424	28	2.87 (48.81)	Inferences involving quantifiers
425	22	2.67 (51.48)	Quantifiers: restrictions and derived rules
426	21	1.41 (52.89)	Using interpretations to show arguments invalid
427	17	4.11 (57.00)	Quantifiers and interpretation
428	23	6.18 (63.18)	Consistency of premises and independence of axioms
429	40	3.96 (67.15)	The logic of identity (and sorted theories)

Students taking a Pass level need on the average about 67 hours of time at a terminal to complete the course. As would be expected, all of the exercises are completed at the terminal. There is no additional paperwork of any kind in the course. Students who go on to take a letter grade of A or B must complete additional lessons. One lesson sequences is on Roolean algebra and qualitative foundations of probability. In this sequence the students prove a number of theorems about Boolean algebra and about the qualitative binary relation of one event being at least as probable as another. In a second lesson sequence that is available for students seeking a higher grade the subject of concentration is social decision theory. In this sequence students prove a sequence of theorems leading up to Arrow's well-known impossibility theorem in the theory of social choice.

The number of hours at a terminal or, as it is put in computer circles, the hours of connect time, does not include the finding-axioms exercises but only the introduction to them in lesson 421. These finding-axioms exercises present the student with a number of statements about a particular theory--for example, statements about elementary properties of natural numbers or elementary properties of the ternary relation of betweenness on the line. The student is asked to select not more than a certain number of the statements and to prove the remainder as theorems. This kind of exercise has been advocated by a number of persons as providing the kind of thinking required for creative work in logic, mathematics, or one of the mathematical sciences, because the student must understand how to find the basic assumptions or axioms and not merely prove something about them once they are given to him. The method is often called the Moore or Texas method in honor of the well-known American topologist R. L. Moore. It is worth mentioning that one of the great defects of finding-axioms exercises when taught in ordinary classroom situations is the tediousness of checking the correctness of student solutions. A happy fact about our CAI environment is that this work is done automatically by the program.

The variation in individual student time spent at terminals is surprisingly large. For most terms the standard deviation for the Pass level of a course is between 15 or 20 hours and the range is from a minimum of about 30 hours to a maximum of about 140 hours.

On the basis of extensive sampling of student opinion, the most preferred features of the course are its self-paced nature and the freedom to work at any time of day or night. The only regular meeting of the course is the organizational meeting on the first day of the term. From that point onward, students come and go at computer terminals according to their own schedules. There are teaching assistants available for approximately 20 hours a week, and students who are having difficulties and want assistance schedule their times so as to be at terminals when the teaching assistants are there.

Stanford requires student evaluation of all large undergraduate courses. Here are a few sample comments from students. I have arranged these comments in order of increasingly favorable responses.

"Lot of time spent on worthless material."

"Ever want to kill an inanimate object like a computer? Very time-consuming."

"Be prepared to invest a lot of time in this class."

"Boolean algebra should be expanded; especially it should be made more engineering oriented."

"TAs very helpful."

"I was allowed to work on my own time, at my own unusual hours."

"I liked being able to do the work any time I want to, not having lectures to feel guilty about not going to . . . "

"This is not an easy course; it's well worth its 5 units. But unlike other courses, it's possible to avoid ever feeling pressured (by doing the work early, not waiting until a deadline as most people do)."

Finally a comment from the standpoint of the instructor. Because I am able to offer this course on a CAT basis as well as a corresponding course in axiomatic set theory, my teaching load at Stanford is the highest of any member of the faculty. Also, because of the substantial enrollment in the logic course I also have the largest number of student units of any member of the Department of Philosophy.

I think that only certain courses can be taught successfully as CAI courses at the present time. These are mainly courses that have logical or mathematical content as far as philosophy is concerned. I do think that a good many specialized courses can be offered that are difficult to offer in smaller departments of philosophy, which includes our department at Stanford. As I have indicated, the enrollment in logic is large but the enrollment in axiomatic set theory is not. In the future I hope to give every term courses at about the same level as that of axiomatic set theory in foundations of probability and in the theory of measurement.

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Patrick Suppes
Stanford University