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The Rise and Fall of Programmed Instruction: Informing Instructional Technologists Through a Study of the Past

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THE RISE AND FALL OF PROGRAMMED INSTRUCTION: INFORMING

INSTRUCTIONAL TECHNOLOGISTS

THROUGH A STUDY OF THE PAST

by

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ABSTRACT

THE RISE AND FALL OF PROGRAMMED INSTRUCTION: INFORMING INSTRUCTIONAL TECHNOLOGISTS THROUGH A STUDY OF THE PAST

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Instructional technologists have recently been called upon to examine the assumptions they hold about teaching and learning, and to consider how those assumptions can affect their practice of the discipline. This thesis is an examination of how the assumptions instructional technologists hold can result in instructional materials that do not accomplish the original goals the developers set out to achieve. I explored this issue by examining the case study of programmed instruction, an educational movement from the mid-20th century that promised to revolutionize education but never lived up to its potential. Programmed instruction was heavily influenced by the assumptions of behavioral psychology, such as determinism (human behavior is controlled by scientific law), materialism (the only real world is the physical world), and empiricism (individuals can know the world around them only through the natural senses). It was also influenced

by the assumptions of social efficiency (society must actively find the most efficient solutions to social problems) and technological determinism (technology is the most important force in causing social change). These assumptions manifested themselves in a variety of ways in the programmed instruction movement, including a redefinition of all learning problems into the terms of behavioral psychology, an over-reliance on standardized processes of instruction, and a belief that technology alone could solve educational problems. The ways in which programmed instruction manifested itself resulted in the movement prescribing a very rigid and inflexible method of instruction. Because of its inflexibility, programmed instruction quickly fell out of favor with educators and the public.

Some modern applications of instructional technology, such as online learning, seem to rely on the same assumptions as programmed instruction did. I conclude this thesis with a discussion of how understanding the assumptions of programmed instruction, and how they led to the movement's rigidity, can help modern instructional technologists develop online learning materials that are more flexible and able to meet the needs of the students for which they are intended.

ACKNOWLEDGMENTS

It is a little difficult to write acknowledgments when so many people have been influential in my writing of this thesis. I first express sincere thanks to my committee for their support during the past months. I also want to thank my colleagues at BYU's Center for Instructional Design. The management of CID was very generous in the resources they lent to me so I could complete my research, for which I am very grateful. Additionally, many of my friends at CID took time to share how they felt my research could affect the day-to-day, practical work of instructional technology. I also feel my thesis is stronger because of their suggestions.

On the personal side, I feel very appreciative of my parents, who have encouraged me as long as I can remember to pursue a quality education. I am also grateful to my wife, Jennifer, and my children, Emily and Jason, who supported me as I spent so much time each day researching and writing. Thank you all for the roles you played to get me where I am. You all deserve to be recognized along with me in this thesis.

Finally, I thank my Heavenly Father, who blessed me with the talents and drive to start this project, then blessed me so generously with His guidance throughout the whole research process. The many miracles I experienced while writing make me feel that while I am listed as the author of this thesis, the real credit for the good in this work goes to Him above.

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THE RISE AND FALL OF PROGRAMMED INSTRUCTION: INFORMING INSTRUCTIONAL TECHNOLOGISTS THROUGH A STUDY OF THE PAST

One of the frustrations in the history of instructional technology has been how infrequently the intended audience actually uses the materials that instructional technologists develop. In their most candid moments, many who are involved in the design and development of instructional materials admit that they wish educators and students were more accepting of the instructional solutions they create (Burkman, 1987). One reason for the lack of acceptance for their work is because, despite the wide variety of technologies and methodologies they have used over the years, instructional technologists have rarely addressed some of the basic concerns that have been raised about their approaches (Ehrmann, 2001). One of the major criticisms of instructional technology has been that the solutions the practitioners develop are too rigid and inflexible to be effective in real instructional settings, and do not offer those implementing the solutions the latitude they need to determine how to implement the materials (Gordon & Zemke, 2000; Riboldi, 2000).

To assist instructional technologists in developing solutions that are more helpful to those who use them, commentators have recently challenged those in the field to examine their foundational assumptions to better understand the implications those assumptions have for their work. Part of the challenge is finding a more balanced approach to the practice of instructional technology, with critics claiming that in the pursuit of efficiency the discipline has neglected other factors that are an important part of an effective education (Borrás, 1998; R. T. Osguthorpe & Osguthorpe, 2002; Solomon, 2000). This challenge assumes that no one sets out to create poor instruction, bore their students, or rely on inappropriate methods to achieve desired learning outcomes. However, unexamined assumptions can have all of those unintended consequences if they remain unexamined, because they in part determine the ways one defines problems and the types of possible solutions to those problems (Yanchar & Hill, 2003).

For example, one work on philosophical assumptions presents a hypothetical example of how various assumptions can explain the causes of a person's rude behavior. If observers held a one set of assumptions about what causes behavior, they might assume this person made a conscious choice to have a bad attitude. Other observers might claim that environmental factors caused the person's behavior. Others might blame the behavior on genetics. These wildly different explanations all sprang from observations of the same behavior, but based on the assumptions they held, observers would either pity or be angry with the rude person (Slife & Williams, 1995). In the world of instructional technology, unexamined assumptions can constrain instructional technologists to a narrow view of teaching and learning, and result in the inflexible instructional solutions they have so often been charged with creating (Wilson, 1997).

A specific case from the history of instructional technology, the case of programmed instruction, vividly illustrates the results of inflexible instruction. Programmed instruction (also known as programed instruction), was a movement in instructional technology that developed in the mid-1950s, peaked in the 1960s, and then disappeared almost completely by the end of the 1970s. Programmed instruction has been called "the first true technology of instruction" (Jonassen, 1991, p. 6). The movement was characterized by self-paced, modular instruction, with some automated method of providing students with intensive feedback to help them shape their future responses (Lumsdaine, 1959/1960). However, amid charges that programmed instruction was boring, uninspiring, and overly-rigid, educators rather quickly dropped it in favor of other instructional techniques (Saettler, 1990) (for examples of programmed instruction, see Appendixes A and B). This thesis explores some of the foundational assumptions that influenced programmed instruction, as well as how the consequences of those assumptions resulted in the rigid outcomes with which critics charged the method. In a sense, programmed instruction occupied one extreme along the continuum of possible instructional technologies. Because it was so far in the extreme, it is a good case for examining how strong the relationship between the foundational assumptions of instructional technologists and instructional materials they create can actually be (see Yin, 1994).

To help today's instructional technologists use this study of programmed instruction, this thesis also compares the movement to one of the more recent manifestations of the instructional technology: online learning. Some features of online learning seem very similar to the defining features of programmed instruction. For example, a great deal of online learning is self-paced, modular, and attempts to intelligently diagnose learner needs and modify future instructional materials based on those needs. I am fully aware of the view of online learning that defines it in terms of collaborative technologies such as threaded discussions, virtual classrooms, or other online spaces for students and teachers to communicate and share resources (Khan, 1997). However, self-paced instruction is still a large part of the world of online learning

(Galvin, 2001; Romiszowski, 1997). I argue that self-paced, online learning is a significant enough movement that it is worthwhile to improve it by studying the case of programmed instruction. In saying this, however, I do hope readers will consider how my argument might influence their professional work, even if this thesis does not specifically discuss that type of work.

The research question guiding this study is: Can examining the philosophy and history of programmed instruction help the current generation of instructional technologists create more effective online learning? The following questions will also help answer my guiding question:

1) What is programmed instruction?
2) What were the philosophical assumptions underlying programmed instruction?
3) What resulted from the assumptions of programmed instruction?
4) What philosophical assumptions are common to both self-paced, online learning and programmed instruction?
5) How can the developers of online learning use their knowledge about the results of programmed instruction to create more successful online learning materials?

Method

Methodology

This thesis relies on the historical case study of programmed instruction to illustrate how the foundational assumptions of instructional technology have influenced the practice of the discipline. Because of their nature, philosophical assumptions cannot easily be studied using quantitative methodologies such as “experiment and observation” (Noddings, 1995, p. 4). They are more appropriately studied through qualitative methods, because the goal of studying assumptions is to richly describe them and their results. The best method to accomplish this is through examination of the evidence in the records of what the promoters of programmed instruction were trying to achieve and what they claimed the method to be (Hatch, 2002). After they understand the historical context surrounding programmed instruction, modern instructional technologists can then more easily consider how relevant the conditions and situations programmed instruction encountered may be for their current practice (Merriam, 1998).

Sources

This study relies on both primary and secondary sources to tell the story of programmed instruction. Primary sources are sources “in which the creator was a direct witness or in some other way directly involved or related to the event” (Johnson & Christensen, 2000). Examples of primary sources I used in this paper include theoretical descriptions of programmed instruction authored by the founders of the movement and original research conducted on the effectiveness of programmed instructional methods. Additionally, I cite philosophical works describing what are foundational assumptions and what are some of their logical consequences. Secondary sources are “books and articles written by historians and social scientists about a topic” (Tuchman, 1994). The secondary sources I cite in this paper are primarily histories of psychology or educational technology. Their purpose is to aid in the interpretation of the primary sources used, as well in some cases to provide other accounts that I was not able to locate in any original, primary source.

I took steps during my research to ensure the internal and external validity of the sources I cite in this study. External validity is concerned with how authentic the sources themselves are. Internal validity deals with how well the information in a document represents the events that were purported to have taken place (Schumacher & McMillan, 1993). Regarding the external validity of my sources, I have little concern. For example, there is no reason to doubt that a book or article that B. F. Skinner is credited with writing was in actuality written by someone else.

To protect the internal validity of my research, I performed extensive comparisons among my sources to help ensure that the views I reported are an accurate representation of the thoughts, feelings, and beliefs of those involved. I have looked for evidence from the authors of the literature on programmed instruction to determine how they defined the terms they used, and how they interpreted the events they experienced. Where the sources disagreed, I attempted to tell both sides of the story to give a more balanced view of the issue. Additionally, my interpretations of historical evidence are consistent with those of other historians and commentators on the era. Where appropriate, I have used their histories to help tell the story of programmed instruction. Finally, I have attempted to rigorously document the sources I consulted for this work. I have cited sources based on their ability to demonstrate how its proponents, its critics, and others viewed programmed instruction. Different interpretations of the documents I considered in this study are welcome.

The Researcher's Perspective

As is common in much of the research of this type, the data I collected influenced my understanding of the problem, the development of my hypothesis, and the design of my study (Johnson & Christensen, 2000; Schumacher & McMillan, 1993). Certainly what I studied has shaped me as much as I, in turn, have shaped the story I tell. Some of my beliefs have been challenged, while others have been strengthened. In the spirit of providing the most accurate picture possible of my research, what follows are some of my own assumptions. I include these to help the reader judge how fairly and accurately I have told the story of programmed instruction.

I am deeply committed to the ideal that instructional technologists should help people learn. I do not feel that theorists or practitioners should be so committed to a certain way of conducting their work that they neglect this central purpose. I believe the ultimate goal of learning is to help people achieve their greatest potential. Other goals (such as socialization or preparation for a career) may be important parts of that aim, but they should not be the aims in-and-of themselves. I believe that the best education happens in an environment where the students feel free to explore and experiment with the concepts and skills they are learning.

However, through this study I have also gained a new respect for those methods of instruction that are often criticized in the world of education today, i.e. methods of drill and practice, or rote memorization. I have come to believe that such methods have their place, but only as they help the student more fully achieve the real purposes of learning (I believe the same is true, incidentally, of any other instructional method or technique). And finally, I believe we should take advantage of any method or means of education that can help us achieve our greatest goals, regardless of the theory of learning that generated them, as long as they remain methods to achieve our ends and do not become the ends in themselves.

Historical Development of Programmed Instruction

"The student places his identification plate in a slot . . . [and] the machine then proceeds to tutor the student. Some machines present questions of the multiple-choice type. . . . This sets the student up for other machines which are adjusted to his special needs and teaches him in Socratic-like question-and-answer fashion" (Glaser, 1960, p. 27).

Early Efforts

While programmed instruction was a movement of the mid-20th century, educators had experimented with the methods and technologies involved for many years prior to that. These predecessors of programmed instruction were not connected with programmed instruction in the sense that they recognized themselves as contributing to the movement. However, identifying them and their work helps show the intellectual heritage that later proponents drew upon as they developed their theories and methods.

The methodology perhaps used most often by proponents as the earliest example of programmed instruction was the Socratic method of tutoring. This method of instruction takes its name from the Greek philosopher Socrates, who was known for teaching students exclusively by asking them questions, which he believed would help students uncover their inborn sources of knowledge (Saettler, 1990). Programmed instruction researchers extolled Socratic tutoring, because they felt the technique of asking questions to lead students to the correct answer was a powerful instructional method that educators had never fully exploited (Deterline, 1962; Lysaught & Williams, 1963; Pressey, 1963/1964).

Other early innovators were concerned with how machines could help them teach, and experimented with a variety of devices to improve the educational experience of their students. While these devices were crude by modern standards, and even in some cases of questionable value, they reflected the desire of their developers to improve education in ways they felt were not practical for human teachers to accomplish. Some of the individuals who developed mechanical teaching devices included H. Chard in 1809, Haylcon Skinner in 1866, Herbert Austin Aikins in 1911, and Maria Montessori in 1914 (Casas, 1997; Mellan, 1936/1960).

Finally, other researchers experimented with ways of letting students proceed through a sequence of instruction at their own pace. According to Saettler (1990), these efforts were primarily intended to break apart the American "lockstep educational machine" observers felt schools had become (p. 64). These efforts quickly became connected with the efforts to teach by machine as researchers attempted to find some way of allowing students to learn without the intervention of a teacher. Some of the researchers who investigated individualized educational systems included Frederic Burk in 1912, Carleton Washburne and Helen Parkhurst in 1919, and Henry Morrison from 1925-1935.

While later researchers felt these early endeavors were an important part of their inspiration, Sidney Pressey's work in the 1920s has widely been credited as the first actual contribution to programmed instruction. Pressey, a researcher at The Ohio State University, was attempting to find ways to free teachers "of much of [their] burdensome routine so that [they] could do more real teaching." His solution was to automate some teaching tasks by developing a device which automated the administering and scoring of tests (Pressey, 1927/1960, p. 42) (Figure 1).

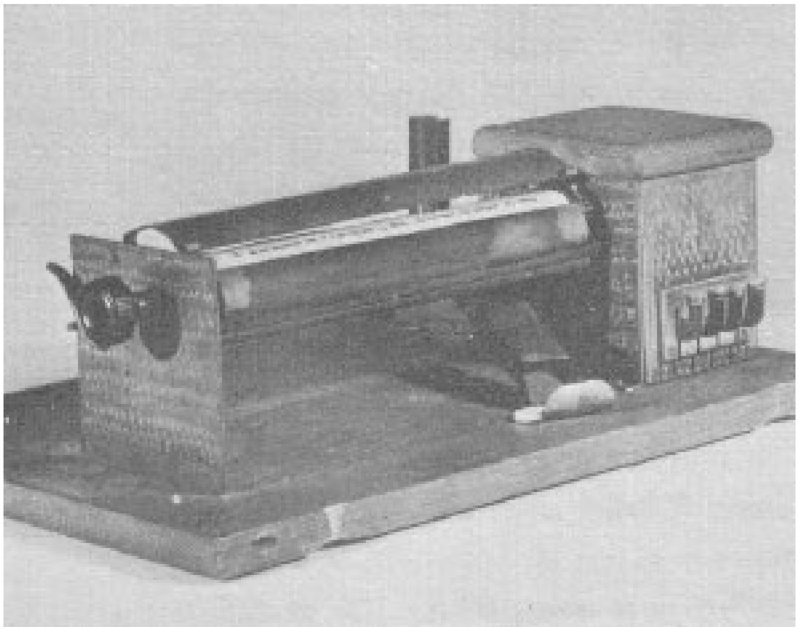

Figure 1. *Sidney Pressey's Testing/Teaching Device. Copyright Department of Photography, The Ohio State University.*

According to Pressey (1926/1960), his machine only required a small set of features to be useful as a labor-saving device for teachers. His machine accomplished its testing functions through a window that presented the student with a multiple-choice question, a series of buttons which corresponded to each of the question's responses, and a series of gears which recorded the student's answer and advanced the machine to the next question. Additionally, Pressey included a feature that he felt changed his device from an automatic *testing* machine into an automatic *teaching* machine. A small switch could be set so that the device would not move from the current question until the student answered the question correctly. When explaining the purpose of this feature, Pressey articulated a number of themes that would resurface in the work of later researchers of programmed instruction, including how students using his machine received immediate feedback on their performance, how efficiently they seemed to learn course material, and how much potential his machine had to become a labor-saving device.

Pressey's work did not lead to the revolution in education he had hoped for. Although convinced of his work's importance, Pressey ended his research in 1932 because of lack of acceptance by educators and others, as well as the economic effects of the Great Depression (Pressey, 1932/1960). During the next twenty years, he and others tried to revive his early work (Pressey, 1950/1960; Stephens, 1953/1960), while other researchers made similar investigations independently (Burton, Moore, & Magliaro, 1996; Dale, 1967). But despite their efforts, nothing of substance materialized.

The Contribution of B. F. Skinner

It took another twenty years before programmed instruction truly began to materialize. Educators in the early 1950s became deeply concerned with what they perceived to be mounting pressure on an already overtaxed educational system. For example, there was a growing dissatisfaction with the progressive educational movement (Dewey, 1916), which had gained the reputation of sacrificing educational rigor in an attempt to make education less authoritarian and controlling (Schramm, 1962). The public worried that their children were not being prepared to become world leaders in technological and scientific subjects (Casas, 1997). Some commentators also felt that the structure of the educational system (both in terms of physical and human resources) could not cope with the ever-growing population (Goodman, 1962; Stolurow, 1961). Additionally, society began to recognize that educational establishments had never served some people well, which contradicted the American ideal of providing high-quality education to all people (Foltz, 1961; Hines, 1965). And finally, other institutions (such as the military) were becoming increasingly concerned about training large numbers of people in a short period of time (R. T. Osguthorpe & Zhou, 1989).

One of the people who attempted to fix these problems was B. F. Skinner, still considered to be the most influential person in the history of psychology since World War II (Delprato & Midgley, 1992). Skinner, a professor of psychology at Harvard, had already pioneered the principles of operant conditioning in the training of animals. Operant conditioning, as Skinner (1986) described it, was a method of conditioning that reinforced an organism's spontaneous, natural behaviors when they approximated a desired terminal behavior. According to operant conditioning, when the approximate behaviors were appropriately reinforced, the organism would display those behaviors more often. The person performing the conditioning would then reinforce the behaviors only if they began to more closely approximate the terminal behavior. With continued conditioning, the organism would eventually display the desired behavior consistently. Skinner became convinced that operant conditioning could be as effective for teaching human beings as it had been in the training of animals (Skinner, 1968).

But as Skinner observed teachers in action, he began to feel that the traditional classroom actively worked against the principles of operant conditioning. He became frustrated when he saw teachers using methods of behavior modification that he felt were not effective at actually changing behavior. He also was discouraged by the length of time it took for teachers to give students meaningful feedback on their performance (to Skinner, even the time between a student turning in an assignment and a teacher returning it was too long). Additionally, he observed that teachers presented large quantities of material at once, which he felt worked against effective behavior shaping because students were being asked to make too large of a behavior change at any given time (Skinner, 1968). Finally, and probably the most problematic to Skinner, was the fact that too often learning goals were not carefully defined, and even were they were defined they were often not in terms that specified the terminal behaviors the teachers desired from the students (Skinner, 1965). Skinner concluded that some revolutionary way of addressing his concerns was necessary, because even if teachers recognized the value of operant conditioning, they did not have the skills to implement the principles in a meaningful way (Skinner, 1954/1960).

In March of 1954, Skinner presented a paper, entitled "The Science of Learning and the Art of Teaching," which described his solution to these problems: the *teaching machine* (Figure 2).

Figure 2. *One of B. F. Skinner's Early Teaching Machines. Copyright Meredith Corporation.*

In this paper, Skinner described how a mechanical device could effectively apply the principles of operant conditioning (1954/1960):

> Reinforcement for the right answer is immediate. The mere manipulation of the device will probably be reinforcing enough to keep the average pupil at work for a suitable period each day. . . . The gifted child will advance rapidly . . . [and] can be given special sets of problems which take him into some of the interesting bypaths of [the subject].

> The device makes it possible to present carefully designed material in which one problem can depend upon the answer to the preceding and where, therefore, the most efficient progress to an eventually complex repertoire can be made. . . . Additional steps can be inserted where pupils tend to have trouble, and ultimately the material will reach a point at which the answers of the average child will almost always be right. (pp. 110-111)

These principles, as stated by Skinner, are the basis for what became known as *programmed instruction*. For the rest of his life, Skinner held the conviction that these methods of instruction could solve the most serious problems that education would face (Skinner, 1986).

Later Developments

Many of the prominent researchers in the field of instructional technology quickly began to contribute to the development of programmed instruction. Some of these individuals are still remembered in the field today, such as Robert Gagné, Robert Glaser, A.A. Lumsdaine, Susan Markle, and Lawrence Stolurow (Gagné, 1965; Glaser, 1965; Lumsdaine, 1959/1960; Markle, 1969; Stolurow, 1961). One individual in particular, Norman Crowder, began to develop programmed instruction that broke with some of Skinner's methods, and harkened back to some of the methods Pressey originally developed (Saettler, 1990). The differences between what Crowder and Skinner accomplished are so significant that they merit further consideration.

One important difference between Crowder's programs and Skinner's was in the method of *branching*. As Skinner originally described his method, a student began a learning sequence, stepped linearly through each section of the instruction, and eventually finished. Because of the linear nature of Skinner's method, it was sometimes called *linear programming*. The only variable involved was time (how long it took a student to complete the sequence). According to Skinner, a linear program was necessary to ensure that each student acquired the same terminal behaviors. "Like a good tutor, the machine insists that a given point be thoroughly understood, either frame by frame or set by set, before the student moves on" (Skinner, as quoted in Markle, 1969, p. 195). Crowder disagreed. He felt that students brought a wide variety of needs and prior experience to an instructional situation, and so the instruction should be modified for each individual student. He named his branching methodology "intrinsic programmed instruction" (Figure 3).

Figure 3. *An Example of an "Intrinsic" Teaching Machine. Copyright John Wiley and Sons, Inc.*

As Crowder (1959) described it, intrinsic programming differed from linear programming in that, "the program of instructional material is completely flexible. Each piece of material that the student sees is determined directly by that individual student's immediately precedent behavior" (p. 109). In other words, the students take a different path through the material based on their earlier answers.

Intrinsic programming also varied from linear programming in other notable ways. Skinner felt that the most effective learning took place when students composed their own responses to questions in an instructional program. Crowder preferred multiple-choice questions. Skinner felt teaching machines held important advantages over programmed instructional materials presented in other formats (such as a book). Crowder seemed much more willing to use any media that could present programmed instructional materials. Crowder was also much more willing than Skinner to create programmed instruction that did not always have a clear right or wrong answer to a presented question (Crowder, 1960; Skinner, 1968). To those involved, the differences between Skinner and Crowder were not superficial. Crowder was so adamant about the differences between his and Skinner's style that he actively tried to distance his instruction from Skinner's (Crowder, 1963/1964). The differences between the two types eventually became so important that people even referred to them as "Skinner programs," and "Crowder programs" (Hoth, 1961/1964, p. 195).

On the question of the effectiveness of programmed instruction, early research was very encouraging. A review in the early 1960s of all available research regarding programmed instruction (over 150 studies), concluded that there was "no doubt" that students learned from programmed instructional materials (Schramm, 1964a, p. 3). In approximately half of the studies, students performed as well using programmed instruction as they did using other methods. In the other half of the studies, students using programmed instruction performed better than students using other methods. Only one study showed that programmed instruction was worse than other methods. Other studies during the early years of programmed instruction were similarly positive. (Hosmer &

Nolan, 1962; Hughes, 1962a; Porter, 1959; Schramm, 1962; Stolurow, 1961; Taber, Glaser, & Schaefer, 1965). For example, Williams (1965) reported that programmed instruction not only increased learning immediately following an instructional situation, but the students also retained the knowledge longer. Programmed instruction appeared to deliver the revolutionary effect its promoters hoped for.

With this initial success, educators and others began to produce programmed instructional materials at a high rate. James Holland (1962), one of Skinner's early collaborators, reported that within a few years of Skinner's original publication of "The Science of Learning and the Art of Teaching," most school subjects had some type of programmed materials available. The military and corporate training divisions also began to adopt programmed instruction (Hughes, 1962b). One research organization, The Center for Programmed Instruction, commissioned studies in 1962 and 1963 to determine exactly how many programmed materials were available. In 1962, 122 programs, representing over 2600 hours of instruction, were for sale commercially (these numbers do not reflect materials that individual organizations may have developed for their own use, or materials developed for research purposes) (The Center for Programmed Instruction, 1962). That number had increased to 352 programs one year later (The Center for Programmed Instruction, 1963). Even in 1973, when programmed instruction was clearly in decline, another guide listed over 900 programs commercially available for use in the elementary and high schools (*Entelek programmed instruction guide: Elementary / high school*, 1973).

The Decline of Programmed Instruction

By the late 1960s, the popularity of programmed instruction was rapidly declining (Saettler, 1990). As the decade progressed, fewer and fewer studies demonstrated the superiority of programmed instruction over other methods. Even more damaging were studies that favored traditional methods over programmed instruction (Kulik, Cohen, & Ebeling, 1980). Additionally, some studies also showed that even in successful programs the principles of operant conditioning were not as important to a student's success as originally thought (Brown, 1970; Krumboltz, 1964; Kulik, 1982; Lublin, 1965). While as far as I have been able to determine no one has specifically studied what caused the shift from favorable to unfavorable research results, it appears that one important factor was the movement of research from the laboratory and into the classrooms. In later research, factors that had never been considered in the early research began to have an effect. For example, as more studies were conducted in real educational situations, it became evident that one important factor that contributed to the success of programmed instruction was the teachers' attitude toward the materials (Casas, 1997).

Promoters of programmed instruction tried to defend their methods against attack. Some promoters of programmed instruction continued to advocate the basic premises of individualized instruction and teaching machines while at the same time downplaying the importance of some of the principles in dispute. Others took the opposite route and claimed that the technology they were using was still too immature to give good demonstrations of the power operant conditioning held for education (Markle, 1964; Mechner, 1977; Skinner, 1986). However, it appeared that programmed instruction was not so easy to defend. By the early 1970s, programmed instruction had clearly fallen out of favor with educators and researchers. While there are still some programmed materials produced today (for example, see the website for The Center for Programmed Instruction at http://www.centerforpi.com), it has never again enjoyed the popularity it did the 1950s and 60s.

As I examine the writings of those most influential in developing programmed instruction, I cannot help but sense that those pioneers felt strongly that they were breathing life into a stagnant educational system. For example, B. F. Skinner described the traditional classroom as a place where "getting the right answer is in itself an insignificant event, any effect of which is lost amid the anxieties, the boredom, and the aggressions which are the inevitable by-products of aversive control [used by teachers]" (1954/1960, p. 104). In contrast, through the use of programmed instructional materials:

> Schools can be designed so that students will profit from an immediate evaluation of what they have done and will move forward as soon as they are ready. . . . Teachers will have more time to talk with their students, and students will learn to express themselves more effectively. . . . Teachers will have more time to get to know students and to serve as counselors. They will have more to show for their work, and teaching will become an honored and generously rewarded profession. (1986, p. 110)

Skinner was not alone in describing such an ideal. Most of the other founders of programmed instruction also felt similar outcomes were possible through the adoption of teaching machines and programmed instruction (Fry, 1963; Glaser, 1960; Goodman, 1962; Stolurow, 1961). The question then becomes, if they had such noble aims and effective methods, why are we not all today learning from teaching machines and reading from programmed texts? Having told this story of programmed instruction, I now turn to an explicit examination of the assumptions that helped to shape the movement. As I will show, these assumptions led many to feel excitement about the possibilities of programmed instruction. And, as the assumptions played out to their logical conclusions, they also led directly to programmed instruction's decline.

The Foundations of Programmed Instruction

"The most important long-run contribution of PI . . . will probably turn out to be the assumption that learning is the responsibility of the materials, that the author can, to a great extent, control and engineer quality and quantity of learning and is, by extension, accountable for the results" (Post, 1972, p. 14).

The Assumptions of Programmed Instruction

Programmed instruction adopted many of the assumptions from the behavioral school of psychology, as well as assumptions of social efficiency and technological determinism. Some of these assumptions dealt directly with what the advocates of programmed instruction felt was real, and what were legitimate ways of learning about that reality. Others dealt with what types of instructional systems were important for society to invest time and money in to produce acceptable results.

In all fields of inquiry, these types of assumptions affect the theories produced, the research conducted, the interpretations of the data collected, and the types of solutions considered (Yanchar & Hill, 2003). These assumptions did not affect programmed instruction in isolation of one another. It was how the assumptions worked together that resulted in such a distinct educational movement (Figure 4).

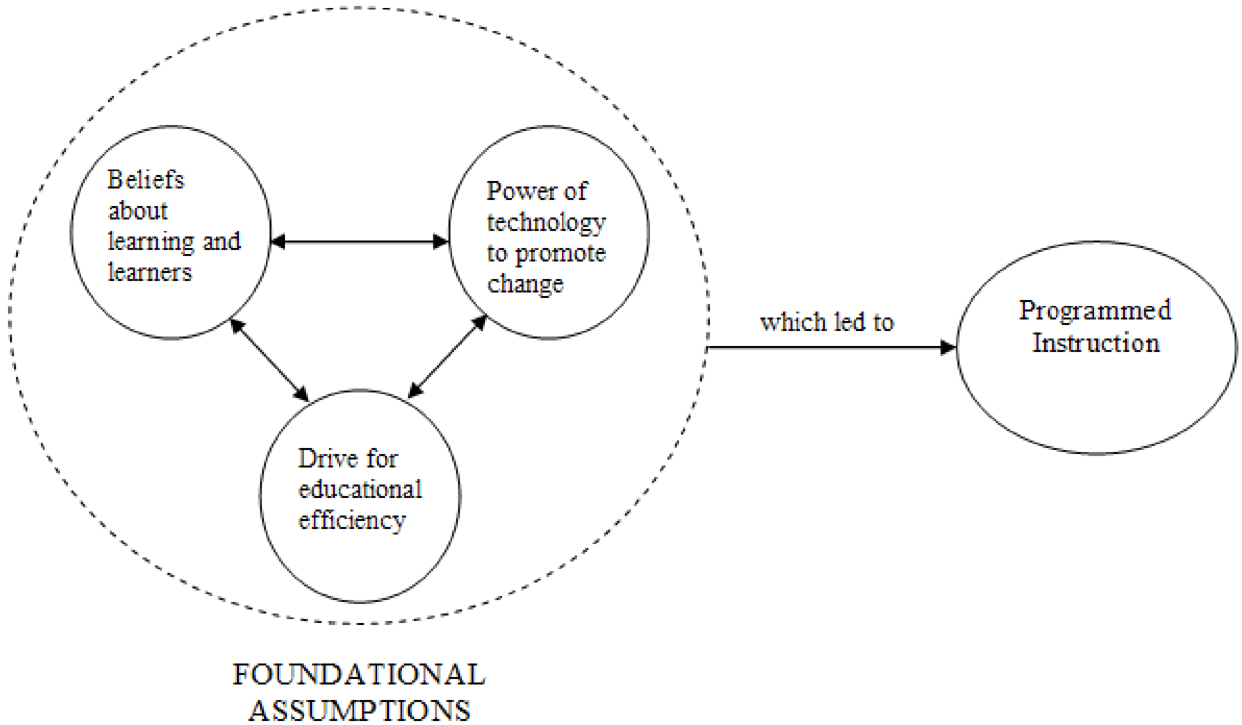

Figure 4. The Development of Programmed Instruction.

To a large degree, the assumptions shaped the community of practice that grew up around programmed instruction. Coming to understand these foundational assumptions helps one to understand why the supporters of programmed instruction saw the world the way they did, and why they made some of the decisions they made (Slife & Williams, 1995).

The first set of assumptions that affected the development of programmed instruction was adopted from the behavioral school of psychology. It was generally accepted that programmed instruction was an outgrowth of behaviorism (Espich & Williams, 1967), and some of the most important beliefs of programmed instruction can be traced back to its behaviorist roots. Behaviorism is perhaps best known for the sentiment John Watson first stated in the early part of the 20th century: "psychology, as the behaviorist views it, is a purely objective, experimental branch of natural science which needs introspection as little as do the sciences of chemistry and physics. It is granted that the behavior of animals can be investigated without appeal to consciousness" (1913, p. 176). Derived from this statement are the three most important assumptions of behaviorism that were adopted by programmed instruction: materialism (the physical world is the only reality that exists), determinism (a person's behavior is under the control of scientific laws), and empiricism (humans can know the world around them only through the natural senses) (Delprato & Midgley, 1992; Driscoll, 2000; Slife & Williams, 1995; L. D. Smith, 1992).

The assumption of determinism was very evident in the writings of those who most influenced the early development of programmed instruction. For example, B. F. Skinner stated plainly that teaching machines were "a technology based on a deterministic science of human behavior" (1968, p. 170). Others described this assumption in more detail. Edward Green, another early advocate, wrote that "just as the concern of the physicist is with the prediction and control of events and objects in space and time, so must the concern of the psychologist be with the prediction and control of behavior" (1962, p. 2). And Susan Markle (an early student of B. F. Skinner) stated that, "the student learns only what he has been led to do" (1969, p. 6).

The assumptions of materialism and empiricism generally seem to be interdependent in behavioral psychology (Robinson, 1985), and the connection between the two assumptions was no different in the case of programmed instruction. Programmed instruction tended to accept the position that there were no components to knowledge other than manifest behaviors (Glaser, 1962/1964). Others tempered this extreme position by stating that even if there were other factors involved in knowledge (such as a mind), they could not be studied and were fundamentally unimportant to understanding learning (Driscoll, 2000). Both views represented a position that gave validity only to a material world. As Mechner (1967) stated, anything other than observable behaviors were simply not “useful as analytic units for purposes of describing, analyzing, and building any kind of knowledge” (p. 84). Additionally, only the observable behaviors students displayed were accepted as evidence that they had actually learned. It became very important for the developers of programmed instruction to define every learning goal in terms of observable behaviors so teachers and other evaluators could judge whether students had or had not learned (Glaser, 1962/1964).

Researchers of programmed instruction also relied on other ideas in addition to behaviorist assumptions to help them determine specific educational solutions. One of these was the assumption of social efficiency, which stated that it was imperative for schools to eliminate all unnecessary costs (both in terms of time and money) from instructional situations (De Vaney & Butler, 1996). Supporters of programmed instruction turned to the developing field of scientific management to find methods of improving educational efficiency (Niemiec & Walberg, 1989). Efficiency became another variable to manage in the experimental process, and measures were developed to help assess the degrees of efficiency achieved (Lumsdaine, 1965; Stolurow & Davis, 1965). The importance of this goal to programmed instruction cannot be overstated. The founders of programmed instruction were absolutely convinced that education must find ways to doing more, in less time, or it could not succeed (Skinner, 1968). As Dale (1967) noted, “there is a heavy social demand that students learn more [and] learn it more efficiently” (p. 52).

The assumptions of technological determinism, which stated that technology was the most important force in causing social change (Misa, 2003), also heavily influenced the development of programmed instruction. To many advocates, the importance of the machines themselves in the learning process is another point that also cannot be overstated. One technologist said "[some people feel] that machines are merely aids to teaching. . . . Our thesis is quite the opposite. These machines, when they work, are a theory of teaching" (Galanter, 1959, p. 1). B. F. Skinner also argued that "the number of reinforcements required to build discriminative behavior in the population as a whole is far beyond the capacity of teachers. Too many teachers would be needed and many contingencies are too subtle to be mediated by even the most skillful. *Yet relatively simple machines will suffice*" (Skinner, 1961/1964, p. 47, emphasis in original). Even though books containing programmed materials became popular among some programming advocates, and some tried to advocate the preeminence of the techniques involved over the media used (Plattor, 1965; Schramm, 1964b), a very common view was that separating the machine from the instructional methods resulted in too narrow a view of what programmed instruction could accomplish (Gotkin & McSweeney, 1967).

The Culture of Programmed Instruction

As is common to many movements, the supporters of programmed instruction began thinking of themselves and their approaches as members of a unique culture. A culture is a set of "common symbols and meanings" that influence a group's "behaviour, social events, institutions, and processes" (Alvesson, 2002, pp. 3-4). People involved with the movement created professional organizations and offered courses and degree programs to certify the developers of programmed instruction (Saettler, 1990). Those who actually designed and developed programmed instructional materials joined the ranks of a new profession known as *programmers*, and experts quickly began to codify the qualifications and characteristics of good programmers (Garner, 1966; D. E. P. Smith, 1959).

The culture of programmed instruction viewed teaching and learning in ways that were perfectly logical outgrowths of the foundational assumptions of the movement. Just as the foundation of a building influences the type of structure that it can support, the foundations underlying programmed instruction appear in many of the ways in which programmers set out to formalize the practice of their discipline (Figure 5).

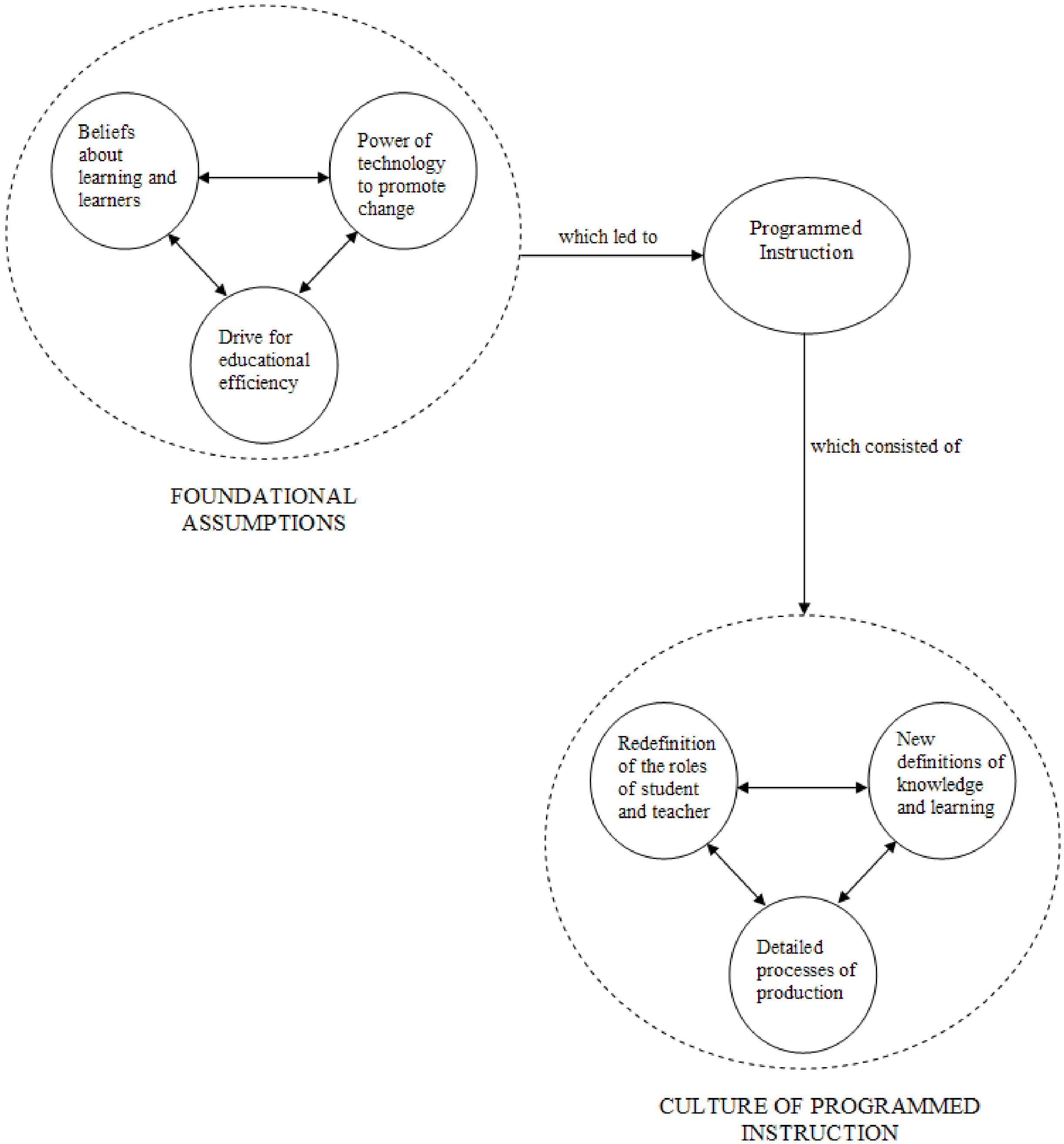

Figure 5. The Culture of Programmed Instruction.

The behaviorist assumptions of materialism and empiricism appeared in the culture of programmed instruction in how programmers began to speak about teaching, learning, and instructional problems. Because the behavioral science upon which programmed instruction was built defined learning in such a specific way, programmers sought to define all learning problems in terms of the same language. This is a common manifestation of the assumptions of a discipline. According to Slife (1998), when researchers adopt a particular worldview they attempt to translate all the phenomena they encounter into terms that are easily understood under that view.

As a result, when researchers with strong biases towards a certain way of looking at events investigate a new event, "only the translated [portions of the new event are] tested. That is, only those aspects or that particular rendition of [an] original idea is truly investigated" (p. 213). Creativity, complex problem solving, ethics, thinking, motivation, self-control, and language acquisition were all subjects that programmers attempted to explain in behavioral terms (Goff, 1965; Resnick, 1963; Rocklyn & Moren, 1962; Schramm, 1964a; Skinner, 1959, 1968). The problem of Johnny not being able to read would, in the language of the programmer, become a problem of Johnny not receiving the right types of reinforcements to cause him to consistently perform the behaviors of reading. Similarly, Mary's frustration with math could be a problem with Mary not receiving enough feedback to help her adequately predict what her next appropriate behavior should be.

The behaviorist assumption of determinism manifested itself in the culture of programmed instruction in how programmers adopted for themselves and their materials the responsibility for their students' learning experience. Traditionally, either teachers or students had been held responsible for the outcomes of instruction. But in the view of the programmer this was incorrect. Programmers felt that because learning was such a technical activity, it simply was not possible for teachers to meaningfully influence learning outcomes. Similarly, they felt that students could not learn on their own without being the influence of some type of external force. The only alternative was that students learned from a program, or a machine, that was a concrete manifestation of the scientific principles of learning (McClellan, 1961/1964). This was not a simple matter of semantics. This was a view that guided programmers in many of the important decisions they made. In the words of one programmer, "if the student errs, the programer flunks" (Markle, 1969, p. 16). According to another, programmed instruction had the "ability to *guarantee high achievement*" in students (Padwa, 1962/1964, p. 273, emphasis in original).

The assumption of efficiency became visible in the culture of programmed instruction through the processes programmers developed to create instructional materials. These processes specified how programmers should translate the general principles of operant conditioning into standardized rules that would result in consistent results. Every input and output had to be defined as precisely as possible (Green, 1967). The process of programming then became a simple matter of putting all the pieces together in the right way (Schramm, 1964b). Programmers believed that an effective instructional product was the sum of its constituent parts, and that if all of the pieces were there and presented in the optimal order, students would succeed (Lysaught & Williams, 1963).

Some examples of programming rules may help illustrate how programmers translated operant conditioning into rules of programming. B. F. Skinner (1968) originally advocated that students be presented with small amounts of information at a time to properly shape their behavior. He also claimed that proper shaping occurred only when students made very few, if any, mistakes. In many processes of programming, these principles became the 30-word rule (any given frame of programmed materials should not have more than 30 words) and the 90/90 rule (programmers should revise their material until 90% of students could answer correctly 90% of the time) (Molenda, 1997; Zemke & Armstrong, 1997). Similarly, the principle of active response (learning will occur only when students actively responded to a stimulus) became the rule of synonymous phrasing. This rule prescribed that questions be changed in minor ways to let students actively respond to every piece of the subject matter. For example, the instructional materials asked students both "What country is Paris the capital of?" and "What is the capital of France?" to make sure students knew that "France" and "Paris" were conceptually connected (Markle, 1969, pp. 4-5).

These manifestations of programmed instruction's culture were compounded when combined with the assumption of technological determinism. Often, the programmer claimed that teaching machines themselves had power to make instructional situations better, because as the tools became more sophisticated they would in turn lead the instructional theories and techniques to become more sophisticated (Finn, 1963). Because of the power they felt was inherent in teaching machines and in the programmed instructional methodology, some advocates were comfortable stating, "even a bad program is a pretty good teacher" (Schramm, 1962, pp. 11-12). But despite this claim, people began to have serious doubts about how "good [of a] teacher" programmed instruction really was.

The Results of Programmed Instruction

"The Savage was silent for a little. 'All the same,' he insisted obstinately, 'Othello's good, Othello's better than those feelies.'

'Of course it is,' the Controller agreed. 'But that's the price we have to pay for stability. You've got to choose between happiness and what people used to call high art. We've sacrificed the high art'" (Huxley, 1932, p. 264).

During the 1960s, critics began to attack the methods of programmed instruction for a wide variety of reasons. Some of these reasons related to how the advocates of programmed instruction viewed human beings, as well as how they viewed the nature of teaching and learning. Some commentators have raised thoughtful and serious questions about whether or not a deterministic, materialistic model of human learning really reflects the reality of human existence. Some of the questions they raised include: what role do students' desires, beliefs, and actions play in learning? If the teacher views the student as a passive vessel for knowledge, how does that attitude affect the teacher-student relationship? Are people best served when they are taught that the solution to every problem lies in some type of stimulus and response? And, what role do cognitive processes, motivation, values and morality, emotions, aesthetics, and spirituality play in teaching and learning? (For more on these and similar topics, see Borrás, 1998; Driscoll, 2000; Garner, 1966; R. D. Osguthorpe & Osguthorpe, 2001; R. T. Osguthorpe, 1996; Solomon, 2000.)

In the case of programmed instruction, these (and similar) questions led to some serious problems that directly contributed to the downfall of the movement. For example, many teachers felt the advocates of programmed instruction were trying to put them out of a job (Nordberg, 1965). Few programmers explicitly stated that this was their goal; rather, they claimed that they wanted to free teachers to perform more meaningful tasks (Carter, 1962; Fry, 1963; Skinner, 1968). However, their messages about the role of the teacher seemed to get lost in the rhetoric of the instructional inadequacies of the teacher.

Understandably, teachers did not respond favorably to the idea that machines could replace them (Heinich, 1984/1995). Additionally, some students experienced frustration when they could not keep up the same pace through the instruction as could their peers. For these children, the pressure to succeed detracted from the learning they should have experienced (Casas, 1997).

But perhaps most significantly, programmed instruction as a method became very rigid, inflexible, and resistant to adaptation. Looking at the decline of programmed instruction in light of its foundational assumptions helps show why it became so inflexible, just as looking at its rise in light of its assumptions helps show how the discipline took shape (Figure 6).

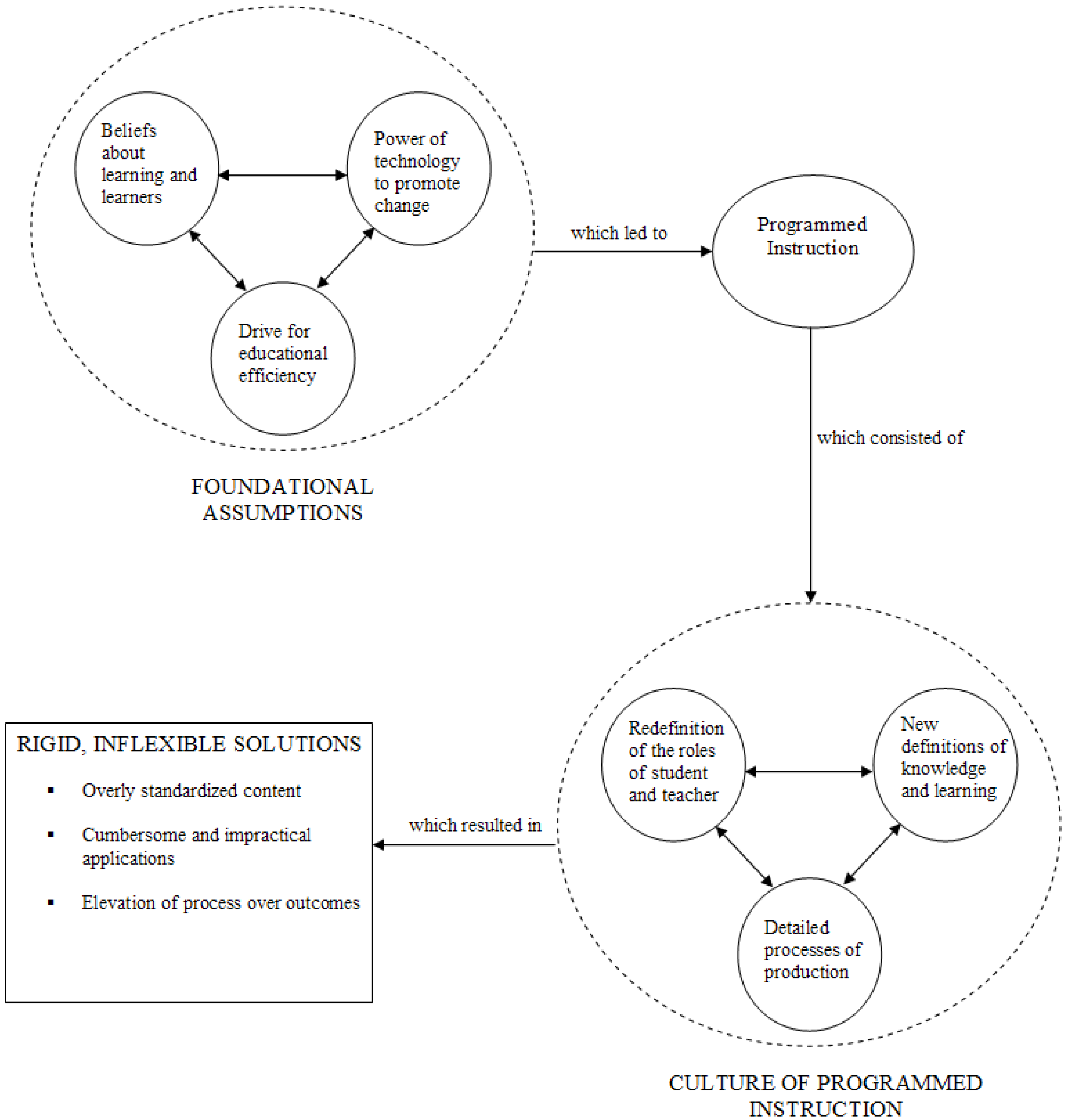

Figure 6. The Results of Programmed Instruction.

One of the ironies of programmed instruction was that its proponents viewed it as a very flexible, versatile method of instructional delivery (Stolurow, 1961). But some thoughtful observers of the movement felt that it was not a method that could be used in all situations, and warned that the practice of programmed instruction could cause problems if it were not used appropriately (see, for example, Blyth, 1962/1964; Espich & Williams, 1967; Garner, 1966; Lange, 1967). Unfortunately, because of the assumptions they held, many others involved in the movement were often blinded to the "costs and consequences" of the choices they made in how to use programmed instruction (Slife & Williams, 1995, p. 10). And many of those beliefs and choices became difficult for other people to accept in the same way that the developers of programmed instruction accepted them.

The rigidity of programmed instruction began to develop as the culture of programmed instruction solidified. As mentioned previously, the culture of programming began to take shape as the first generation of programmers trained the next through participation in professional organizations and conferences and through formal and informal education. One of the purposes of this training was to transfer to the new developers the knowledge and values that the movement considered most important (Kerr, 1996). As this process continued, group members took more for granted the group's basic assumptions and were less willing to (or even less aware that they could) push the edges of the group's boundaries (Alvesson, 2002). Other scholars have termed this phenomenon the "ordering" of a society (Kendall & Wickham, 2001, p. 27), or the process by which a culture becomes more managed, more controlled, more routine, and more stable. Or, as Garner (1966) stated more bluntly, "in an enthusiasm to express elaborations of the theory, dogmas appear. Absurdities usually follow, in the typical cyclical pattern toward decadence that many movements exhibit as their concepts congeal" (p. 2).

The first difficulty arose because programmers felt they had to standardize one content presentation that would remain stable for years. One reason this happened was a result of the assumptions of efficiency. It took a lot of time for programmers with specialized skills to create programmed instructional materials, which became very expensive. Additionally, the teaching machines themselves cost considerable amounts of money. To recover their investment, any organization that adopted programmed instruction felt pressure to use that material unaltered for years (Nordberg, 1965), and any change in content threatened to make the package obsolete (Saettler, 1990). The programmers themselves helped to encourage this view, by claiming that through their scientific analysis of the learning objectives and terminal behaviors necessary to reach those objectives, they had arrived at the optimal way to teach the subject matter (Klaus, 1961/1964). Therefore, in their view, changing a program would be unnecessary, or at very worst a rare occurrence.

These standardized packages of instruction became problematic because they limited teachers' ability to change course during an instructional situation, in response to needs that came up during the instructional period itself. Programmed instruction could handle a variety of situations only as "the programer interpret[ed] *in advance* the error possibilities" a student was likely to encounter (Stolurow, 1961, p. 12, emphasis added). Researchers who studied how teachers actually used programmed instruction discovered that the most successful implementations happened in situations where teachers used programmed instructional materials in conjunction with other teaching methods, and were willing to modify the programmed materials (or switch to another method of instruction) during the course of the instruction as they saw the need arise. Those schools that rigidly tried to implement programmed materials as the programmers recommended ran into problems because the materials were not a perfect fit to the students and the teachers who were using them (Edling et al., 1964).

This result should not be too surprising. If each individual is unique, even a sophisticated instructional package could not possibly be the perfect solution for all of them. In the name of greater instructional freedom (giving students the freedom to complete the instruction at their own pace), programmed instruction constrained the students to one path (or a set of pre-selected paths), regardless of the value this held for that particular student. As one critic stated:

> We need to keep in mind that the teaching machine atomizes and predigests a great deal of the instructional materials. Relatively little latitude is left for individual interpretation and analysis in the process of "operant conditioning." The learner is not permitted to develop a style of inquiry of his own. He must simply conform to the style of the programmer. Under "operant conditioning" the student is not in control of the programed material. Instead, he is under the control of the program. (Tanner, 1957/1964, p. 303)

Another problem arose as programmers attempted to define all instructional problems in terms of observable behaviors. The problem with this was that if programmers wanted to teach something that was not clearly a behavior, they felt compelled to redefine it into something that was. And once they redefined it, they ran in to the problem that it might very well no longer have been what they originally set out to teach. Michael MacDonald-Ross (1973) argued that reducing complex phenomenon down to a list of behaviors effectively prevented teachers and students from exploring that phenomenon in other legitimate ways—ways which may have been more suitable to the particular needs of that group. David Jonassen, in an examination of the basic principles of programmed instruction (1982), argued that “effort spent in responding [to instruction that redefines non-behavioral knowledge in terms of observable behavior] detracts from the amount of effort needed for understanding [that knowledge]” (p. 222).

An example may help to illustrate the problems programmers faced when trying to define all problems in terms of terminal behaviors. B. F. Skinner was perhaps one of the greatest proponents that all learning could be explained in terms of behavioral principles. One learning outcome he attempted to define in this way was learning the trait of creativity (1968). According to Skinner, “if we are to design effective ways of furthering the behavior said to show creativity, we must trace it to manipulable variables” (p. 170). He then built a careful case for how creativity could be explained in terms of discrete behaviors, and how those behaviors could then be modified. Some of the behaviors necessary to teach creativity (according to Skinner) include reinforcing students:

- To not seek the approval of others
- When they transfer behaviors to new situations
- Who can manage their own time
- When they display a behavior that other people are not displaying

Certainly few would argue that people who are labeled creative often do act in these, and similar, ways. However, this does not necessarily mean that these behaviors cause a person’s creativity. An equally viable explanation is simply that creative people exhibit these behaviors. Unless, of course, one has already presupposed that this alternative option is not possible. Because of his commitment to teaching through the method of operant conditioning, Skinner explored only one method of teaching creativity without giving much (if any) thought to how appropriate that method really was. As far as I have been able to determine, no one actually attempted to create programmed instruction to teach creativity. According to Garner (1966), creating such a program would have been very expensive in terms of time and expertise. But Garner's more indicting claim was that programmed materials that attempted to teach complex traits actually tended to teach students to rely on pre-packaged sources of information, rather than trying to solve problems on their own (which is typically not a behavior that encourages traits like creativity).

As a counter example, I offer another set of materials designed to teach creativity, materials developed during the same timeframe of Skinner's writings. E. Paul Torrance (1965) prepared and reported on this set of materials. . His set of materials relied on dramatizations of the lives of people who are typically thought of to be creative (such as Thomas Edison, Louis Braille, or Benjamin Franklin), which were then played for students during a classroom experience. Through telling the story of this person's life, the producers of the tapes introduced and emphasized the values that they felt would improve creativity in the students (for example, courage or persistence). After the dramatization. the teacher would lead a class discussion on the importance of that value, then the students would engage in an activity typically thought of as creative, such as painting, dancing, or writing. According to Torrance's report, the children who participated in these lessons were later more likely to voluntarily engage in creative behaviors than other children. The students also reported they liked school better, and the students in at least one of the groups studied also performed better in other school subjects such as arithmetic.

Few of the factors programmers specified were present in Torrance's lessons, including behavior shaping through the presentation of small amounts of material and immediate and individualized feedback on students' performance. The developers also seemed comfortable letting each class define creativity in whatever terms best helped them come to a better understanding of the trait. Torrance certainly analyzed and evaluated the instructional situation, but not in an attempt to "end in [a] formula" that he could then apply entirely whole to other situations (Noddings, 1992, p. xi). In the cases presented by these two examples, it certainly appears that the approach that relied less on the assumption of behavioral analysis resulting in behavioral objectives was the better approach, which has unsettling implications for the views of teaching and learning Skinner and others presented.

The third problem was that as programmers attempted to reduce complex problems to simple solutions, the process of creating the instruction sometimes became more important than the desired instructional outcomes (Molenda, 1997; see also Wilson, 1997). This certainly was not unique to programmed instruction, as most movements eventually try to reduce intricate relationships into a "standardized form" that merely "require[s] us to check boxes and fill in blanks" (Postman, 1992, p. 84). In the case of programmed instruction, this tendency resulted in programmers who were overly concerned with the outward form of their materials rather than with the learning outcomes the materials were intended to produce (Markle, 1967). Another critic stated that programmers tended to tailor material "to the lowest common denominator," without worrying about the differing levels of readiness the students may have brought to a situation. This same author also felt that programmers conducted their jobs as if "no other stimulus or response [besides reading and writing] were useful, or available" (Garner, 1966, pp. 11, 13). Similar to the tendency to reduce all knowledge to observable behaviors, this meant that programmers were often guilty of "misrepresenting the thinking or mental process required by [a] task. . . . [as well as misrepresenting] the nature of the content" (Jonassen, 1991, p. 8).

The most classic example of this problem has come to be known as *over-prompting*. Over-prompting happened when programmers attempted to increase student motivation by ensuring that students were successful as often as possible. "Perhaps one student is unable to deduce a conclusion from the evidence given. Remedy: give him more hints or even tell him the conclusion rather than let him fail" (Markle, 1964, p. 148). Over-prompting can be seen in the following example from a program intended for coin collectors over the age of 12:

> 1 – Coins are graded according to their condition, which are compared to a freshly minted coin from the mint. There are eight (8) accepted grades for coin collectors. Coins are graded by their _______.
>
> 2 – The ______ (six, four, eight) grades of coins are derived from the condition of the coin.
>
> 3 – The PROOF coin is the very highest grade a coin can have. A proof coin has a high luster, mirror-like finish produced by striking a polished die into the metal. ________ coins are the highest grade a coin can have.

4 – Proof coins are highly regarded by collectors and require extreme care to protect their ______-like finish. (The Center for Programmed Instruction, 1963, p. 145)

As noble as their intentions may have been, programmers chosen method of reaching their goal unfortunately had unintended consequences. Over-prompting often caused students to pay less attention to the instruction, because they quickly figured out that the materials would compensate for them (Holliday, 1983). It also resulted in students who were bored and uninspired. While some students did report that they actually enjoyed completing programmed materials, most of the historical record indicates that students quickly tired of, and eventually developed an aversion to, programmed instruction (Casas, 1997; Edling et al., 1964; Post, 1972; Reiser, 1987; Roth, 1963/1964; Saettler, 1990; Sohn, 1964; Tyler, 1975). And, despite the claims Skinner made that simply getting the right answer was enough to keep a student engaged (1954/1960), more recent research suggests that student boredom has a large impact on what students actually learn (Small, Dodge, & Jiang, 1996).

Even though advocates of the teaching machine were willing to say that using technology could solve some of the shortcomings in individual applications of programmed instruction, some of the features of the machines may have actually made programmed instruction less flexible. For example, one advantage advocates considered to be very important was that teaching machines enforce the order in which students were presented with instructional materials. Believers in this approach claimed that it prevented cheating (Hughes, 1962b). While this was certainly the case, it also prevented students from using the materials in ways that may have better met their individual needs.

Teaching machines also contributed to the elevation of production process over instructional outcomes. Because of the novelty of the machines, many corporations built and sold them without giving any attention to the materials that would be used with them. As a result, any material that superficially resembled programmed instruction was sold, regardless of how well (or poorly) it actually met the defining conditions of the method (Schramm, 1962).

Despite the striking results of all of the assumptions of programmed instruction, it appears that the developers of programmed instructional materials did not learn much from the failure of the method. Programmed instruction became part of the intellectual heritage of the computer-assisted instruction movement, which has been accused of some of the same shortcomings as was programmed instruction (Niemiec & Walberg, 1989; Saettler, 1990; Stoll, 1999). And despite the aversion some today seem to have for anything that resembles the assumptions of programmed instruction (Blasi & Heinecke, 2000; Mayer, 2001), they still have a powerful effect on the world of instructional technology.

Conclusion

"If you sterilize and control the learning environment and teach only *your targeted objectives, learners will* fail *to learn how to be the thing you want them to be. They may learn some* things *you want them to learn, but they will fail at the role you're asking them to play in a real world of practice" (Wilson, 1997).*

Instructional Technology Today

This study should be of more than historical interest to people concerned about improving education through the use of technology. While researching and writing this thesis, I had moments when I recognized modern instructional technology in the assumptions, language, or practice of programmed instruction. Many of these moments came as I compared programmed instruction to the assumptions, beliefs, and practices that those who design online learning frequently espoused. I make this comparison partially because it has been too easy for critics to dismiss programmed instruction without really examining it. Promoters of instructional technology sometimes assume that because so much new research has been conducted during the past forty years, the issues of the past are of no concern today (Ehrmann, 2001). After all, if we embrace collaborative environments and discovery learning, we have nothing to learn from a movement that advocated self-paced instruction and drill and practice, right?

While online learning can support learning communities that are rich in human interaction and provide for flexibility in the learning situation, the majority of online learning materials are still individual-study classes (Clark & Mayer, 2003; see also Wiley, 2002). For example, a number of producers of online courses, such as MindIQ (http://www.mindiq.com), NETq (http://www.netg.co.uk), and d'Vinci Interactive (http://www.d-elearning.com), offer online, self-study courses on a variety of topics, including as software skills, auditing, sexual harassment, managing upset customers, ethics in both animal and human subjects research, and genetics. Some of these courses are virtually indistinguishable from the programmed materials produced in the 1960s, other than the modern materials perhaps include multimedia elements that were not available forty years ago. Also similar are the promised benefits of providing standardized instructional materials, shifting the responsibility for learning from teachers or students to the instructional materials, and of allowing the student to take an individualized path through the instructional materials (Bork & Gunnarsdottir, 2001).

Many people are as dissatisfied with the current state of online learning as they were with programmed instruction (see Brignall, 2001; Mayer, 2001; Navarro, 2000; Stoll, 1999). This is partially because even though new technologies, methodologies, and philosophies have informed instructional technology, some of the foundations upon which programmed instruction was built are still evident in modern applications of technology to learning. Modern instructional technology is partially descended from movements like programmed instruction, even though in recent years the discipline as a whole has begun to embrace other philosophies, such as constructivism (Jonassen, 1991). Even though there are some obvious differences between the two movements, comparing programmed instruction to online learning reveals several parallels, which should be of interest to anyone concerned with how to create online learning experiences that are of the most value to potential students. The three assumptions I have discussed throughout this thesis appear in the movement of online instruction: technological determinism, the importance of efficiency, and the influences of behavioral psychology.

One point of similarity between the two types of instruction becomes obvious when comparing how the assumption of technological determinism manifested itself in both learning environments. Advocates of online learning are as enthusiastic about the power of modern technology to cause positive change as the previous generation was about teaching machines. One technology advocate asserts that "[Internet] technology itself both mandates and assists active learning" (Crane, 2000, p. 10). Another claims that "the Net *is* the future. . . . Kids learn to ask better questions, to make better arguments, and to present themselves more positively over the Net" (Ellsworth, 1994, p. 5). Finally, the claim has also been made that "online education is much more humane and personal than most forms of classroom instruction" (Kearsley, 2000, p. 11). While all of these ideas certainly can contribute to effective learning experiences, and are true in certain circumstances, attributing this much power to the use of technology is as likely to lead the developers of online learning to the same place as it did the developers of programmed instruction—too often the developers buy in to technologies assuming they alone will improve learning, without worrying about other factors important in improving learning (Feenberg, 1999).

Another area of similarity is how the assumption of efficiency has led to the tendency to rely on standardized approaches to solving instructional problems. The creators of programmed instruction tended to reduce instructional technology to a well-defined set of guidelines and rules. Some promoters of online learning have begun to show the same tendencies. For example, a host of checklists have sprung up specifying what characteristics must be included in a good online course. One website on how to develop effective online courses prescribes two or three methods for each type of instructional problem, such as, "attitudinal changes *require* role play and situational practice" (*Principles of online design: Instructional design*, n.d., emphasis added). Another common guideline directs course writers to keep text to a bare minimum, using only bolded headings and bullet points of text if possible (for example, see Krug, 2000; Nielsen, 2000; Rajamanickam & Nichani, 2001).

As happened with programmed instruction, when developers of online learning attempt to rigidly standardize instruction, it begins to lose its personality, even if those guidelines are valuable when reasonably applied. Good instruction is not only a matter of following a checklist. Only one of many possible problems to this approach is the “danger . . . of locking ourselves into set ways of thinking and not being open to innovations or new solutions” (Wilson, 1997). According to another expert, “if your [only way of judging the quality of your training] is, ‘It’s good training because it was developed using [a certain process], what you’ll produce is [not good training]” (Fred Nickols, as quoted in Gordon & Zemke, 2000, p. 49).

An example of an online course offered by Portland Community College (http://www.pcc.edu) helps to illustrate how beliefs in the power of efficiency and of technology can shape online courses. The subject of the course is the history of rock and roll music (Figure 7).

Figure 7. History of Rock and Roll Online Course. Copyright Portland Community College.

One of the goals of this course is for students to appreciate the wide variety of styles that fall under the category of rock music. Each lesson in the course consists of a few pages of text, enhanced by snippets of audio and video by the artists under discussion. When I saw this course demonstrated at a recent conference, the other attendees were amazed at the use of technology. For example, there were many comments about the advantages of letting students listen to these clips even though they would not be in a traditional classroom. The crowd also praised the instructional designers of the course for their ability to follow good course production guidelines. But no one asked any questions about whether or not this course helped students learn better than they did through other methods. As another source or evidence, the official press release I found for this course promotes the technology it uses rather than the learning outcomes the students in the course achieve (Thorbeck, n.d.).

However, despite the praise, the course as a learning experience felt quite uninspiring and actually a little bland. The course developers have seemingly fallen into the trap of assuming that simply providing web-based materials will create an effective learning environment (Wijekumar, 2001). Even though the course rigidly adhered to the rules of online course production, the developers seemed to have held so tightly to these rules that they also stripped the course of the sense of excitement that the instructor presumably feels about the topic. They rely on “boring, cookie-cutter [approaches] geared to the slowest and most ignorant learners in the audience” (Gordon & Zemke, 2000, p. 51) that students too often find to be formulaic and trite (R. T. Osguthorpe, Osguthorpe, Jacob, & Davies, 2002). For example, the introduction to the course, which consists of only 150 words spread over three web pages, seems to fail in inspiring students with the sense of enthusiasm they should feel at they begin a course. The introduction in whole reads:

> Most popular music today is secular, meaning that generally speaking the music can not be performed in church. The terms sacred and secular were used during the Middle Ages to distinguish between music that could be performed in church

> and music that could not be performed in church. The earliest musical song *[sic]* were brought to America by British and other European settlers. The National Copyright Act in America in 1790 (one year before Mozart's death in Austria), protected a composer's music and allowed him or her and the publisher to receive payment for published songs that were sold. During this time the music industry grew rapidly in the United States. The invention of the phonograph and the radio beginning in the 1920s also added to the popularity of music. During the 1940s television helped to strengthen the recording industry. Rock music developed into an extremely developed industry during the 1950s. (*History of rock and roll [online course]*, 2003)

Another way in which online learning can be as inflexible and rigid as was programmed instruction comes from the influences of behavioral psychology. Despite the fact that instructional technology has undergone both a cognitive and constructivist revolution since the decline of programmed instruction, instructional technologists are still disposed towards many of the assumptions that influenced behaviorism (Blasi & Heinecke, 2000; Jonassen, 1991). Some online learning reflects the same manifestations of behavioral assumptions as did programmed instruction, such as the idea that students learn only when the course materials lead them to learn, and that the only real learning outcomes are measurable learning outcomes. The designers of these types of courses also act as if all problems should be addressed by behaviorist methodologies, rather than attempting to find the most appropriate techniques for the task at hand.

For example, one of the sample courses offered by the MindIQ Corporation (mentioned previously) is designed to address the problem of sexual harassment in the workplace (Figure 8). While this course appears similar to the History of Rock course in its use of technology and embrace of efficiency, it also illustrates the results of behavioral assumptions, particularly in how the developers of the course redefined the course's learning goals into observable behaviors.

Figure 8. Preventing Sexual Harassment Online Course. Copyright MindIQ Corporation.

One could speculate that to effectively reach the goal of preventing sexual harassment, participants should learn not only what behaviors are acceptable and unacceptable, but they should also experience a change of attitude towards sexual harassment, in effect becoming the type of person that would not want to harass another. Unfortunately, since this course adopts a model of learning that is very reminiscent of programmed instructional materials, it probably does not adequately address the underlying causes of harassment. Similar to the History of Rock course, in each lesson the students read a few short pages about what actions are and are not appropriate, then take a quiz about the material they have read. So while it is likely that students who complete this course may learn to avoid a few behaviors, they probably have not "learn[ed] how to be the thing [the stakeholders] want them to be" (Wilson, 1997).

Since the developers of this course redefined the all of the instructional problems in observable terms, they created a course that avoids some of the real problems in favor of content that is easy to teach and test. In one critique of instruction of this type, a commentator stated, "imagine the difficulty of selling an online travel experience, where you took the vacation from the PC in your living room, rather than boarding an airplane" (Elliott Masie, quoted in Rosenberg, 2001, p. 36). Unfortunately, when courses are designed in this way, they can unintentionally discourage students from being thoughtful about the material being taught. Rather, the design of these courses encourages a superficial approach to the topic, leading to little or no real learning (Davies, 2002).

Learning from Programmed Instruction

Programmed instruction fell out of favor primarily because it was too rigid and inflexible to be widely applied to a variety of instructional settings, yet at the same time promoters of the method attempted to generalize it to as many instructional settings as possible. And, as has been discussed, some applications of online learning closely parallel programmed instruction (Table 1).

Assumption	Example from Programmed instruction	Example from Online learning
Behavioral psychology	Redefinition of the trait of creativity into observable outcomes.	Redefinition of how to prevent sexual harassment into observable outcomes.
Efficiency	The 30-word rule and the 90/90 rule.	Rules dictating how long web pages should be.
Technological determinism	"These machines are a theory of teaching" (Galanter, 1959, p. 1).	"[Internet] technology itself both mandates and assists active learning" (Crane, 2000, p. 10).

Table 1. Parallels Between Programmed Instruction and Online Learning.

To avoid the same fate as did programmed instruction, developers of online learning should plan flexible solutions and more carefully consider how appropriate online methods are to the context for which they are developing. For example, some recent, interesting explorations in online learning investigate how to do this, such as through self-organized learning systems, or by incorporating multiple instructional strategies and methods into learning environments (Levin, Levin, & Waddoups, 1999; Wiley & Edwards, 2002). To help instructional technologists develop these more flexible types of online learning and avoid the rigidity of programmed instruction, I offer a short set of questions that online learning developers can ask themselves about their products (Table 2). These questions are based on the assumptions of programmed instruction and how they contributed to the inflexibility of the movement. I have included the specific assumptions and results which guided me in writing each question after the question, to help the reader refer back to the relevant discussions earlier in the paper.

Question	**Assumption**	**How the Assumption Resulted in Inflexibility**
Does your online course attempt to remove responsibility from the students for their learning?	Determinism	Overly standardized content
Does your online course cater to the "lowest common denominator" (Garner, 1966, p. 11) that students may bring to the situation? Does it suffer from the problem of over-prompting, or similar problems that indicate it does not appropriately challenge students?	Efficiency	Elevation of process over outcomes
Do you feel your online course offers the one optimal path to master the particular subject being taught?	Materialism and empiricism	Overly standardized content
Do your online courses reflect a wide variety of methodologies, depending on the characteristics of the students and the subjects being taught? Or, are practically identical forms and methods used for all?	Efficiency	Elevation of process over outcomes
Do the objectives and content of your online courses reflect the reality of the subject being taught, or do your courses define all objectives in terms are easy to observe, teach, or test?	Materialism and empiricism	Cumbersome and impractical applications
Do your online courses rely on the underlying technology to make up for shortcomings in other aspects of the instructional solution?	Technology	Overly standardized content; elevation of process over outcomes
Do you judge your online courses based primarily on factors like how closely a development process was adhered to, or how strictly they conform to a template, or do you judge them based on their success with students?	Efficiency	Elevation of process over outcomes

Table 2. Questions for Online Course Developers.

In conclusion, I return to my own perspective, as I described it at the beginning of this thesis. As developers of educational solutions, we cannot become so wedded to a process, theory, or method of delivery that we let it get in the way of our ultimate accomplishment—helping another human being learn. I strongly encourage everyone concerned with the improvement of learning to adopt the enthusiasm and excitement held by the proponents of programmed instruction. I also encourage instructional technologists to adopt the attention to excellence that many of developers of programmed instruction showed in their professional practice.

At the same time, I call for today's instructional technologists to be more broad-minded about what makes for an effective instructional experience. Powerful instructional techniques can be found in more places than we might think. If we fail to consider them because of any bias besides the bias toward improving peoples' lives, then we may be setting ourselves up for failure regardless of the logic, theory, or research behind our methods. This is the reason professionals in the field of instructional technology need to understand what assumptions they hold as they develop solutions to instructional problems. They must also be willing to adopt assumptions that let them be flexible in the types of solutions they consider. As this case of programmed instruction shows, refusing to consider other possible approaches increases the likelihood that the solutions will not be applicable beyond a narrow range of possible instructional needs.

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Appendix A: Examples of Teaching Machines and Programmed Instructional Books

Figure 1. A Student Using a Programmed Flipbook. Copyright Educational Methods, Inc.

Figure 2. A Classroom of Students Using Teaching Machines. Copyright National Educational Association of the United States.

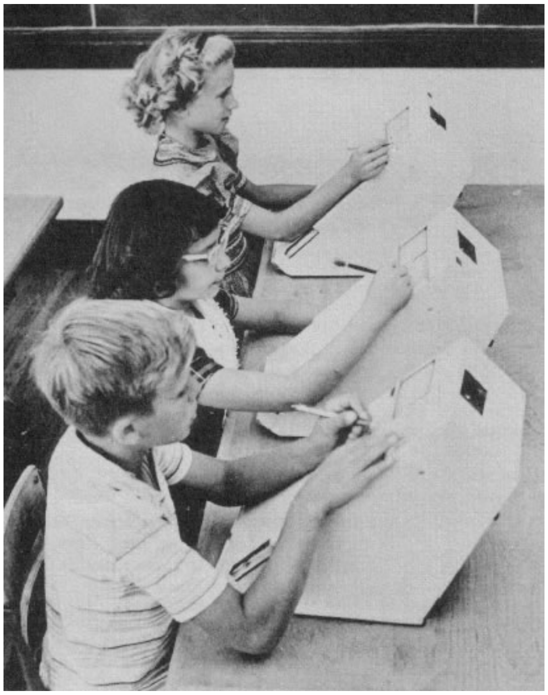

Figure 3. Students Using Teaching Machines. Copyright Sterling Publishing Co., Inc.

Figure 4. A Teaching Machine to Teach the Names of Machine Parts. Copyright Sterling Publishing Co., Inc.

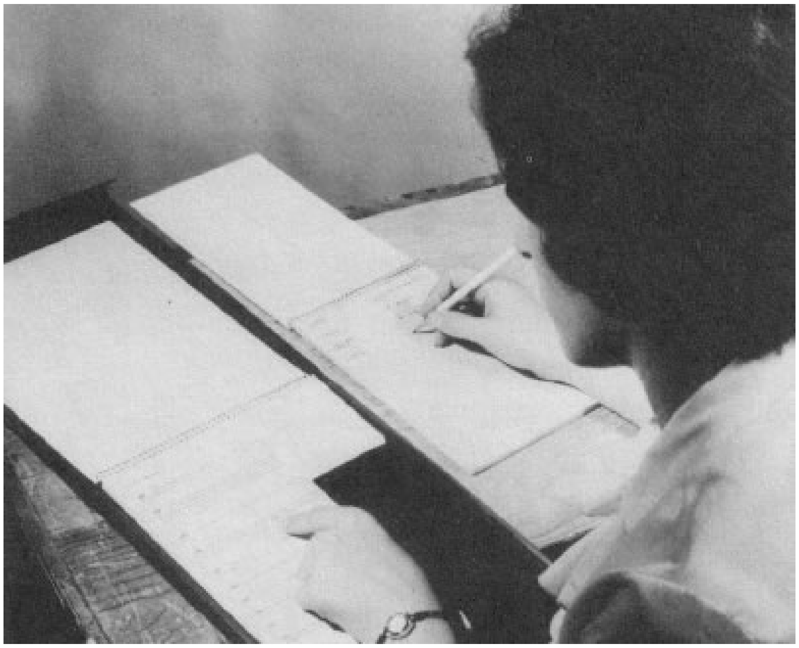

Figure 5. A Programmed Text to Teach Algebra. Copyright Sterling Publishing Co., Inc.

Figure 6. A Man Using a Teaching Machine to Learn Chinese. Copyright Sterling Publishing Co., Inc.

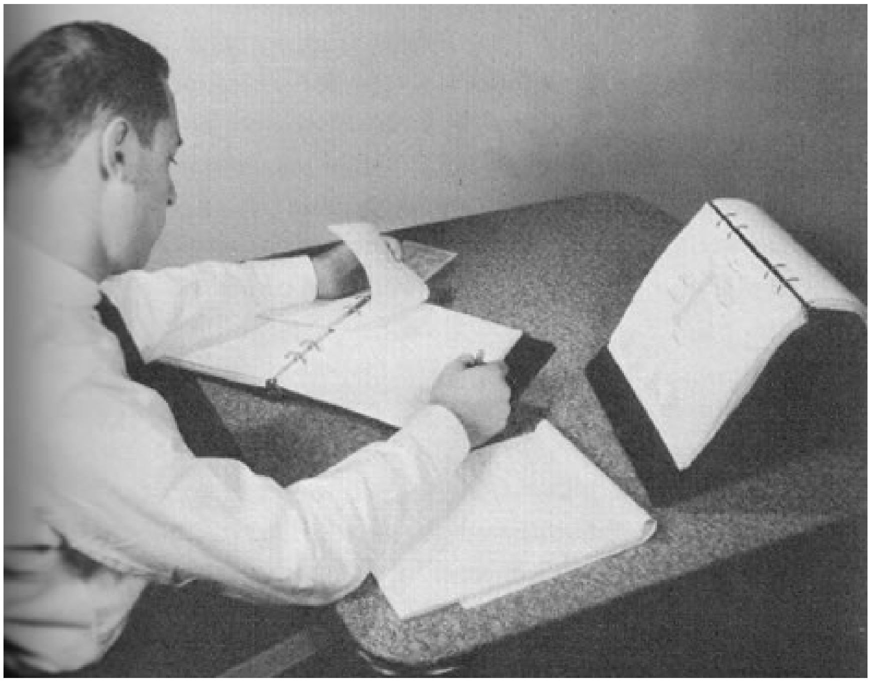

Figure 7. A Student Using a Programmed Book. Copyright Educational Methods, Inc.

Figure 8. A Student Using a Teaching Machine to Learn Music. Copyright Meredith Corporation.

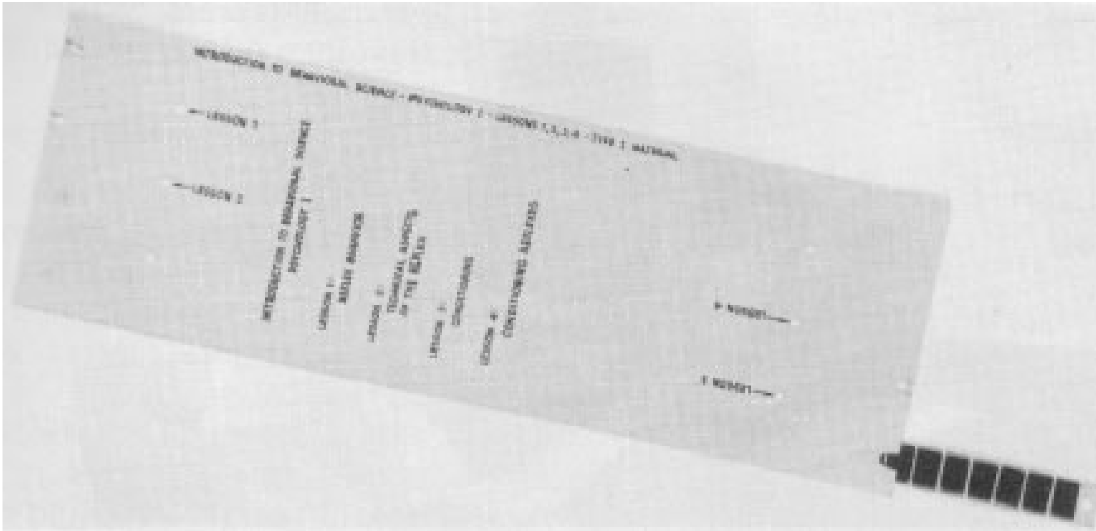

Figure 9. Card Used to Project Programmed Materials onto a Screen. Copyright John Wiley and Sons, Inc.

.

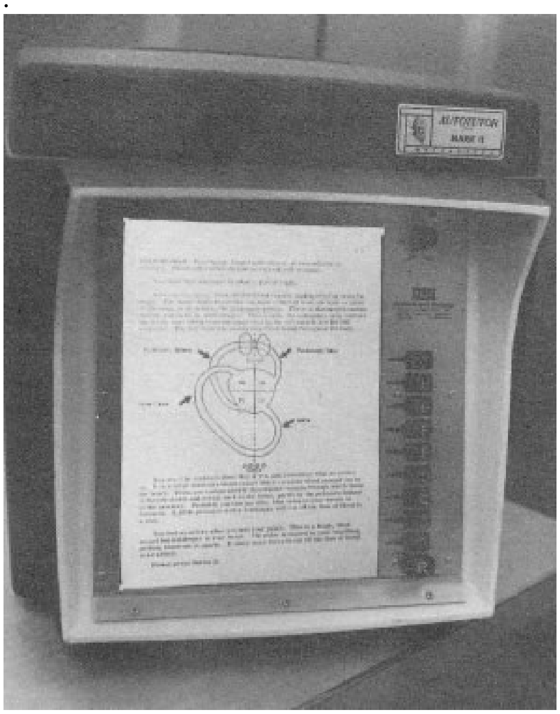

Figure 10. The AutoTutor Mark II Teaching Machine. Copyright U. S. Industries, Inc.

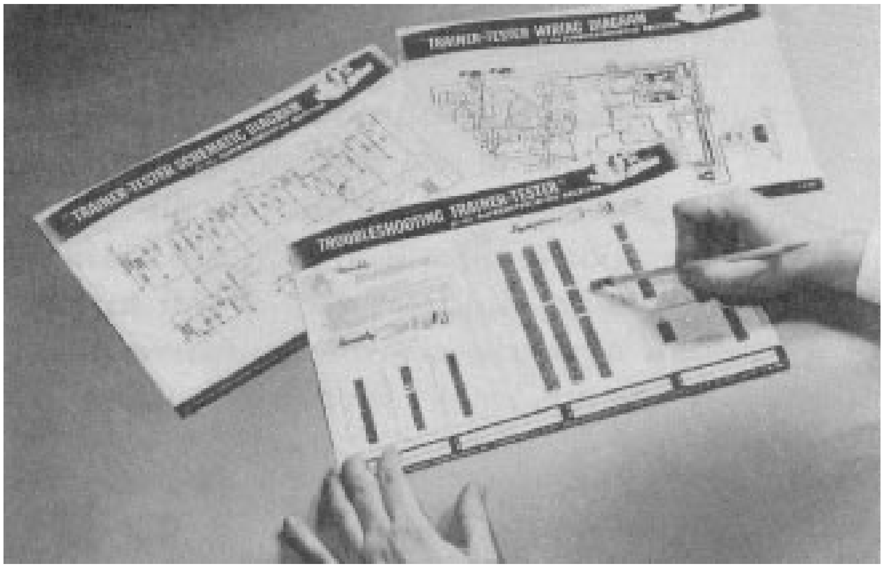

Figure 11. A Programmed Text to Teach Equipment Troubleshooting. Copyright Van Valkenburgh, Nooger and Neville, Inc.

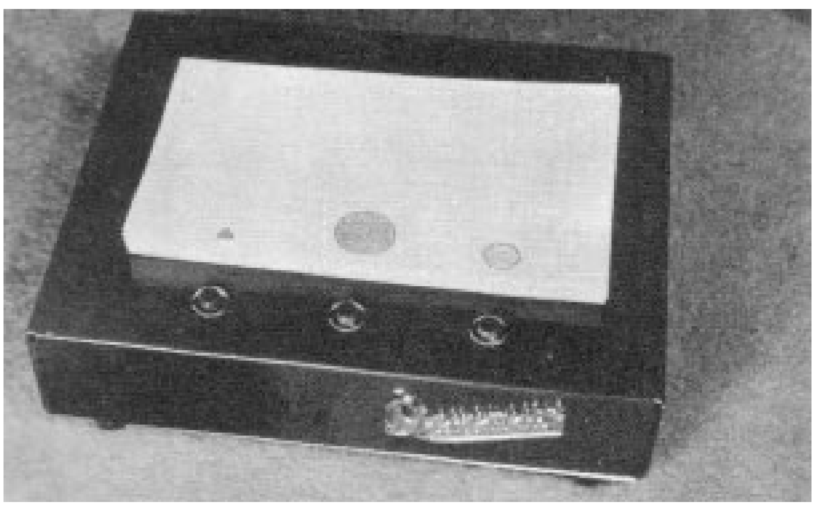

Figure 12. A Teaching Machine for Preschoolers, to Teach Size and Shape Discrimination. Copyright Electronic Teaching Laboratories.

.

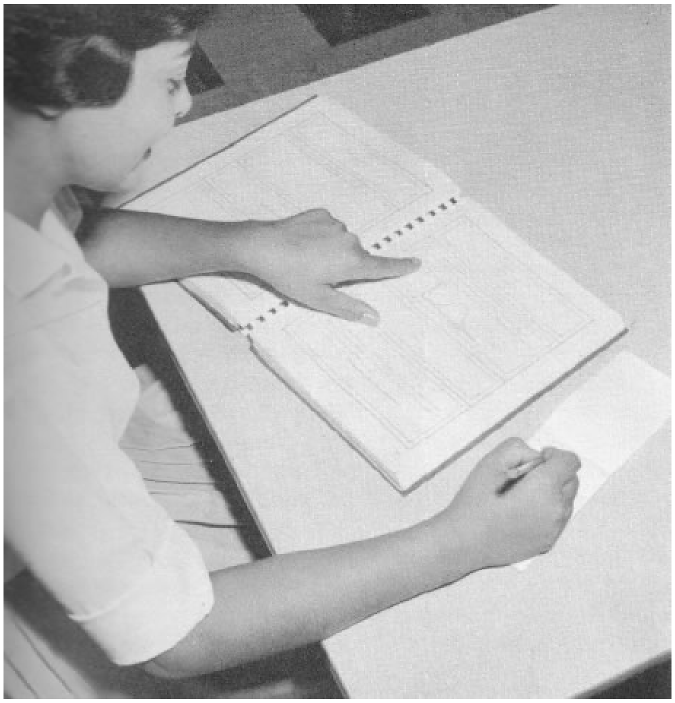

Figure 13. A Student Using a Programmed Textbook in Statistics. Copyright Electronic Teaching Laboratories.

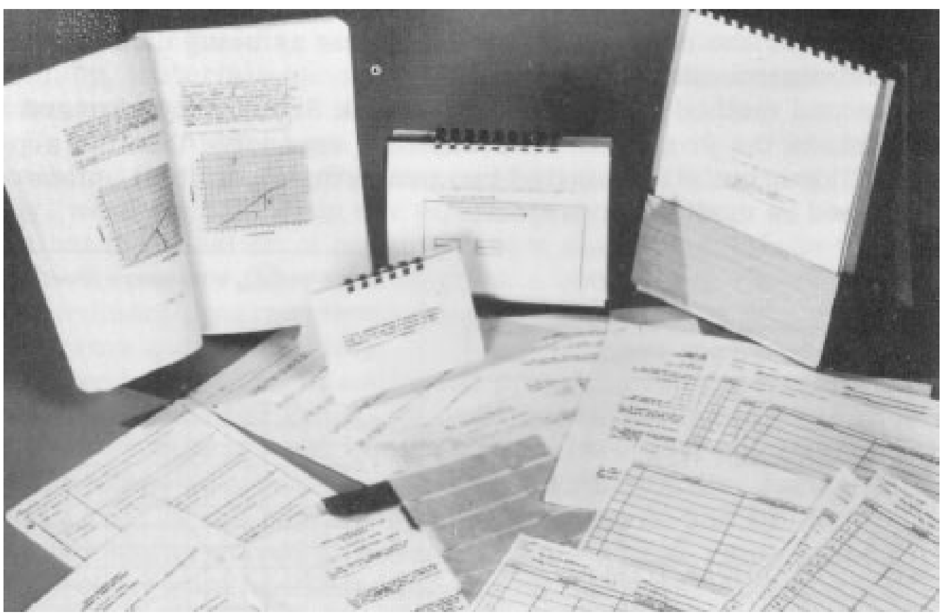

Figure 14. A Variety of Programmed Textbooks Prepared for Industrial Training. Copyright John Wiley and Sons, Inc.

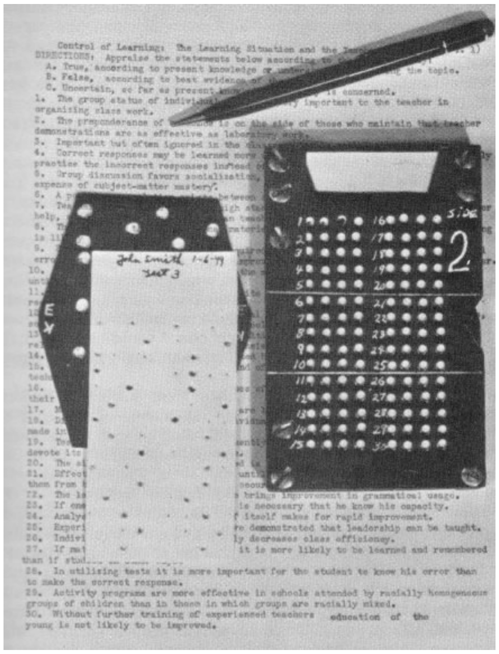

Figure 15. A Punchboard Scoring Device, Developed by Sidney Pressey. Copyright National Education Association of the United States.

Appendix B: Examples of Programmed Instructional Materials

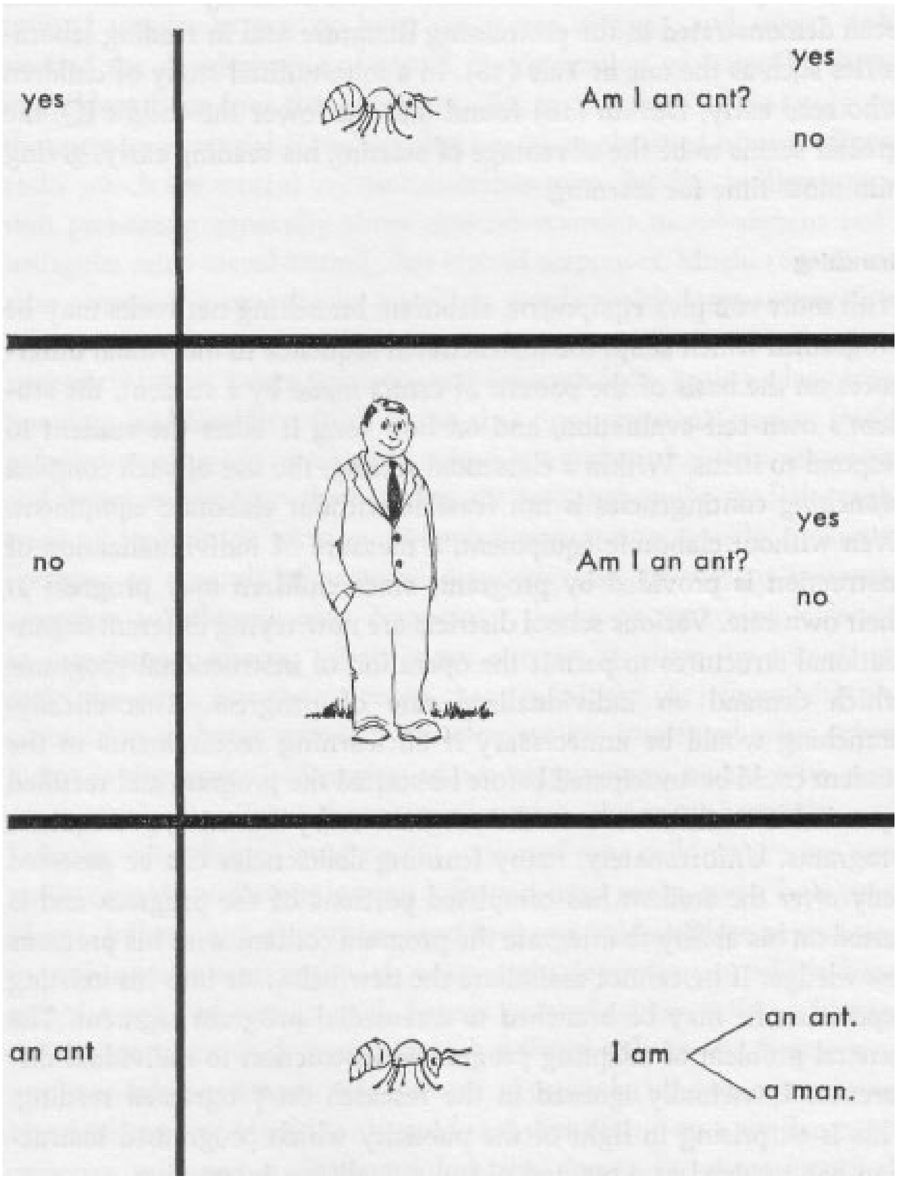

Figure 1. A Page from a Programmed Reading Textbook. Copyright McGraw-Hill Book Company, Inc.

1 Your being born was not a "response-event" for you. That is, it was not an action you initiated. Your throwing your rattle out of your crib, however, was an action initiated by you. It was a "response-event" for you. CHECK each sentence below that describes a response-event for the person or animal named in the sentence (note that there is no limit to the number of sentences you can check):	
☐ a. Clara dyed her hair red.	a
☐ b. Herman died of old age.	
☐ c. The dog has fleas.	
☐ d. The cat meowed.	d

Figure 2. Part of a Program to Teach Behavioral Analysis. Copyright National Education Association of the United States.

1. Manufacture means to make or build. Chair factories manufacture chairs. Copy the word here: _ _ _ _ _ _ _ _ _ _ _ _
2. Part of the word is like part of the word factory. Both parts come from an old word meaning make or build. m a n u _ _ _ _ u r e
3. Part of the word is like part of the word manual. Both come from an old word for hand. Many things used to be made by hand. _ _ _ _ f a c t u r e
4. The same letter goes in both spaces: m _ n u f _ a t u r e
5. The same letter goes in both spaces: m a n _ f a c t _ r e
6. Chair factories _ _ _ _ _ _ _ _ _ _ _ _ chairs.

Figure 3. Part of a Program to Teach Spelling. Copyright B. F. Skinner and Science Magazine.

YOUR ANSWER: If $y = 3(5 + 4)$, $y = 27$
You are correct. The 3 multiplies the entire quantity inside the parenthesis. So, if

$$y = 3(5 + 4),$$
$$y = 3(9) = 27$$

Now, we would get the same result in this case if, instead of adding the two numbers inside the parentheses and then multiplying by 3, we first multiplied each number inside the parentheses by 3 and then added the products together.

$$y = 3(5 + 4)$$
$$y = 3(5) + 3(4)$$
$$y = 15 + 12 = 27$$

In ordinary arithmetic is it always true that, if a, b, and c are numbers,

$$a(b + c) = ab + ac?$$

Yes. **page 121**
No. **page 129**

Figure 4. A Page from an Intrinsic Program. Copyright Sterling Publishing Co., Inc.

1. To "emit" light means to "send out" light. For example, the sun, a fluorescent tube, and a bonfire have in common that they all send out or _______ light.
emit
2. A firefly and an electric light bulb are alike in that they both send out or ______ light.
emit
3. Any object which gives off light because it is hot is called an *incandescent* light source. Thus, a candle flame and the sun are alike in that they both are _______________ sources of light.
incandescent
4. When a blacksmith heats a bar of iron until it glows and emits light, the iron bar has become a(n) _________________ source of light.
incandescent
5. A neon tube emits light but remains cool. Unlike the ordinary electric light bulb, then, it is not an ___________________ ___________ of light.
incandescent source
6. An object is called incandescent when
____.
It emits light because it is hot

Figure 5. Part of a Program to Teach Physics. Copyright Homme and Glaser.

Learning should be fun. However, in the early stages of learning a subject, students often make many errors. Most people (do/do not) like to make errors.
do not
When a student makes many errors in learning, he often decides that he does not like the subject. He would be more correct to decide that he does not like to make _________.
errors
For a long time, educators, psychologists, and people in general through it was impossible to learn without making a large number of errors. In fact, they even had a name for this kind of learning. They called it "trial-and-_____" learning.
error
Recent developments in the psychology of learning have cast serious doubts as to the necessity of "trial-and-error" learning. If the learning material is carefully prepared, or PROGRAMED, in a special way, the student can master the subject while making very few errors. The material you are reading right now has been prepared, or ____________ in this special way.
programed

Figure 6. Part of a Program to Teach Programming. Copyright Teaching Machines Incorporated.

Frame	Answer
1. The important parts of a flashlight are the battery and the bulb. When we "turn on" a flashlight, we close a switch which connects the battery with the _______.	bulb
2. When we turn on a flashlight, an electric current flows through the fine wire in the ______ and causes it to grow hot.	bulb
3. When the hot wire glows brightly, we say that it gives off or sends out heat and ______.	light
4. The fine wire in the bulb is called a filament. The bulb "lights up" when the filament is heated by the passage of a(n) ______ current.	electric
5. When a weak battery produces little current, the fine wire, or _________, does not get very hot.	filament
6. A filament which is *less* hot sends out or gives off _______ light.	less

Figure 7. Part of a Program in High School Physics. Copyright Sterling Publishing Co., Inc.

10. Most employees contribute part of their salary for insurance. The Federal Government provides insurance for an employee in the Fed___ Ins_____ Contributions Act. (Complete the words)	10. Federal Insurance
11. Federal insurance is financed partly by employees. The Congressional Act establishing this insurance is called the F_______ I_________ C________ Act. (Complete the words)	11. Federal Insurance Contributions
12. "Social Security tax" is a common non-technical term for F.I.C.A. tax. What act establishes this tax?	12. Federal Insurance Contributions Act.

Figure 8. Part of a Program in Business Mathematics. Copyright John Wiley and Sons, Inc.

Frame 1	
The 7070 is a data processing system. To prepare a payroll, to maintain an inventory, or to perform other accounting applications, a customer can use the 7070 data __________.	PROCESSING SYSTEM
Frame 2	
All data processing systems require some type of input unit or units. In order to put information into the 7070 ___________, and ______ unit is required.	DATA PROCESSING SYSTEM INPUT
Frame 3	
In addition to one or more input units all data processing systems require some sort of processing unit or units to operate on the input data. The 7070 has several _________ units to process input data.	PROCESSING
Frame 4	
Data are put into the 7070 by means of an _______ unit. The information (data) is then operated upon by several ____________.	INPUTS PROCESSING UNITS

Figure 9. Frames from a Program to Teach the IBM 7070 Data Processing System. Copyright IBM Corporation.

The way to write an objective which meets our first requirement, then, is to write a statement describing one of your educational intents and then modify it until it answers the question, "What is the learner DOING when he is demonstrating that he has achieved the objective?" Let's apply this test to some examples. Which of the following objectives would you say is stated in behavioral, or performance, terms? *To develop an appreciation for music……………………………………….turn to page 15.* *To be able to solve quadratic equations……………………………………..turn to page 16.*

Figure 10. Part of a Program to Teach the Writing of Performance Objectives. Copyright Fearon Publishers, Inc.

(Frame 1) The prefix "kilo" means 1,000. Since this is the case, a kilogram is _____________ grams.
(Confirmation) 1,000
(Frame 2) If 1,000 grams equal one kilogram, then 5,600 grams equal 5.6 ______________.
(Confirmation) kilograms

Figure 11. Two Frames from a Program to Teach the Metric System. Copyright Fearon Publishers, Inc.

1. A conductor will carry electric current. A Wire or any substance that will carry or conduct an electric current is called a ________________.	conductor
2. A copper wire will conduct or carry an electric current because copper wire is a good _____________.	conductor
3. A conductor is a substance that will carry or _________ an electric current. Rubber is not a conductor, so rubber will not __________ an ____________________.	conduct conduct electric current
4. An insulator will not conduct an electric ___________. Rubber is a good _________ because it will ________________. (complete)	current insulator not conduct an electric current (or) not conduct current
5. Electric current can flow or travel along a ____________, but cannot flow along an ____________.	conductor insulator

Figure 12. Part of a Program in Physics. Copyright Prentice-Hall, Inc.

YOUR ANSWER: The rule won't work in this case. Courage! The division rule got us through b^0, where m = n, and it will get us through the case where m is smaller than n. In this case we have $b^2/b^3 = ?$ and applying the rule $b^m/b^n = b^{(m-n)}$ we get $b^2/b^3 = b^{(2-3)}$. So the exponent of our quotient is (2 – 3) which is -1, isn't it? So just write $b^2/b^3 = b^{(2-3)} = b^{(-1)}$ as if you knew what it meant. Now return to Page 101 and choose the right answer.

Figure 13. Page from a Text in Mathematics. Copyright National Education Association of the United States.

A collection of dishes can also be called a set of dishes. Several crayons can be called a ____ of crayons. Response: set
Every member of the set of crayons is called an element of the set. Every member of the set of dishes, similarly, would be called ___________. Response: an element
In general, the members of a set are called its _______________. Response: elements
A collection of elements is a ___________. Response: set
Make a sentence using the words **set** and **element**. Response: A set is defined as a collection of elements.

Figure 14. Frames from a Program to Teach Mathematics. Copyright Addison-Wesley.