EXPERIMENTS IN TEACHING ECONOMICS

AN EXPERIMENT WITH TIPS: A COMPUTER-AIDED INSTRUCTIONAL SYSTEM FOR UNDERGRADUATE EDUCATION*

By ALLEN C. KELLEY
University of Wisconsin

I. *Introduction*

Computer-aided instruction, while admitted by many to have great teaching potential, has remained for most a phenomenon belonging to the twenty-first century. The presumed necessity of expensive machines and computers, wide-scale feasibility testing, and large quantities of scarce technical and instructional resources has been considered to relegate the day of practical, economical, and extensive use of computer-aided instruction in the college classroom to the distant future.

In this paper I report on a Teaching Information Processing System—TIPS for short—which applies computers to teaching in a manner which is not only economical and implementable—indeed, it has been utilized at the University of Wisconsin—but which also contributes to the effectiveness of the educational process itself. In what follows I shall present a description of the TIPS system and report the results of an experiment in which it was used in an economic principles course. I will conclude with several observations on the long-run potential of TIPS.

II. *TIPS—Motivation and Objectives*

The problems of effectively teaching large classes, say in excess of fifty students, or of coordinating instructional programs over geographic areas—for example, extension activities—are many. First, informal information conveyed to the professor on either student performance or on student reaction to discussion sections, lectures, and reading materials is highly biased and is typically drawn from extremely small samples. With respect to student performance, the usual sources of information are rapid-fire, student-professor question and answer sessions immediately following lectures, conferences with students during office hours, and reports by teaching assistants on student performance in sections. The usefulness of the latter improves throughout the se-

* Duane T. Kexel, assisted by F. M. Freymiller, not only carried out all the tabulations upon which this study is based, but also contributed significantly, at each stage, to the development of the analysis. Also, particularly helpful criticisms on a first draft of this report were provided by my colleagues, W. L. Hansen, Harold Watts, and B. A. Weisbrod.

mester as graduate students attain experience and increased competence in teaching. Even then, however, the variability of reports of student progress by teaching assistants makes them difficult to interpret. Only formal examinations, quizzes, and course surveys tend to yield consistently satisfactory data.

Second, a problem common to all courses but especially prevalent in large ones is that information on student performance to be used for teaching purposes is typically untimely and costly. The information is untimely since it is usually obtained at discrete six- to eight-week intervals. It is costly since quizzes and exercises demand extensive inputs of professorial, section leader, and student time.

Third, the effective use of teaching devices—workbooks, problem sets, lectures, audio and/or visual aids, assigned or optional reading lists, games, programmed materials, tutorials—which should ideally be designed for the individual student (or group of students) is difficult. Identification of students of varying capabilities or understanding of the subject matter, coupled with designing for each student a mix of teaching materials (a "systems approach" to teaching) suitable for optimal and somehow "efficient" instruction, is time-consuming and expensive. As a result, good students often waste time on exercises of little merit; time is also wasted in evaluating these efforts. Poor students, who should sustain different assignments, also of necessity receive materials designed for the "typical" student. A processs of teaching whereby instructional instruments are varied according to individual aptitude and progress has not yet been perfected within the lecture framework.

Finally, the possibilities for undertaking serious research on methods of undergraduate instruction are partially constrained by the availability of data. While the research-oriented professor may speculate on the relative merits of alternative teaching devices, his intellectual curiosity will not usually be sufficiently strong, given the structure of incentives confronting the successful academician, to induce him to undertake an adequate testing of the various hypotheses.

III. *A General Introduction to TIPS*

To overcome these and other problems a research project based on TIPS is presently in progress at the University of Wisconsin at Madison.[1] While this project is currently being used only in selected economics classes, the basic concepts are quite general and can be applied to other disciplines.

[1] While the long-term project is a research and development effort, the work to date has been solely on research into the relative merits of TIPS. This research has been supported by AIM (Articulated Instructional Media) through a Carnegie Grant, the School of Letters and Sciences, and the Graduate School.

TIPS involves periodic collection of information from students regarding either their understanding of course materials or their reaction to various aspects of course presentation, such as lectures and readings. TIPS then provides a means of efficiently utilizing this information for instructional purposes. The information, currently collected on specialized forms suitable for machine processing,[2] is composed of student responses to a series of multiple-choice questions. Surveys of six to twelve questions take about five to ten minutes to administer. Within a few hours—and in the future, within a few minutes—this information is processed and summarized in three separate reports: one for distribution to each student, a second for each section leader, and a third for the professor. An examination of these three reports yields a useful first impression of TIPS capabilities.

The student report contains a summary of his performance: his response to each question, the correct answers, and the total number of his correct answers. On the basis of this information, assignments for the forthcoming period are also indicated. The assignments—some of which are required and others optional—vary considerably in nature, level, and intensity. A student scoring well may receive optional assignments and/or required work at a higher level—for example, essay writing—for which honors or extra course credit may be awarded. The student performing poorly may receive not only a heavy dose of required work but also a set of materials designed to bring him toward the mean class performance. Since on a specific TIPS survey several "concepts" may be evaluated, e.g., the multiplier, deflationary gap, and full employment surplus, the mix of assignments may vary considerably from student to student.

Additional information on the student report is generated on the basis of past as well as current performance. If the student has performed poorly over several surveys, he will be instructed on the student report to establish an appointment with the instructor or teaching assistant. Significantly, special tutorials or sections may be arranged well before the student takes his first major examination. If the student performed consistently and exceptionally well, he may be notified that a short paper may be substituted—at his option—for the midterm examination.

The teaching assistant report contains information to help him appraise the performance of his individual sections, including statistics on percentage correct by question or by group of questions (concepts), actual responses on the survey, lists of students required to establish appointments or tutorials, and so forth. Since a section leader usually

[2] Machine readable forms are but one of many alternative means by which the information could be assembled.

is responsible for four to six weekly sections, the information on each individual section enables him to vary the way he handles each session. In one section he may emphasize the mechanics of the multiplier; in another, more advanced concepts or applications. It is significant that while tutorials and paper supervision require additional time of the teaching assistant, the experience thus far has been that the "released" time deriving from reduced grading (for students doing well) about offsets additional time spent on tutorials and paper supervision. Thus, as TIPS has been utilized to date, the emphasis has been toward allocating existing teaching inputs more effectively.

The professor report is similar to that received by the teaching assistant, although the information available applies to the total of enrolled students rather than to particular sections. With this information the professor may elect to alter lectures, section coverage, problem sets, or other teaching instruments for the forthcoming period.[3]

In summary, TIPS is a system for gathering and reporting objective and timely information useful for more effective teaching. This information, among other things, facilitates: tailoring assignments and teaching devices to the needs and progress of individual students; developing greater flexibility in course structure; imposing course discipline according to individual student motivation and aptitude; increasing the efficiency in the utilization of student, teaching assistant, and professorial time; and undertaking empirically-oriented research in methods of undergraduate education.

Ironically, rather than depersonalizing education, the computer, as used in the TIPS program, will permit instruction to move toward an individualized basis. Instead of developing more formal and structured courses designed to cope with the swelling numbers of students, TIPS allows a degree of flexibility in teaching hitherto practical only in very small courses.

The basic approach of TIPS sets it apart from many contemporary experiments in the utilization of advanced technology in the education process. In contrast to employing machines to alter basically the classroom framework, TIPS is simply a tool to assist the professor, the teaching assistant, and the student, both in and out of the classroom. It is thus not a substitute for the existing instructional framework; it is a complement to it.

IV. *Pilot Project*

A pilot project using TIPS in a principles of economics course was implemented during the fall semester of 1966. The primary objective

[3] Given the "cumulative" nature of much of economics, early diagnosis of deficiencies enables elimination or attenuation, not only of one misunderstanding, but also of potential future misunderstandings.

of the project was to provide the students with enough exposure to the system so that a preliminary objective appraisal of it could be obtained. Additionally, classroom experience with TIPS was needed in order to identify desirable modifications.

TIPS was introduced after the six-week examination so that comparative information on class performance and student opinion with and without the system could be obtained. In their initial introduction to the system the students were assured that this was solely an information gathering device to be used for instructional purposes, that the TIPS surveys were not examinations—the results would never be used for grading purposes—and that during the semester neither the teaching assistant nor the professor would have access to the individual scores.

A total of four TIPS surveys were administered, three prior and one subsequent to the twelve-weeks examination. The surveys encompassed groups of questions pertaining to the nature and application of nine individual topics, including the public debt, the multiplier, money expansion, price indexes, determinants of aggregate demand, impact of inflation, deflationary and inflationary gaps, full employment government surplus, and the adjustment process to equilibrium of aggregate supply and demand. Problem sets, designed to correspond to each concept surveyed, were provided as optional or required depending on student performance.

The data used to evaluate TIPS comprises responses by 278 students to an anonymous survey administered in the last class lecture. Each student revealed, in addition to responses to twenty-six questions, five attributes about himself: major, class, overall grade point average, and the scores on each of the two midterm examinations.

The organizational framework for analyzing this body of data is a cost-benefit evaluation of the system.[4] Although quantification of the desired variables is often tenuous, use of cross-tabulations, Chi-square tests, and regressions has, to a limited extent, enabled us to isolate statistically various categories of students that found TIPS particularly helpful or harmful, and why. From this information we have been able to make selected tentative inferences concerning the value of TIPS.[5] Future experiments will employ a control group to enable a more rigorous test of the nature and effects of TIPS. The present experiment can be considered as a preliminary assessment designed, in part, to identify areas of research meriting more intensive study.

Consider first the overall evaluation of TIPS by the entire class.

[4] This paper examines the benefits and costs of TIPS. It does not compare the benefits and costs of this teaching approach with alternatives.

[5] Given the large amount of statistical information upon which the analysis is based, a set of summary tables (frequency, percentage, and contingency) and a copy of the questionnaire have been prepared separately to conserve space. They are available from the author upon request. Unless otherwise stated, all hypotheses tested statistically are accepted at the 95 percent level of significance.

General student opinion was strongly supportive of TIPS as contributing to understanding economics, with particular emphasis on its capacity to point out key concepts and areas of weaknesses prior to examinations. An overwhelming majority recommended future use of TIPS in its present and even broader contexts. There was no perceptible hostility to the use of a computer in a system such as TIPS.

Five main statistical findings support these conclusions. First, 86 percent of the class felt that TIPS helped them learn the course materials either "much better" or "somewhat better" with only 12 percent registering the opinion that the system "did not help." These responses were invariant to class, major, or grade point average. Second, key benefits, ranked by students on the basis of their significance, revealed that TIPS "indicated key concepts and areas of importance" (32 percent), "pointed out areas of weakness sooner" (23 percent), and "stimulated learning materials more conscientiously and thoroughly" (22 percent). Third, in appraising possible disadvantages of TIPS, while 51 percent felt "that there were no particular harmful effects of the system," a significant proportion, 24 percent, suggested that "TIPS did not accurately reflect knowledge of the material, and thus gave a false sense of confidence." The validity and importance of this factor will be assessed in detail below. Fourth, not only did more than 90 percent of the class favor use of TIPS in principles of economics in future years, but many students (41 percent), with no measurable bias by major, felt that a TIPS program would be applicable to most other courses. Some (33 percent), however, felt it to be most useful in science and problem-oriented courses while others (12 percent) particularly supported its use in reading courses. Finally, despite the frequently acknowledged student animosity toward the use of computers in education, support for their use in TIPS was striking: 54 percent appraised computers as a "significant" educational aid, 37 percent felt them of "some help," and only 2 percent saw computers so used as "another undesirable move toward mechanized human existence."

Given the students' conclusion that TIPS contributed to learning of economics, it is important to identify the specific channels through which the system accomplished this result. TIPS motivated most students to keep abreast of their work and to review more frequently although they appeared not to be preparing specifically for the surveys.

This conclusion—deriving from a question on the final course survey asking if TIPS had affected methods of study—is supported by the finding that about 65 percent either felt "TIPS increased the tendency to do the assigned reading prior to coverage in class or sections," that "TIPS increased the frequency of reviewing the covered materials," or both. Furthermore, on another question some 76 percent indicated they did not prepare specifically for TIPS surveys. Each group selecting

one of the above alternatives comprised a representative cross-section of the sample in terms of GPA, class, and major. An underlying hypothesis, as yet untested, is that the more systematic study program induced by TIPS results in greater retention of the subject matter, in contrast to one focusing on short-term achievement accomplished by somewhat infrequent but intensive study.

Apart from highlighting its pronounced impact on study habits and motivation, students identified several additional features of TIPS as having a favorable effect on their study of economics. Students who thought TIPS helped them learn economics better (86 percent) found it most valuable as an identifier of key concepts, as a motivational device, and as a system which enabled instructors to tailor instruction to the needs of specific students. These students did not regard TIPS particularly beneficial in the role of providing extra free time or as a stimulus to attend lectures, although these features were found most helpful by those students who indicated that TIPS had not helped (12 percent) or had hurt (2 percent) their economics performance.

These results, strongly supported by cross-classifications of students by degree of endorsement and ranking of benefits, are generally invariant to the student attributes examined in the study.

Since TIPS, as it was used in the pilot project, provided significant amounts of free time compared to the amount of time students would have been required to spend on the course had all assignments been mandatory—there were, in fact, 1,000–1,500 such "released" hours—the above findings suggest the need to examine the impact of this conserved resource. Surprisingly, this free time was not considered important by the students to their performance in economics. This fact does not in itself, however, imply that conserved free time is an unimportant attribute of TIPS. On the contrary, the following several observations point to just the opposite conclusion. The freshman, who obtained a disproportionately large share of optional assignments, found the study time so released relatively more valuable than his classmates.

This result has intuitive appeal since one would expect that the value placed on free time varies directly with the opportunity-cost to each student of using the time to study economics. Since, as it was implemented, the pilot project did not provide particularly attractive alternative uses of the released time in the study of economics, it is thus not surprising that the freshman, who may have relatively time-demanding course loads outside economics and who may be less efficient in study methods, would particularly appreciate the greater flexibility accorded him by TIPS in his allocation of time. Of the two alternative uses of released time, additional study of economics and other curricular or extracurricular activity, the very bright and the very slow students in economics chose the latter, while the high-average (C+) and the good (B) students chose the former.

This observation appears consistent with the hypothesis that students determine the allocation of their time in a manner which *ex ante* optimizes their overall measured performance (GPA). Presumably the bright student, who does not require the drill of assignments, and possibly the poor student, who may be resigned to his status in the course, do not benefit from the assignments (designed for the "average" student) as much as the intermediate group.[6]

If our interpretation of the manner in which students allocate their time is correct and if it can be shown that student performance in principles of economics was not impaired by the granting of optional assignments, then the free time accorded by TIPS may be considered as a very important beneficial attribute of the system. Even if performance were impaired, in fact, the loss in this course may have been more than offset by the subsequent gain in some other course to which efforts were then directed. Thus, the finding that the performance in principles of economics was unimpaired would be a very strong result and would provide substantial evidence relating to the merits of TIPS.

A test was performed to provide evidence on the effect of free time on economics attainment. The results are consistent with the hypothesis that providing students greater flexibility in allocating their time did not impair measured student performance.

As seen in equation (1) below, "free time" (F), measured as "those students who received at least 50 percent of the assignments as optional," had an insignificant influence on the second examination score ($E2$). While both the first examination score ($E1$) and (GPA) entered significantly into the prediction equation, neither class, section leader, nor major contributed to the explanation of examination performance.[7]

$$(1)\quad \underset{}{E2} = \underset{(9.10)}{27.49} + \underset{(8.16)}{34.85}(GPA1) + \underset{(6.36)}{26.20}(GPA2) + \underset{(5.66)}{18.51}(GPA3)$$

$$+ \underset{(6.64)}{20.20}(GPA4) + \underset{(3.64)}{12.47}(GPA5) + \underset{(3.77)}{8.85}(GPA6)$$

$$+ \underset{(3.31)}{2.46}(GPA7) + \underset{(.15)}{.28}(E1) + \underset{(2.27)}{3.02}(F)$$

$$R^2 = .45$$

[6] An alternative explanation of the choice by poor students not to work their occasional optional assignments lies not in their feeling of futility, but rather is based on the premise that these students are poor in part because they lack ambition and/or motivation.

[7] *GPA* was entered as a binary variable with *GPA*1 through *GPA*7 representing, respectively, greater than 3.5, 3.25–3.49, 3.00–3.24, 2.75–2.99, 2.50–2.74, 2.25–2.49, 2.00–2.24. Under 2.00 is captured in the intercept term. All estimated parameters in the equation except *GPA*7 and *F* are significantly different from zero at the 99 percent level of confidence. The sample excludes all freshmen (since *GPA* data were unavailable), 47 students participating in a "special" experiment carried out during the semester, and a few other students for which specific data were missing.

Turning from the favorable aspects of TIPS, we should next consider the student reaction regarding the disadvantages of the system as employed. While a surprisingly large number of students felt that "there were no particular harmful effects of the system" (51 percent in all), 24 percent of the class did answer that "TIPS did not accurately reflect knowledge of the material and thus gave a false sense of confidence." The relevant issue here is one of assessing the significance of the "false confidence" cost. Two arguments appear particularly appropriate. First, an attempt was made to test statistically for a differential influence of survey results on second examination performance for the group who indicated "false confidence" as a concern as opposed to the remainder of the class. The results of the regression experiment employing *GPA* in binary form and average survey performance as independent variables indicated that survey performance directly, and thus false confidence indirectly, did not demonstrate a significant differential impact on examination performance as between the two groups. Second, one could argue that the problem of false confidence arises from all teaching methods which offer students interim appraisal of achievement; namely, maintaining motivation in the wake of success.

A final but extremely important issue relating to the appraisal of TIPS is its ability to discriminate student competence. Recall that the information upon which the program operates is obtained from a periodic sampling of student performance under non-examination conditions, using multiple-choice questions. Two pieces of information suggest that TIPS performs acceptably in its measuring capacity. First, several regression experiments showed that the surveys apparently contributed slightly more to the prediction of the second examination score than even the first formal class examination. While the TIPS surveys were admittedly more closely related in subject matter to the second examination, neither the similar formats of the two examinations nor the fact that the surveys were offered under non-examination conditions tended to outweigh the superiority of surveys vis-à-vis the first examination in predicting subsequent performance. Second, of those students who had an opinion regarding TIPS measurement capacity, 69 percent felt that the surveys were either a "particularly good" or a "good" measure of knowledge of those materials covered by TIPS.

My own view, as yet unsubstantiated, is that properly designed multiple-choice questions can reliably measure student competence at least at the general diagnostic level to which TIPS is aimed. Admittedly the measures may not provide an adequate reflection of the creative or exceptional abilities of the very capable student. However, since this student can be identified as possessing an understanding of the basic

concepts, the additional capabilities of TIPS in providing him with options of essay writing and research papers may ultimately allow an accurate appraisal even of this student.

V. *The Potential of TIPS*

While the initial results of the pilot project at Wisconsin indicate that TIPS can be effectively utilized in an economics classroom, two factors are frequently cited relating to the practicability of its implementation on a large scale.

First, concern is expressed about the demands placed on scarce professorial time in designing adequately discriminating surveys and properly individualized problem sets tailored to the differing needs and abilities of the students. In recognition of this problem, a comprehensive bank of questions and problems classified by concept, together with extensive tutorial materials for the weaker students and suggested projects for the more able students, is presently under development.

Second, the availability and costs of "hardware" (computers and input-output devices) are often posed as constraints, not only on TIPS, but on most computer-aided instructional systems. However, most large universities already possess or have access to the requisite equipment, though not necessarily in an optimal configuration for a large-scale TIPS program. Finally, a detailed cost analysis of the TIPS pilot project revealed that computer, labor, and overhead costs (including a portion of the research and development costs) required to run the system yielded a maximum average total cost of about one dollar per student per semester.[8] With more efficiently designed computer programs and logistical systems, with the economies deriving from large-scale utilization, and with greater experience, average costs would lie in the twenty-five to fifty cent range. TIPS can thus be viewed as a feasible low-cost method of increasing professorial control over the instructional process.

The expansion in the range of choices open to the professor in teaching is a particularly valuable means of summarizing the role of a system such as TIPS. One might view an economics class at matriculation as normally distributed across some range of economics knowledge. Instruction then involves shifting and/or skewing this distribution so as to maximize some prespecified objective function. Thus, for example, one may wish to raise the mean level of performance while maintaining the distribution of performance among students as constant. Alternatively, one might seek to maximize the total increment to knowledge. A specification of the objective function would undoubtedly involve both economic considerations and social judgments. Given the objective

[8] Frederick M. Freymiller, "TIPS: A Cost-Benefit Analysis" (June, 1967, mimeo.).

function, together with information relating to the educational payoff of alternative teaching instruments for students of varying capabilities and aptitudes—that is, the production function—TIPS could then readily be used to implement an "effective" program of instruction developed by the solution to this constrained maximization problem.[9]

It is not clear, a priori, what the format of this instructional program would be. For example, with a fixed level of resources one may realize a greater total increase in economics knowledge by redirecting resources away from the most capable students and toward the weak or average students where the return from more intensive instruction may be relatively high. In fact, given the currently somewhat rigid curricular structure offered in most universities, even if the educational returns per unit of input of raising the level of economics competence for a group of students (most likely the bright ones) are relatively high, unless credit is awarded or redundancy reduced in subsequent course offerings, the returns deriving from such a reallocation may be overstated. Needless to say, the above framework could also be employed to minimize costs (as distinct from maximizing output), given a specified level of output.

This discussion serves to illustrate possibly the most important short-run benefit to be derived from a system such as TIPS; namely, increased flexibility in meeting the educational needs of individual students. The system does not dictate the professor's approach to teaching, but rather provides him objective and prompt information on individual student knowledge—information to be used in any manner he chooses. This choice may be made by different professors on the basis of quite diverse philosophies of education.

The long-run potentials for TIPS are even more numerous and important. By providing extensive, disaggregated information that has not formerly been available at sufficiently low cost, TIPS could provide the means of revealing the differential impacts of alternative teaching methods on various types of students. More "scientifically-based" prescriptions would then become practical in a field that has too long remained a subjective art. Additionally, research could blossom into areas such as instructional programs aimed at maximizing alternative educational objective functions, refinement of measures of economic and other knowledge, and differential techniques for motivating various classes of students.

Viewing the professor in a dual role as a researcher and teacher, the implementation of TIPS could reinforce the complementarities between the two roles and increasingly enable a professor to fulfill both functions simultaneously. In fact, given the research orientation of many

[9] As a part of the TIPS research project a considerable amount of effort is presently being planned to fill partially the "gap" in our knowledge of these payoffs.

academicians and a reward system which cultivates this orientation, the possibility that TIPS may induce research in the areas of economics education in particular, and in college instruction in general, suggests that herein lies possibly the single most important contribution TIPS can make to the educational process.