
Teacher Adoption of Technology: A Perceptual Control Theory Perspective.

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There is an ironic and costly contradiction in the attempt to integrate technology into education. While evidence of the educational benefits of technology abounds and investment in hardware and software has dramatically increased, relatively few teachers use technology regularly in their teaching and the impact of computers on existing curricula is still very limited. What lies behind this contradiction? Why don't teachers make wider use of instructional technologies?

In this article we introduce a novel model of goal-oriented behavior, Perceptual Control Theory (PCT), as a framework for understanding teacher adoption of technology. Unlike other approaches that examine this issue by studying the external environment, this new framework attempts to understand teacher adoption of technology from the inside. It considers teachers' use of technology by examining the goals of teachers and how the use of technology might help or hinder their goals. While it is too early to provide systematic findings to show the usefulness of this application of PCT, we have used it here to interpret and synthesize the findings of a number of studies on teachers and technology. We also make suggestions derived from this model for the infusion of technology into schools.

To summarize the major themes, in order to understand why and why not teachers use technology, we must look at teachers as goal-oriented, purposeful organisms. PCT provides a comprehensive model for understanding technology infusion. From a PCT perspective three conditions are necessary for teachers to use technology:

1. The teacher must believe that technology can more effectively meet a higher-level goal than what has been used.
2. The teacher must believe that using technology will not cause disturbances to other higher-level goals that the he or she thinks are more important than the one being maintained.
3. The teacher must believe that he or she has or will have sufficient ability and resources to use technology.

There is an ironic and costly contradiction in the attempt to integrate technology into education. While evidence of educational benefits of technology abounds (Bialo & Sivin-Kachala, 1995; Education Week, 1997; Fletcher, Hawley, & Piele, 1990; Garner & Gillingham, 1996; Kulik & Kulik, 1991; McKinsey Inc., 1996; Means, 1994; Office of Technology Assessment, 1982, 1995; Wenglinsky, 1998)) and investment in hardware and software has dramatically increased (Mageau, 1991; Heaviside, Riggins, & Farris, 1997), relatively few teachers use technology regularly in their teaching (McKinsey, 1996; OTA, 1995) and the impact of computers on existing curricula is still very limited (David, 1994; Education week, 1997; Harper, 1987; OTA, 1995). What lies behind this contradiction? Why don't teachers make wider use of instructional technologies?

Interestingly, in spite of the widespread recognition of the underutilization of technology and the central role of teachers in the effective use of technology (Cuban, 1986; Education week, 1997; Harper, 1987; Luke, Moore, & Sawyer, 1998; McKinsey, 1996; OTA, 1995; Wenglinsky, 1998), "there has been relatively little research on how and why American teachers use technology" (OTA, 1995, p. 51). There is even less research on why teachers do not use

technology. Most research about educational technology has focused on the impact of technology on learners. The few studies conducted on teachers have typically focused on a special subset, the successful "accomplished" technology users (Sheingold & Hadley, 1993), rather than the majority, those who do not use technology.

The lack of empirical studies notwithstanding, a set of assumptions about why teachers do not use technology does exist and is currently functioning as the theoretical base underlying many efforts to help teachers integrate technology with their teaching (Charp, 1995; Lauro, 1995; Persky, 1990; Sammons, 1995; Strudler, 1994). Lack of suitable training, technical and administrative support, and systemic incentives (e.g., tenure and promotion), traditional pedagogical beliefs, and resistance to change are among the most widely held ones (see OTA, 1995). Therefore, in order to help more teachers use technology in their teaching, educational institutions at all levels have begun to invest in providing sufficient professional development opportunities for teachers to develop technical skills while enhancing access to technological resources.

These assumptions, while rightly recognizing the complexity of the issue by casting a net to capture as many contributing factors as possible, present a number of puzzles and potential problems. Most notable perhaps is the assumption that the lack of teacher involvement in technology has been caused by the lack of suitable training and thus providing more opportunities to develop technological skills to teachers will lead to more technology integration. While at first consideration this may seem quite reasonable, upon closer examination this assumption becomes problematic. The assumed direction of the relationship between use of technology and training could be just the reverse. In other words, it would be as reasonable, if not more so, to assume that teachers did not want to receive training in technology because they saw no need to use it. It may be that in response to teachers' needs (or lack thereof), the teacher preparation system did not provide training opportunities. Or when training was provided, the teachers, not considering using technology, did not take the opportunity to develop the needed skills. At least two pieces of evidence can be used to support this interpretation. First, the "successful" technology users are not necessarily more technically competent nor have access to more resources (technical, financial, or time) than others to start with. The pioneers have often been described as "adventurous," working well in advance of significant support from the system (e.g., see Garner & Gillingham, 1996) by digging deeply into their own pockets and schedules (Schrum, 1995). While there is little empirical research on how the pioneers started, anecdotal evidence and personal experiences suggest that the pioneering users had to not only seek ways to develop their expertise with their own resources, but also fight with the administration or their colleagues for permission to use technology. Indeed, none of the usual assumptions made can adequately explain this.

Another piece of evidence that supports the counter argument to the assumption that lack of preparation causes lack of teacher adoption of technology is that some teachers who are provided both the expertise and equipment refuse to use technology. For example, one high school teacher, who did not use the computer he had been given for his class of gifted and talented students, explained, "It didn't do anything I couldn't do easier and cheaper on the blackboard" (OTA, 1995, P. 134). A home economics teacher in that same high school stated, "If I could see a really good use for a computer I would use one...but I have yet to think of anything I could do on a computer that I cannot do by myself just as well" (OTA, 1995, p. 134).

Evidently, this assumption cannot adequately explain the aforementioned data. So more factors are included and more assumptions generated. In this case, it is assumed that these two teachers needed more training on the "usefulness" of technology to help them understand what technologies can do (OTA, 1995). This is a great assumption but the only problem here is that what the trainer considers "useful" might not be viewed "useful" by the teacher. What the technologies can do in the mind of the trainer or workshop organizer could be just what the teachers oppose. As an example, when the first author was working as the coordinator of a language learning center, he demonstrated the usefulness of a Spanish spell-checking and thesaurus program hoping that the Spanish instructors would at least encourage their students to come to the center to use it. But before the demonstration was over, three of the four instructors asked that their students not to be allowed to use the program because "it

would make them lazy."

The other assumptions are similarly problematic. What is missing in these assumptions is the recognition of teachers as active, goal-oriented living organisms. Although some of the current assumptions take into consideration teachers' pedagogical beliefs (Cuban, 1994), attitudes toward technology, and understanding of technology, the essential logic underlying these assumptions is that the lack of teacher use of technology is caused by the lack of a conducive environment to technological integration. Therefore, by creating a better environment (more workshops, on-site technical expert, more computers, and rewards to technology users), all teachers will eventually use technology in their teaching. As good as it may sound, this if-you-build-it, they-will-use-it approach would not work for the high school geometry teacher who said:

I'm the old-fashioned type-after so many years, you build up a file on your subjects...For me to go into teaching [with] computers...I would have to start over. I would have to actually sit down and work everything out, and it would require a lot more work on my part to run a class the way I want it run...I just don't want to do it...Don't want to change. (OTA, 1995, p. 132)

The failure to recognize teachers as purposeful human beings whose behaviors are goal-oriented makes it impossible to really understand why under the same circumstances, some teachers would spend their own money to bring computers to their classrooms (Garner & Gillingham, 1996) while others would not use the computers given to them (OTA, 1995) or intentionally miss the time slots assigned for their students to work in the computer lab (Griffith, 1993). To understand why the same demonstration would turn some on and others off, we must look at the perceptual world of the teachers. This paper presents such a framework that attempts to look at teacher adoption technology from the inside. Based on PCT, this framework examines this issue by considering the goals of teachers and how the use of technology might help or hinder their goals.

The remainder of this paper is divided into three sections. The first section presents a brief introduction to PCT. The second section delineates a framework for understanding teacher adoption of technology from the perspective of PCT. Findings of a number of studies will be drawn on to demonstrate the potential of this framework. The last section discusses the implications of this framework for designing and implementing projects to help teachers adopt technology. Findings from a number of studies are used to illustrate the usefulness of these implications.

UNDERSTANDING PURPOSEFUL BEHAVIOR: PERCEPTUAL CONTROL THEORY

PCT is a model of behavior based on control theory (for details of the theory see Powers, 1973, 1989). Essentially, PCT maintains that human beings, and all other living organisms control perceptual input, or reference condition, not motor output. In other words, they have internal goals which they strive to meet. As control systems, human beings act to keep their perceptions matching these reference conditions-what they think it should be. They do this by acting on the environment, producing effects which, when combined with prevailing disturbances from the environment, produce the desired perceptions. Human goals are hierarchical. In order to maintain a higher-level goal, it is necessary to vary lower-level goals. In other words, lower-level goals serve as means to achieve higher-level goals (Cziko, 1995; Marken, 1989; Powers, 1989). A rather simple example of a control system with which many readers may be familiar is the cruise control system, and this example will be used here to introduce the basic properties and functioning of a control system.

The Control System

A cruise control system on a car is used to keep the car moving steadily at a speed set by the driver. When engaged, the cruise control system will increase or decrease the amount of fuel it delivers to the engine as needed to maintain the desired speed. Figure 1 depicts the basic structure of a control system. At the top of the figure is a box labeled "goal" which supplies the reference condition representing the system's goal state to the loop below (say, a speed of

55 miles per hour). This reference condition is compared to the current sensor signal (say, 45 miles per hour) in the comparator where the latter is subtracted from the former (55-45). This comparison results in an error signal (10) which is used to determine the amount of output (behavior) of the system needed to correct the signal in order to maintain the goal (55 miles per hour). This action affects the input (the sensed speed) through the feedback loop in the environment which is being continuously compared to the reference condition. This process takes place as a continuous loop of sensing, comparing, and acting with all three processes occurring simultaneously. However, the action of providing the calculated amount of fuel will not have a completely predictable effect on the sensed speed (the input) because environmental disturbances which are not under the control of the system (e.g., condition of the road, wind directions, tire pressures, etc.) will also influence the speed of the car. Also the output of the cruise control system will affect other variables (e.g., engine temperature, noise, and vibration), which are not under the control of the system.

A cruise control system shares a number of characteristics with all control systems. First, a control system does not control what it does, it controls what it senses, control meaning to maintain some sensed variable at or near a specified reference condition (representing a goal) despite the influence of environmental disturbances that would otherwise cause the sensed variable to vary. The system can only control what it senses to be the speed of the car and it does so by changing its output as required. As a result, the use of a cruise control system allows one to fairly accurately predict how long it will take to cover a certain distance, but not how much fuel it will take to get there since fuel is not under control, varying as it must to compensate for unpredictable disturbances met along the way. Since a control system controls what it senses and since an organism's sensing of the environment is generally referred to as perception in psychology, the application of control theory to the behavior of living organisms is now referred to as Perceptual Control Theory to distinguish it from the control theory applied by engineers and physicists to non-living control systems such as the cruise control system.

Second, a control system's behavior is clearly influenced by its environment, but its behavior is not determined by its environment. Instead, its behavior is a function of what it perceives (senses) compared with its internal goal, which can change over time. Here lies the crucial difference between living organisms and engineered control systems. While engineered control systems are often designed so that their goals can be manipulated by the operator, it is usually impossible to directly manipulate the goal of a living control system. We can certainly ask a teacher to use computers in her teaching or to attend a workshop on instructional technology, but we can never be certain that another person will comply with our wishes and actually behave as requested.

Finally, the relationship between perception (input) and behavior (output) is what Runkel (1990, p. 92) has referred to as "circular causation" with neither the perception nor the behavior serving as the independent variable since each influences the other reciprocally and simultaneously. In other words, while perception influences the responses in a control system, the system's response also influences its perception. Therefore, what ultimately determines how the system behaves is the reference condition (which in living organisms can be considered a perceptual preference), not the perception or the behavior.

This model of behavior is consistent with the purposeful, closed-loop nature of behavior noted long ago by William James and John Dewey. Just at the dawn of so-called scientific psychology, William James (1890) pointed out that living organisms differ from other kind of nonliving objects in one crucial respect: they produce consistent ends by variable means:

Romeo wants Juliet as the [iron] filings want a magnet; and if no obstacles intervene he moves toward her by as straight a line as they do. But Romeo and Juliet, if a wall be built between them, do not remain idiotically pressing their faces against its opposite sides like the magnet and the filings with [obstructing] card. Romeo soon finds a circuitous way, by scaling the wall or otherwise, of touching Juliet's lips directly. With the filings the path is fixed; whether it reaches the end depends on accidents. With the lover it is the end which is fixed, the path may be modified indefinitely (1890, p. 7).

Dewey made similar observations in an essay published six years later in 1896. Questioning the then-emerging analysis of behavior in terms of stimulus-response connections, Dewey noted that instead of a one-way causal connection from stimulus to response.

What we have is a circuit, not an arc or broken segment of a circle. This circuit is more truly termed organic than reflex, because the motor response determines the stimulus, just as truly as sensory stimulus determines movement. Indeed, the movement is only for the sake of determining the stimulus, of fixing what kind of a stimulus it is, of interpreting it (1896, p. 363).

The understanding of how a rudimentary control system functions already provides some insights into understanding human behavior, but it is not complete. For a more complete, adequate account for the complex goal-oriented human behavior, such as teachers' using technology or Romeo's encounter with Juliet, we will need to consider a hierarchy of perception and control.

A Hierarchy of Perception and Control

What we have seen in the cruise control system example would probably be called a "homeostatic" system, a system that maintains a one-dimensional variable at a constant level matching a fixed reference condition. This system might behave very energetically as disturbances come and go, but the result of its action would be an outcome that is held constant. While it should be clear that the control system's action focuses on keeping its own perceptual signal matching its perceptual preference, it is not clear what specifies the value of that reference condition, which as discussed earlier can vary as well.

Let's return to the cruise control system example again and see how it is used in a concrete example. This time let's put a human driver in the picture. The cruise control system, while able to accurately maintain a steady speed once activated, cannot by itself determine what this speed should be nor can it vary this speed to comply with varying traffic and road conditions. It is the human driver who decides whether to turn it on and what the desired speed should be. This is an example of a hierarchy of control whereby the reference conditions of any one control system are determined by the goals and subsequent output of higher levels in the hierarchy. In this example, the reference condition of the cruise control system is supplied by the driver, whose goal, in normal situations, should be more than maintaining a steady speed. We might assume that she has the goal of getting to her workplace as fast as safety and legal considerations permit and that this takes precedence over maintaining a constant speed of 55 miles per hour. In order for the driver to maintain her higher-level goal of perceiving herself as driving safely and legally, she will need to vary the lower-level goal of driving speed.

In fact, in order to maintain this higher-level goal, the driver needs to vary not only the speed, but also other lower-level goals such as the position of the steering wheel and even the route she takes. That is, to maintain a higher-level goal in a hierarchy of control might require varying the reference conditions (goals) of multiple lower-level control systems. These goals could be either compatible with or irrelevant to each other. Varying one goal does not necessarily affect the control of another. But sometimes these goals are related. In other words, the act to maintain one goal can function as a disturbance to another one, necessitating action on the other system. For example, the goal of maintaining a certain speed can affect the goal of staying in the center of the lane. When the driver needs to make a turn, she has to vary the speed. But since both lower-level goals are subject to the higher-level goal of driving safely and legally, they are not necessarily in conflict with each other.

Nevertheless, it is quite possible that varying a lower-level goal to maintain a higher-level goal may disturb other higher-level goals. In this case, one needs to decide which of the higher-level goals is more important. The importance of a goal is often determined by its capacity in maintaining even higher-level goals. Staying with the driving example, we can add another level of goal in addition to the one of driving safely and legally. At this level, her goal is to get to her workplace on time. Because of a snowstorm, she needs to dramatically lower her speed

in order to maintain the goal of driving safely, which makes it impossible for her to arrive at her office on time. Conversely, in order for her to maintain the goal of arriving on time, she will have to ignore her goal of driving safely. In this case, she will need to decide which is more important.

The concept of a hierarchy of perception and control reveals the other source of error signals in a control system. Recall that a control system acts to compensate for disturbances in order to maintain its reference condition since environmental disturbances would otherwise cause the perceived input to depart from the reference condition. In a hierarchy of control, a higher-level goal causes a lower-level reference condition to depart from the sensed input as well. Thus there are two sources of reasons for a lower-level system to vary its behavior: environmental disturbances and higher-level goals. In the cruise control system example, while road conditions cause the system to vary the amount of fuel delivered to the motor, variation of the goal speed (as a result of the driver's perception of driving safely and legally) has similar effects on the system.

Powers has conceptualized an 11-level hierarchy of human control systems which are labeled (from the bottom up): intensity, sensation, configuration, transition, event, relationship, category, sequence, program, principle, and systems concept. (Since space limitations do not allow a complete discussion of these levels, interested readers are referred to Powers, 1979, 1989). Such a hierarchy of goals and control systems provides a useful framework for pursuing answers to the question of why some teachers do and do not use technology. The following section examines the issues of teacher adoption of technology within this framework.

THE INTEGRATION OF TECHNOLOGY: WHY AND WHY NOT?

To apply PCT to understanding teacher uses of technology, teachers, as all living organisms, are considered to have a hierarchy of goals. They vary lower-level goals to attain higher-level ones. Technology can be viewed as a possible means to achieve goals at a higher level. What then determines whether or to what extent a teacher uses technology in her teaching? Answers to this question can be pursued by examining three aspects of teachers' perceptions of technology in relation to their hierarchy of goals.

The Effectiveness of Technology in Maintaining Higher-Level Goals

PCT argues that human beings vary means to produce consistent ends. When there is a discrepancy between the reference condition (goal) and the perceived state of the controlled variable, means are varied to reduce the discrepancy to regain the desired control. In other words, no action will be taken if there is no error signal in the system. For the purpose of discussion, let's assume a teacher has the goal of delivering quality instruction to his students. One reason for him to start thinking about using technology might be that he feels that somehow his teaching can and should be improved. If he perceives that his instruction is excellent, his perceived input matches his reference condition (goal), he will not change anything he is currently doing.

As discussed before, an error signal results from comparing the perceived input with the reference condition. Thus, either a change in the reference condition or perceived input due to environmental disturbances will result in a discrepancy between the reference condition and perceived input that calls for the system to act. In this case, such a discrepancy could occur when the teacher raises his standards for good teaching (perhaps as the result of reading a book, attending a workshop, or serious reflections on his teaching). It could also take place when more and more students fall asleep or otherwise appear disinterested during the class periods, students' evaluation becomes more and more negative, or the school starts to reform the curriculum. For whatever reason, the teacher realizes that what he has been practicing for however many years no longer sufficiently maintains his goal. He needs to vary his teaching practices.

While for a cruise control system, there are only three possible variations of behavior-- increase, decrease, or maintain the same amount of fuel delivered to the motor--there are far

more choices for a teacher to improve his teaching. These choices are influenced by the goal and lower-level control systems. Let's assume that the teacher reads a book about teachers using the Internet in their teaching whose students are learning much more than in traditional classes. So he realizes his teaching can actually be much better than he has believed. His definition of good teaching has changed from delivering excellent lectures to encouraging student-centered collaboration. To maintain this newly set reference condition, he needs to vary his teaching practices.

Finding key-pals (the Internet equivalent of pen-pals) for the students and having them work collaboratively with students in other schools, as one of the teachers in the book did, is certainly an option. Having the students work on a project and publish the results on the Web is another. Since his goal is to encourage student-initiated learning, not using the Internet, having students writing essays collaboratively would also help to maintain the goal. Of course there are many more options assuming the teacher is creative and experienced. Faced with these possible options, the teacher needs to make a decision on which one he should pick. Unlike the much simpler cruise control system, the choice is often not very clear. However, the criterion for selection is essentially the same: the availability (discussed below) and effectiveness in maintaining the goal. For the cruise control system, when a decrease in speed is sensed, the most effective way to act is to increase the amount of fuel, so it does and the goal is maintained. The teacher needs to make exactly the same decision based on the effectiveness of the possible variation.

The effectiveness of a possible variation is the result of a series of vicarious trial-and-error (Cziko, 1995, p. 140) or to use Powers' (1989) term "imagination connection" (p. 277) based on his knowledge of and experience with each particular choice. That is, because a human being can think abstractly, he does not need to physically act on the environment to see the result. The teacher applies the different variations to the situation in his mind to see if one better achieves the goal than others.

The perceived effectiveness of a possible lower-level control system is an important parameter in this model not only because it decides whether it is selected to achieve a higher-level goal, but also because it can often act as a disturbance causing the individual to change. In the hierarchy of control, as discussed earlier, there are often more than one lower-level systems that can be varied to maintain higher-level goals. These systems can differ in terms of their effectiveness in maintaining the higher-level goal, in terms of factors such as speed and overall quality. A cruise control system can be used to maintain a steady speed; so can a human driver. But in terms of accuracy and the amount of disturbances caused to other higher-level goals (to be discussed below), a cruise control system will usually do a better job. So it is selected over a human driver on a highway when traffic is light. However, it is less flexible, thus in heavy traffic, the human driver takes over. Thus when a new, more effective lower-level control system is available, it presents a disturbance to a higher-level system that is often in search for better control.

Therefore, the knowledge that technology can more effectively maintain a current reference condition can create an error signal in the system. A teacher may start to think about using email not necessarily because she has decided to change her pedagogy, nor because her students ask her to do so, but rather because she finds email enables her to collect and give feedback to students' essays faster and she does not have to carry stacks of paper around the building. In fact, many teachers use technology for the reason that it maintains the current goal more effectively than the traditional method rather than that it helps to maintain a new goal (Olson, 1995). Since technology use is at a lower-level of the hierarchy than pedagogical beliefs and teaching approaches, and because lower-level goals are easier to vary, it is no surprise that many teachers adopt technology without changing their pedagogy (Bruce, Peyton, & Batson, 1993; Veen, 1995). Although this practice has been seriously criticized recently (Means, 1994; OTA, 1995), it should be encouraged if we are to promote the use of technology among teachers. We will return to this point later.

Potential Disturbances to Other Goals

While the perceived effectiveness of a system is an important consideration, perceived possible disturbance to other goals is another one that influences teachers' decision about using technology. As previously discussed, a control system's actions on the environment can have side effects. A cruise control system, while varying the amount of fuel provided to the engine in order to maintain a steady speed, varies engine noise, temperature, and vibration. While these variables are not under the control of the cruise control system, they can cause disturbance to other systems, which may result in action on the current control system. For example, if the driver dislikes noise and yet the engine noise is very high when the cruise control system increases fuel to the motor while climbing a steep hill, the driver may decide not to use the system. Similarly, using technology can have side effects on other higher-level goals unrelated to the desired one.

Let's return to the example of the teacher who has started to think about changing his teaching. He is thinking about using email, the Web, or just in-class collaboration. After considering the effectiveness of all three options (assuming all are available), he ranks them (in order of perceived effectiveness): publishing on the Web, email collaboration, in-class collaboration. But he eventually decides to use in-class collaboration without involvement of any technology instead of the more effective Web or email solution. Why? Simply because it is easier.

"Easier," interpreted within the current framework, means two things. First, it causes less disturbance to other goals, and second, it requires less resources, which may be used to maintain other goals. For a teacher, delivering quality instruction is not the only goal she wants to maintain. In addition, there are many other goals she needs to control. For instance, she may want to be seen as a competent teacher, an intelligent person, the authority of knowledge, a humanist instead of a computer nerd. At the same time, she is working on an article for a journal. She is also the mother of a newborn baby. Using either email or the Web requires her to deal with computers, about which she is not particularly confident although she has been using email and surfing the Net. She is afraid that she might not know enough to answer the students' questions, which would disturb her goal of maintaining the image of being competent and knowledgeable.

Moreover, using email or the Web would require her to spend more time learning the technology, which she needs to spend with her new baby and on her article. Moreover she is concerned that the parents might be upset if the students, as she has heard from other teachers, are exposed to indecent materials on the Web. After weighing these possible side effects of using the more effective means, she decides to use the less effective one because it does not cause as much disturbance to many other important variables.

In reality many teachers do not use technology for just this reason. As one teacher said:

You can't have trouble or be messing with the machine in front of a class. It may be due to my lack of confidence, but I have to be comfortable with it if I'm going to use...My computer phobia, I'm actually over that. I'm not afraid of using the machine anymore, like I was, but I am afraid of how they [the students] might react (Allum, 1991, p. 185).

So, for various reasons, using technology may create more disturbances for many teachers than not using technology. In addition to being afraid of "looking like a fool in front the students," using technology may also require pedagogical changes, which could be a disturbance to many teachers who do not share the same philosophy embedded in the changes. For instance, the use of technology often means more individualized, student-centered classrooms in which teachers are no longer the sole source and authority of knowledge. This could be very disturbing to many teachers who are used to lecturing and other teacher-centered approaches because it requires them to abandon their routines and learn new ways of teaching. Not all teachers will be able to do so and even if they can, it would take time and energy that has already been committed to other activities. Studies have suggested that "high-tech" teachers tend to hold a student-centered approach to learning (Cuban, 1994; Honey & Meoller, 1990). This is because for these teachers using technology does not create as much disturbance to other goals as to those who hold a different view of

teaching.

The Ability to Control

The final aspect of technology adoption by teachers that this framework considers is the teacher's ability to control, or in simpler terms, can he do it? According to PCT, while a higher-level control system supplies the goal (reference condition) to lower-level systems, it does not tell lower-level systems what to do to achieve the goal. The lower-level control systems have to be able to act on the environment to obtain the goal on their own. Again, the cruise control system example, the driver sets the speed, but it is the cruise control system that senses the current speed, compares it to the reference speed (set by the human driver), and acts on the difference (by varying the amount of fuel) to maintain the goal. The cruise control system can do the job because it has the ability to control, which means two things: (a) the system has a functioning structure (or capacity) that enables it to perceive, compare, and act when needed, and (b) the system has access to the necessary resources with which to act. Otherwise, control would be impossible. If, for example, the speedometer is malfunctioning, the cruise control system would not work. Or if there is no fuel to deliver, the system would certainly not be able to maintain a steady speed.

While a cruise control system is designed to accomplish the type of control the task requires a teacher may not have a functioning control system when it comes to technology. In order to use email in class, the teacher needs to be able to perceive whether his students receive his messages, and if not, he should be able take actions to make that happen. If he perceives himself not having such capacity, it is unlikely that he will use it.

Fortunately, a human teacher can develop such a control system via reorganization:

Reorganization is a process akin to rewriting or microprogramming a computer so that those operations it can perform are changed. Reorganization alters behavior, but does not produce specific behaviors. It changes the parameters of behavior, not the content. Reorganization of a perceptual function results in a perceptual signal altering its meaning, owing to a change in the way it is derived from lower-order signals. Reorganization of an output function results in a different choice of means, a new distribution of lower-order reference conditions as a result of a given error signal. Reorganization is an operation on a system, not by a system. (Powers, 1973, P. 79)

Space limitations do not allow a detailed discussion of reorganization; interested readers should consult Cziko (1995, esp., Chapters 8 and 12) for an elaboration and application of the concept of reorganization to education and learning. It should be at least mentioned here, however, that reorganization involves a type of trial-and-error learning in which control over new variables is developed.

As technology progresses, computers have become increasingly easier and "friendlier" to work with. Moreover, a human teacher does not actually have to have a computer-specific control system in him in order to use technology because he can utilize other people's control systems to accomplish the same task. This is another fortunate consequence of human society, which allows members to in effect share each other's control systems. Not everyone can fly an airplane, but we can all take an airplane ride. Similarly, while a teacher does not have the control system that enables him to use technology, he can "borrow" that from a technical expert or even a computer savvy student.

Another component of the ability to control is the availability of external resources. As a cruise control system needs fuel to function, a teacher needs hardware and software to use technology. While what is specifically needed depends on the available technology and the activities the teacher plans to use, the teacher needs to perceive that it is or will be available to him when needed.

It is a deliberate decision to place the discussion of the ability to control last. While most

current assumptions about factors that facilitate or prevent wider use of instructional technologies seem to emphasize teacher's technical skills and external resources as the primary variables affecting teachers' decision to use technology, in the current model they are considered secondary to the effectiveness and potential costs of technology. This is because from a PCT perspective the ability to control a piece of technology is lower in the hierarchy of goals of a teacher than the use of technology and lower-level systems can be varied to maintain a higher-level goal. In other words, if a teacher decides to use technology because it can more effectively maintain the goal of delivering quality instruction, he or she can vary other lower-level systems to bring about that goal. They can learn to use technology if they do not already know how. Or they can ask for help from technical experts if available. Or they can ask students to help. In terms of hardware and software, if it is not available, they can think about applying for small grants, asking the PTA for donations, using their own personal equipment, or asking the administration to invest in technology. In fact, the widespread phenomenon of "underutilization" of equipment (Charp, 1995; McKinsey, 1996; OTA, 1995) is an indication of the availability of external resources.

SUMMARY

The basic considerations of a PCT-based framework for understanding issues in teacher adoption of technology have been discussed. This framework suggests that in order to understand why teachers do or don't use technology, we must attempt to look from the inside instead of the outside. Focusing on the central role of goals, this perspective views technology as a possible way to achieve higher-level goals, while at the same time the use of technology is a goal to be maintained by varying even lower-level systems. This framework outlines three conditions needed to ensure the use of technology by a teacher.

1. The teacher must believe that technology can more effectively maintain a higher-level goal than what has been used.
2. The teacher must believe that using technology will not cause disturbances to other higher-level goals that he or she thinks are more important than the one being maintained.
3. The teacher must believe that he or she has or will have the ability and resources to use technology.

For a teacher to use technology, these three conditions must be met. Otherwise, it is unlikely that she will use technology in her teaching.

Before moving to the next topic, we would like to emphasize the concept of perception. We can only control what we perceive and it is our perceptions in relation to our goals that determine our behavior. Thus, it is not the objective effectiveness of technology that determines whether it will be used, but the perceived effectiveness of each individual teacher that decides whether it is to be used. The same is true with disturbances to other goals and the ability to control.

IMPLICATIONS

This framework has important implications for research and practice in the application of technology to education. We believe that, as an alternative model to the existing models of teacher adoption of innovations (Budin & Meier, 1998; Fullan, 1991; Huberman, 1995; Roberts & Ferris, 1994), the PCT framework presented above provides a fresh perspective on teacher adoption of technology. This perspective, we argue, may lead us to a better understanding of factors affecting teacher adoption of technology and eventually better ways to help teachers integrate technology in their teaching. This section starts with a discussion of the major differences between the PCT model and existing models. It then outlines a number of suggestions derived from this perspective for developing programs to help teachers integrate technology into the curriculum.

Why PCT?

While we argue that PCT provides an alternative way to understand and develop programs to support teacher adoption of technology, we are by no means suggesting that it replace existing approaches, but rather that it be considered in addition to the existing models. With this in mind, we highlight three areas where PCT differs from existing approaches.

Group vs. individual. Currently many professional development efforts intended to promote technology adoption (Budin & Meier, 1998; Huberman, 1995; Luke et al., 1998; OTA, 1995; Roberts & Ferris, 1994) are group-oriented. The emphasis is on changes at the system level, systemic support, and synchronized activities that involve everyone (O'Bannon, 1997; OTA, 1995). Whereas the focus on group and system is necessary, it fails to recognize that teachers are purposeful individuals who actively and constantly act to maintain their own goals. If not carefully implemented, the group approach often treats teachers as passive recipients of technology training and orders to use technology from the administration. The PCT model, however, stresses the importance of teachers as purposeful individuals. Focusing on individual teachers helps us recognize individual differences among teachers and provide more individualized support for teachers. It also encourages teachers to take initiatives and make the best of what they have instead of waiting for the district to provide complete support and training in technology.

Objective vs. perceived. Another difference between the PCT model and the existing approaches lies in their treatment of effectiveness of and ability to use technology. While both existing approaches and the PCT model suggest that the effectiveness of educational technology and teachers ability to use technology are two important factors that affect teachers' use of technology, they differ in their views of effectiveness and ability. According to PCT, what matters is the perception of the reality, not the reality. In other words, what influences teachers' use of technology is their perceptions of whether technology is an effective educational tool or whether they have the ability to use technology rather than the "objective reality" of the effectiveness of technology and the ability to use technology.

Motivation vs. skills. Current approaches all emphasize that a major reason that teachers are not using technology is that they lack the skills to do so. The PCT model suggests that the reason is that teachers lack the motivation, or the perceived need to use technology. Thus instead of rushing to provide more technology training programs, PCT suggests that we first help teachers realize that there is a genuine need for technology. This realization creates a cognitive disequilibrium. It is expected that teachers will then act to correct this disequilibrium. In this case, such actions would include attending workshops, reading books, or participating in other activities that would help the teacher develop the ability to use technology in their teaching.

Theoretical and Practical Implications of PCT

Having discussed the major differences between the PCT model and existing approaches, we now turn to the implications of PCT for both research and practice in understanding and supporting teacher adoption of technology.

The need for technology. According to PCT, all purposeful behavior is goal-oriented in the sense that behavior results from an individual's attempt to make his or her perceptions conform to internal standards for these perceptions. Only when a discrepancy between the perception and internal standards occurs, either as a result of external disturbances or a changed internal reference condition, does an individual start to vary his or her behavior in an attempt to reduce the discrepancy. In order for teachers to use technology, they must first have the need to do so and the need, according to PCT, results from a sensed discrepancy between the perception and goal. There are a number of ways to create such discrepancies. First, as previously mentioned, teachers can be expected to have the goal of delivering quality instruction. Technology has been reported to improve learning in a variety of forms. Whether a teacher perceives quality teaching as good performance on standardized score or the development of critical thinking skills, research has provided evidence that technology can

help to better achieve the goal. These research findings should make teachers perceive a discrepancy as they realize that technology can help them better achieve their goals of delivering quality teaching. However, since most teachers are not aware of these findings or they are reported in such an abstract fashion that the teachers can not make much sense of them, they are not perceived as disturbances. Thus efforts should be made to make the information available to teachers.

The second way in which technology could create a disturbance to teachers is to require teachers to use technology. While it is impossible to directly manipulate an individual's goal, it is possible to influence a person's lower-level goals by disturbing his or her higher-level goals. By requiring all teachers to use technology (e.g., in the form of a requirement for teacher credentialing), although there is no way to ensure they will definitely use it, it is more likely that they will use it than not requiring it because it disturbs a higher-level goal: to have a job. However, it should be mentioned that such requirement alone may only result in superficial or token application (Cuban, 1986). There are currently few technological requirements for teachers, either preservice or inservice. "Only 18 states include any technology skills among the requirements for teacher credentialing. And in most states, the requirements are too low to matter" (McKinsey, 1996, p.10). There are even fewer requirements for inservice teachers to receive training, let alone use technology. Only Alabama and the District of Columbia require any inservice training in computers or technology for all teachers (Anderson, 1994).

Other sources of disturbance are students, colleagues, and society. As more and more families own computers and the National Information Infrastructure enables more people to use technology, students are coming to classrooms with more experience in learning with technology, making it harder for the teacher to maintain the status quo. For example, when the Web becomes an important information source and email a common medium of communication for students, teachers will have to vary their current behavior in order to maintain the goal of being a good teacher.

Enhance Perceived Effectiveness

As discussed earlier, the perceived effectiveness of means is an important criterion when there are many possible means available to achieve a goal. Therefore, to promote educational uses of technology it is important that teachers perceive that technology can help achieve their goals more effectively. This is a tricky task since effectiveness is not necessarily inherent in any technology, rather what is important is the teacher's perception, which is a function of the teacher's internal goal and knowledge of the technology. It is therefore crucial to understand what each individual teacher's goals are before telling them how powerful technology can be.

Stories from peers are often quite helpful. Case studies and reports of other teachers who have been using technology have proven to be very effective in getting teachers interested in technology (Gillingham, 1996). As an example, the LETSnet project (<http://letsnet.educ.msu.edu>) at Michigan State University organizes and publishes stories and suggestions of teachers who have been using the Internet. It is expected that by reading these stories, other teachers will come to perceive technology as an effective means in achieving their goals. A reportedly very successful version of this approach, Model Technology Schools and Classrooms, has been used in several professional development projects. Monterey Model Technology Schools Project in California, for instance, allows well trained, experienced teachers to share their experiences with other teachers (OTA, 1995). This approach is promising because it is likely that teachers share the goals held by their peers and the teachers can relate to their peers' experiences.

A less effective and unfortunately very popular approach is having technical experts "sell" to teachers the mighty power of technology. Because very often these experts are not teachers themselves, even though they might understand the teaching process very well, they may not be perceived by teachers as individuals who have similar goals. In fact, technical experts are often suspected to have a different agenda than teachers, such as focusing on technology rather than quality teaching. Since they are not perceived as having similar goals, it is likely that the teachers would tend not to be convinced of the power of the means (technology)

being advocated.

Reduce Potential Disturbances

According to this framework, in spite of the perceived effectiveness of technology, teachers may not use technology because it disturbs other important higher-level goals. As Strudler (1994) noted:

When will technology become a high enough priority for a majority of teachers so that they pursue it as a regular part of their professional responsibilities? Data gathered indicate that we are still in an awkward transition period in which the benefits of teaching and learning with technology do not necessarily outweigh the costs. While teachers are increasingly citing the benefits that students derive from computer use, they must weigh the costs in terms of their time and the difficulties of managing to find appropriate software and then get adequate computer access for their students (p. 18).

It is therefore important to reduce the perceived disturbance to other goals (costs) resulting from using technology. There are a number of ways that can help to reduce potential disturbances. First, pedagogical changes should not be required when promoting the use of technology. As previously discussed, pedagogical beliefs and practices are more difficult to change and many teachers do not want to change them. Technology should fit the existing beliefs of teachers (Olson, 1992). If using technology also requires teachers to adopt new teaching approaches as many have argued for (e.g., see Means, 1994), teachers may well resist adopting technology. So although the argument that new pedagogy should be encouraged is well grounded, it should not accompany the introduction of new technology. Once technology is integrated into the curriculum, it will introduce disturbances that will on its own necessitate pedagogical changes.

A second way to reduce potential disturbances is to develop easy-to-use tools so that the teacher does not need to spend extra time and energy learning to use the technology. Easy-to-use tools can also help to reduce the potential disturbance to the goal of maintaining a "good image" before students since it is less likely that technical problems will arise.

An example of such tools is eWeb (Zhao, 1998), a suite of Web-based tools. Since these tools are designed to support a wide range of teaching approaches, they do not require a teacher to change his pedagogy in order to use technology. Moreover, it uses a common graphic-interface Web browser, making it easy to learn and use because many teachers and students have already had experience with such software. As a result, eWeb has been very successful in promoting technological adoption among teachers at different levels. For example, in less than two months in the summer of 1996, over 50 teachers in two small liberal arts colleges have either started to use eWeb for their summer course or plan to use it in the fall after minimum training. The 50 odd users all agreed that eWeb is effective and costs very little in terms of time and energy and equipment. Not every teacher uses all the functions or the same functions provided in the system. Instead, they choose the part that they see as meeting their goals. For instance, some teachers quickly adopted the exercise/test builder that enables them to construct and administer exercise on the Web. Others picked the chat function to have their students practice pattern drills in French. While still others used the forum function to have students report and discuss their findings of a class project.

A third way to reduce disturbances is to provide on-site support so that teachers know that when technical problem arises, they have someone they can turn to for help. At least in one instance "The support provided by an effective [technical] coordinator serves to 'tip the scales' for teachers weighing the costs and benefits of technology" (Strudler, 1994, P. 18).

CONCLUSION

Much ground has been covered in this article. We have introduced a model of goal-oriented behavior that has important implications for understanding teachers' adoption of technology.

We have also attempted to demonstrate how a framework derived from PCT can help us better understand why teachers do and do not use technology. While it is too early to provide systematic findings to show the usefulness of this application of PCT, we have used it here to interpret and synthesize the findings of a number of studies on teachers and technology. We also have made suggestions derived from this model for the infusion of technology into schools.

To summarize the major themes, in order to understand why teachers use and do not use technology, we must look at teachers as goal-oriented, purposeful agents. PCT provides a comprehensive model for understanding technology infusion. From a PCT perspective three conditions are necessary for teachers to use technology:

1. The teacher must believe that technology can more effectively achieve or maintain a higher-level goal than what has been used.
2. The teacher must believe that using technology will not cause disturbances to other higher-level goals that the he or she thinks are more important than the one being maintained.
3. The teacher must believe that he or she has or will have the ability and resources to use technology.

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