A Comparison of Conventional and Self-Paced Web-Based Courses: A Theoretical Analysis

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1. Introduction

Studying and completing a web-based course is behavior. It is something a student does. The current international interest in delivering instruction over the Internet emphasizes the importance of a careful behavioral analysis of this new educational mode. This paper reviews reinforcement theory and applies it to a conventional web course in which instruction is delivered synchronously and to one in which students complete units asynchronously. An example of synchronous delivery is a course developed using courseware such as Prometheus, WebCT, Blackboard, or TopClass in which units are studied, homework is graded, and exams are administered at stated, fixed intervals; an example of asynchronous delivery is a web-based course developed as a strict implementation of the Personalized System of Instruction (PSI) in which students study at their own pace and are evaluated, encouraged, and taught using student proctors. This paper contrasts the different reinforcers, contingencies of reinforcement, and schedules of reinforcement in the two cases. The strengths and weaknesses of both regimes are analyzed from a theoretical point of view. Experimental results are then given for a course using the self-paced strategy to confirm the theoretical predictions.

2. Theoretical background (behaviorism)

The present analysis is based on a theory of learning developed by B. F. Skinner called *behaviorism.*[1,2] Other learning theories exist, to be sure, but the work of Skinner has the advantage of being supported by an extensive body of research over a long period of time. In addition, many of these alternative theories can be subsumed into behaviorism. Behaviorism (or reinforcement theory as it is sometimes called) is based on the Thorndike's Law of Effect.[3] This law asserts that behavior is modified by its consequences. Therefore, to modify a student's study and learning behavior, a teacher should reinforce (reward) good behavior and ignore bad behavior. Theory predicts and experiment shows that this strategy increases the probability that the individual will exhibit the desired behavior in the future.

The first major problem in implementing a reinforcement approach to behavior modification is to determine appropriate *reinforcers* or rewards. Fortunately, this is not a major problem in education because the final course grade is such a powerful motivator. The effect of the final grade can be made more effective by dividing it into smaller pieces and doling it out for the successful completion of smaller learning segments. This is the primary justification for dividing the instructional material into units that are completed sequentially. Other reinforcers such as access to the instructional staff, ability to schedule one's workload, and access to free time are examples of additional reinforcers.

The second problem is determining the contingencies (or conditions) under which the reward is given. The technical term, *contingencies of reinforcement*, refers to this relationship. The most effective strategy is to demand 100% mastery of a unit before the next unit is given, but all too often we see a weakening of this contingency to allow the student to proceed if lesser performance is achieved. The basic notion is to determine, in advance, precisely what behavior is desirable and then to ensure that the available rewards are made contingent on it—and only on it.

It is not, however, usually desirable to reward desired behavior each time it is observed for technical reasons. The *schedule of reinforcement* is the relationship between a series of observed behaviors and the instances for which they are reinforced. The specific schedule has a major effect on the rate and strength of behavior. Although a mixture of primary, simple schedules of reinforcement are usually used, the effect of these elementary schedules will give a general idea of the concept. In a *continuous schedule* the student is reinforced every time the desirable behavior is observed. That is, every time a student studies a unit, he or she is reinforced in some way. As mentioned above, it is usually undesirable, technically, to put the student on a continuous schedule. If for any reason the continuous schedule is interrupted, because, say, he fails to complete the next unit, the predicted result is frustration. A practical example of this with which we are all familiar is the coke machine. We are on a continuous schedule because essentially every time we put in a dollar, out comes a drink. If by chance the machine is broken and a person does not get value for his money, he become frustrated and at times kicks the inanimate machine. In a *fixed interval schedule* the student is rewarded after a fixed period of time irrespective of the amount of behavior within the interval. Again, as mentioned above, this is the usual schedule we see in the classroom. The problem with this schedule is the low rate of behavior. In a *fixed ratio schedule* the student is reinforced after a fixed number of times he or she has exhibited the behavior. Corresponding to the last two of these, a *variable interval* and a *variable ratio* schedule may be defined in which the reward is given after a variable length of time or number of times the behavior is exhibited.

The *rate of learning* is determined by the schedule of reinforcement used. Of the simple schedules, the highest rate of behavior is generated by the variable ratio schedule (the one used by the one-armed bandits in Las Vegas) and a low rate, by the fixed interval schedule (the one used in most cases in education). *Design of the learning environment so students learn in any educational situation is essentially determining the appropriate reinforcers, creating the contingencies of reinforcement, and scheduling these reinforcers.* See any good book on learning theory such as those already cited or the programmed text[4] for a more detailed look at this theory.

3. Technical problem statement

We now move from the general problem of learning to the specific problem of designing web-based courses in which the material is presented in a number of discrete units. Figure 1 shows the typical behavior of an individual completing a specific task. On occasion it has been called a *learning curve* although Dr. Skinner would no doubt have denied vehemently that it was in any way innate. He would have held that it simply represents the past schedules of reinforcement of the individual. In this figure we have plotted the units completed in, say, a web-based course versus the class day, but it could equally show the performance of a professor preparing a research grant or a farmer planting a field. Initially, there is a rapid rate of progress followed by a slower rate, which in turn is followed by a scallop near the end. This general curve of student performance is recognized in most instances by the astute professor.

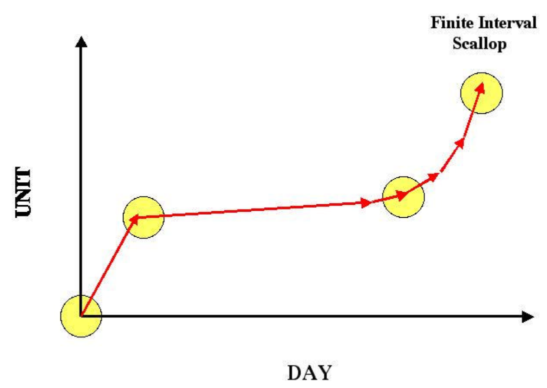

Figure 1. Learning Curve

Several technical definitions are in order. The behavior of a student in the plateau portion is known as *abulia* (technically defined as the pathological inability to act) and the scallop near the end is known as a *finite interval scallop*, named after the finite interval reinforcement schedule considered above. Informally, the professor recognizes the student as "cramming" during this last period. Two problems exist with this observed behavior: first, the student is not allocating his effort reasonably throughout the course, often learning superficially near the end in order to finish, and, more importantly, he runs the risk of not completing the course as time runs out. These problems are often associated with web-based courses.

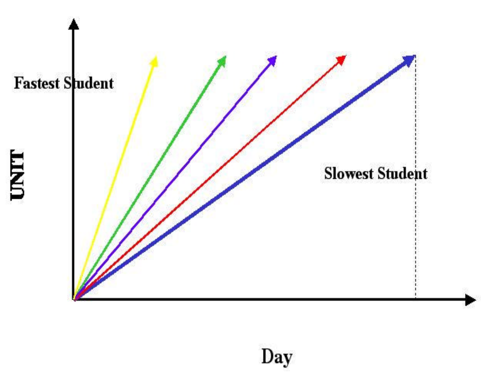

Figure 2. Desired Behavior

Most professors would prefer student behavior similar to Figure 2. In this figure the student who is making faster progress due to better preparation, more intelligence, more time to study, fewer outside demands, etc. is represented by the graph to the left and the slower student, the one to the right. Of course, it would be satisfactory behavior for the faster student to delay beginning the course until nearer the end if his outside workload demanded it. Ideally in a perfectly designed web-based course, the slowest student should immediately begin the course when the semester starts and just finish the course as the semester comes to a close. This behavior is seen in the line to the etreme right in the figure. One additional observation should be made before we leave this graph. Only in a self-paced course, which allows students to study at their own rate, can the behavior in Figure 2 ever hope to be achieved.

Technically our design problem in a web-based course is to convert the input behaviors of a group of students that are similar to Figure 1 to the output behaviors shown in Figure 2 for a web based course in which the learning material is divided into units using behavioral analysis.

4. Contrast in conventional and PSI strategies

Synchronous and asynchronous web-based courses are widely seen on the web. This section looks at each in turn.

4.1 Conventional web-based courses

Often, web-based instruction is created using special courseware such as Promethesus, WebCT, Blackboard, TopClass, etc. Present, although non-essential, limitations on them often confine the courses created to a synchronous mode of instruction. All students study the same material at the same time; chat about the same material at the same time; review the same canned lectures of the professor at the same time; and are evaluated over the same material at the same time. This strategy is a direct translation of the historical lecture mode of instruction to the web with technical embellishments. It is easy to predict the behavior of the students. As in the regular classroom, the students are technically on a series of fixed interval schedules. An example of this is shown in Figure 3.

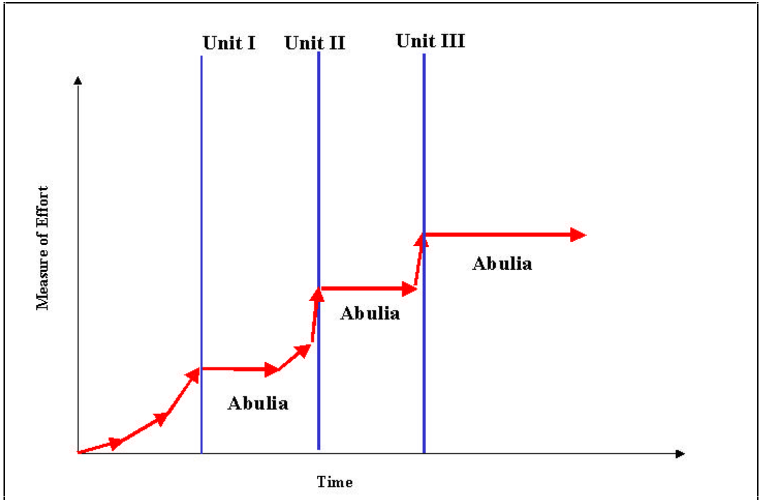

Figure 3. Multiple Intervals

In this figure, some measure of student behavior is plotted against time or class day. The vertical lines indicate the specific time at which a unit of study is to be evaluated. Several characteristics of this curve are worthy of note. First, as expected, there is a finite interval scallop just before each grading period and a plateau characteristic of abulia before each of them. What is not expected unless we remember the experimental results of behavioral analysis are two things: the plateaus become longer (the period of abulia becomes more extensive) as students wait longer to begin studying for the next unit and the effect of cramming becomes steeper in each subsequent interval. Technically we are controlling student behavior by an external clock. If we teach students to complete projects in this way, we should not be surprised to learn that students exhibit this behavior we have taught them as young engineers after they leave our classrooms.

4.1 Personalized System of Instruction

More than one asynchronous self-paced learning strategy exists. We focus on one of them, the Personalized System of Instruction (PSI) or the Keller Plan, because of the extensive research in its effectiveness in a non-web-based situation. Theoretically, it puts students on a variable ratio schedule.

To implement the PSI method,[5,6] course material is divided into units, each containing a reading assignment, study questions, co-lateral references, study problems, and any necessary introductory or explanatory material. The student studies the units sequentially at the rate, time, and place he or she prefers. When he feels that he has completely mastered the material, a proctor gives him or her a *readiness test* to see if he may proceed to the next unit. This proctor is a student who has been carefully chosen for his mastery of the course material. On the readiness test the student must make a grade of 100, but if the student misses only a few questions, the proctor can probe to see if the questions are ambiguous and can reword the questions if necessary. If the student does not successfully complete the test, she is told to restudy the unit more thoroughly. She receives a different test form each time she comes to be tested. No matter how many times a student is required to retake a unit, his grade is not affected; the only interest is that he ultimately demonstrate his proficiency. All students who complete the course receive a grade of A.

The basic features of the PSI method are:

1. The go-at-your-own-pace feature, which permits a student to move through the course at a speed commensurate with his ability and other demands upon his time.
2. The unit-perfection requirement for advance, which lets the student go ahead to new material only after demonstrating mastery of that which preceded.
3. The related stress upon the written word in teacher-student communication; and, finally:
4. The use of proctors, which permits repeated testing, immediate scoring, almost unavoidable tutoring, and a marked enhancement of the personal-social aspect of the educational process.

In the original statement of PSI, Dr. Keller included a provision for using lectures only for motivation. From this overall description, it is obvious that PSI is an appealing educational strategy for use over the web. It is asynchronous, emphasizes interpersonal interaction (often missing in web-based courses), and it is firmly grounded in educational psychology.

5. Experimental design

In this section, focus shifts to actual experiments in instruction. Data from a PSI approach is extensively reported in the literature. It is reviewed here to demonstrate the correspondence between theory and practice. The success of the PSI approach is undeniable, First we define the target population, Then this section describes the ways the reinforcers are managed in this course to aid a professor considering a PSI, web-based course. Finally, the overall results and conclusions are given.

5.1 Target population and course content

The primary target student population is college freshmen students in Mechanical Engineering at The University of Texas at Austin. Typically 50-60% of this population leaves the college of engineering during their first two years of study. The overall educational objective of this required course is to teach a beginning level knowledge of the computer languages C and Matlab as well as to introduce the use of the Internet for email communication, ftp transfers, etc. By blurring the boundary between entering freshmen and advanced high school students, this course should be appropriate for college bound high school students. It should also be beneficial to students on co-operative work study that takes them away from the campus.

PSI is an ideal delivery method for this course over the Internet because the material is concrete; the incoming freshmen have a wide variety of beginning knowledge; and computer programming is obviously a mastery-oriented subject.

5.2 Strict implementation of PSI to maintain student progress

Consistent with the theory of behaviorism outlined above, the correct approach is to reinforce the behavior you want to occur, confident that it will increase in strength. Several of the many uses of this principle are included here.[7] The first group concerns the structure of the units themselves, the last few examples are more general in nature.

- Rather than divide the material into logical divisions that follow the chapters in a book, or into units of equal size, try to make them conform to the needs for reward of the student. The first unit should be short, fun, and easy to "hook" the student.
- Slowly increase the difficulty of the units approaching your best estimate of the "knee" of the learning curve. This is technically called "stretching the ratio."
- At the “knee” the units should again be shortened, made more interesting, and slightly different in style. The effort is to re-engage the student.
- All students think they can finish more work in the last few days than they can. The trick is to train the students with units of a general complexity during the main portion of the course, and then include easier units at the end. In essence, we make the student's usually unrealistic expectations prove true. They can actually finish the last three units in the last week.

One of the author’s colleagues chastised him for the illegal commercial procedure called "bait and switch" in the United States when she heard about this last strategy to improve student performance. The guilty merchant advertises one product and then once he gets the customer into the store, switches to a more expensive model. In this case, however, we are on sound theoretical grounds. For those interested, we are manipulating the ratio in a variable ratio schedule to maintain student progress.

The preceding sections emphasized controlling the behavior of students and encouraging them to finish the course by manipulating the reinforcement value of the units. Other strategies are effective as well.

- One of the strongest known reinforcers in the human community is approval. This is specifically designed into the PSI method. In a regular implementation of PSI, a student making satisfactory progress is encouraged and congratulated by the proctor (a peer) and the professor. This web-based course preserves this important aspect of PSI. Three web cams and a chat window attended by the proctor, the professor, and the student seeking grading of a readiness test afford ample opportunity for selectively using approval as a means of maintaining student progress.

- A fundamental difference exists in a television program and a play with respect to the relationship with the audience. We should expect a parallel difference between live classroom instruction and most sterile web courses. This course tries to blur the difference between the two in a variety of ways. The professor meets the course the first day—in person. Very early in the web course, he appears again with additional instructions in short video segments. When he does so, the style used for the video clip is a professor in the classroom instead of the "talking head" that appears on the nightly news. Throughout the units approximately 15 short clips (some as short as five seconds) offer advice, encouragement, and instructions. The framing of these clips is extremely close and approximates the appearance of the professor when he is live on a web cam. The intent is to blur the distinction between when the professor is live and when he is on video. On course evaluation surveys, it is clear that the students think they know the professor in a personal way. A detailed analysis of this phenomenon is planned for an upcoming meeting of ASEE.

6. Results

This freshman course has been offered five times. A committee chose the course content, coverage, and book before the course was programmed for the web. The first time it was offered was a beta test with five students. All completed the course. The second class consisted of 15 students. Ninety-three percent of these students achieved the previously defined course objectives. The next time was with 60 students. Eighty percent of the students completed the course. During the summer, 2001, the author taught, from Japan, a small number of students at The University of Texas/Austin in a continuation of his research in distance learning.[8] Seven of 14 students completed the course at the mastery level. In the last offering to 120 students during fall, 2001, again approximately 80% of the freshmen students completed the course and got an A.

In all of these cases, the numbers given are conservative. At The University of Texas, students who do not complete a course are given an X and allowed to complete the course in the next semester. We have not included the students who did so in these numbers or those freshmen who leave engineering after their freshman year.

The course has won an award for its construction and effectiveness. Based upon this success, it will be required of all 120 freshmen each semester. In the future the intent is to migrate it to high school students, co-op students, and students at a greater distance.

Several figures (out of many) will show the effectiveness of the PSI mode of instruction on the web. Figure 4 is a snapshot of the number of students working on a specific unit plotted against the class day. It clearly shows the different pace of the students in the class and proves the importance of a self-paced course on the web. The proctors prepare similar graphs each class day as an aid to redesigning the course in the future.

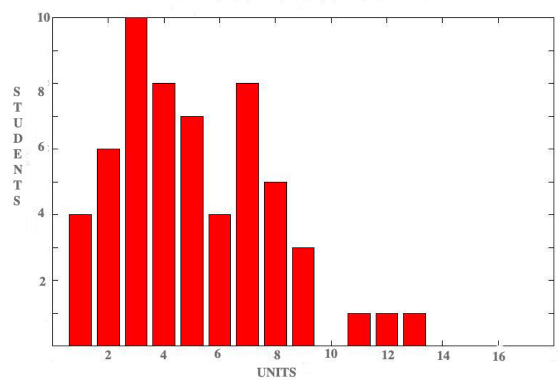

Figure 4. Number Preparing Each Unit

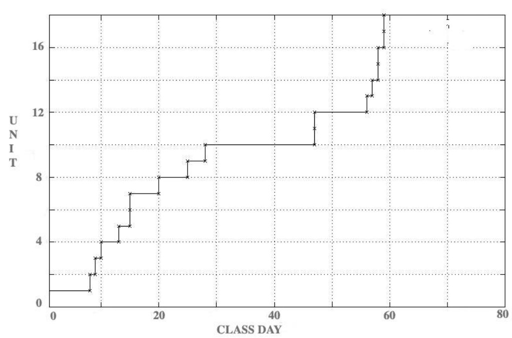

Figure 5. Novice Student

We prepare an individual progress chart for each of the 120 students in the course. Figure 5 is for a student who had never sat down at a computer before, but was highly motivated. She constantly interacted with the proctors, studied on her own, and took every opportunity to learn. Her progress graph demonstrates that the amount of material and the programming of that material is approximately correct

The final progress chart is for a student at the other end of the spectrum. He already knew the course material and was confident in his ability to complete the course in a short time. Although he undoubtedly was aware of the final day of the class and began working to complete the units before this time, he shows no evidence of a finite interval scallop. Unfortunately, most novices designing a web-based, self-paced course would define him as a "procrastinator" and taken measures to intervene. It is worth noting, that if all of the 120 freshmen in the course were graded on a curve based on examinations offered at stated times, the high school computer gurus would get most of the A's, leaving the competent, but less experienced student to begin their college career with a lesser grade.

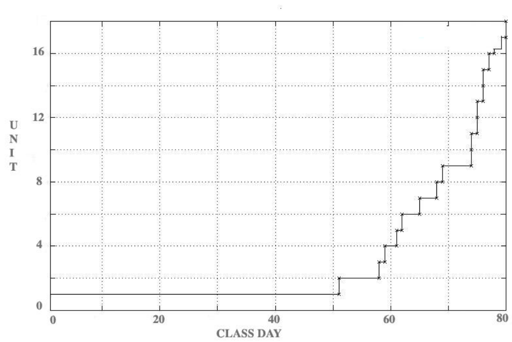

Figure 6. Experienced Student

7. Conclusions

As they used to say on television before Evel Knievel would began a daring jump, "Don't try this at home. Evel is a trained professional." A characteristic of a behavioral approach to instructional design is that it gives strong control over student behavior. Universities are littered with the corpses of PSI courses designed by professors with an imperfect knowledge of the principles involved. This paper was not intended as a primer or user's manual, but as a demonstration of some of the most important principles involved. From the results of this experiment, it is clear that a professor teaching a web-based course using the PSI method can successfully maintain satisfactory progress by managing the contingencies of reinforcement at his disposal without using artificial, aversive control.

One final comment is in order. The research reported here has focused on a freshman level course with 120 students over the web. It is, however, only the latest implementation of PSI in engineering education by the author. In 1969-1970 he made the first use of PSI in engineering education in a nuclear engineering course of 20 seniors and beginning graduate students.[9] In this latter course the proctors always graded the readiness tests face to face with the students at specific times during the week. The results of the initial senior course compared to the present freshman web based one are consistently higher, but strikingly similar with respect to student attitudes. For example, in answer to the question "If given the opportunity, I would take another course taught by this method," 88% of the seniors and 80% of the freshmen answered "yes." To the question "Compared with the other courses I have been taking this semester, I looked forward to the activities of this course much more or more," 88% of the seniors and 54.3% of the freshmen agreed. And, finally, to the question, "Compared with what I initially hoped to gain from this course, I feel that I learned far more than I expected or more than I expected," 77% of the seniors and 62.9% of the freshmen agreed. Although this comparison is far from scientific, and the delivery systems and course content are very different, these results do indicate that PSI holds up well when delivered over the web. This statement should not be taken as a blanket endorsement, however, because very special psychological strategies were implemented in the web-based course to ensure that this was true.

Although the individual units are password protected for obvious reasons and unavailable to the general public, an overview of the site is currently open and available for a limited period of time at:

http://me205serv.me.utexas.edu

A presentation emphasizing the importance of reinforcement contingencies was also delivered at the International Conference on Information Technology Based Higher Education and Training in Kumamoto, Japan.[10]

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9. Biography

In 1969, Billy Koen introduced to engineering education and developed a method of self-paced instruction (PSI) that has become an accepted alternate means of teaching. His current research is in applying PSI to web-based, asynchronous learning and international collaboration over the Internet. In this area he has several recent publications and has taught two ASEE workshops in web-based course construction. Dr. Koen is also known for his definition of engineering method in terms of heuristics. His monograph **Definition of the Engineering Method** was published by ASEE. In the fall, 2002, a more extensive book, **Discussion of the Method** that generalizes engineering method to universal method is scheduled to be published by Oxford University Press. He is also a pioneer in the application of artificial intelligence to nuclear reactor reliability and is a fellow of the American Nuclear Society.

Dr. Koen received M.S. and ScD. Degrees in Nuclear Engineering in 1962 and 1968 from the Massachusetts Institute of Technology. He has been a professor at The University of Texas at Austin since 1968 and was a visiting professor at the Tokyo Institute of Technology in 1994, 1998-1999, 2001 and at Ecole Centrale, Paris, France in 1983. He worked at Saclay, France as a consultant from 1972-73 and 1977-78.

Professor Koen served from 1988-1993 as Vice President for Public Affairs for ASEE. He has held 25 different Society positions and is a fellow of the Society. He has received numerous teaching-based awards including the ASEE awards: Chester F. Carlson award, Centennial Medallion, and W. Leighton Collins Award.