Chapter 9

Gagné and the New Technologies of Instruction

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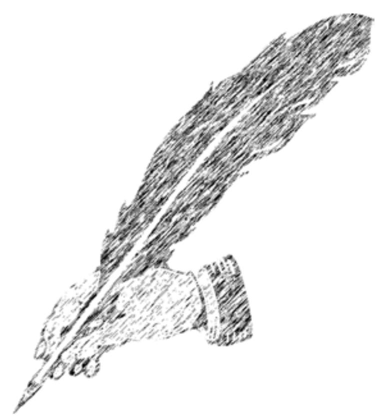
Some people would say that very little in the field of Instructional Technology has not been influenced by Gagné's ideas. The various chapters in this book only begin to chronicle the wide-ranging impact of his work. Others would say that Gagné has had no influence on the new technologies of instruction. He is an instructional theorist after all, not an engineer who designs and builds new technological devices. Therefore, before describing the impact of Gagné's work on the new technologies of instruction, it is necessary to reconcile these two positions. In order to do so, this chapter will begin with a discussion of what is meant by technology in general, and the new technologies of instruction in particular. With some common ground established, it will then be possible to describe those areas where Gagné's work has had an impact on the development and utilization of these new technologies, before some final speculation about how Gagné's ideas may be expanded in the future.



Technology, Instructional Technology, and the New Technologies of Instruction

Ask the ubiquitous "person on the street" to define technology and you are likely to hear descriptions of machines and devices—computers, cellular phones, space ships, or televisions. Indeed, modern civilization is inundated with technological devices, hurtling us toward a future where changes brought about by technological innovations are occurring at an ever increasing pace (Toffler, 1972). We have entered a period in human history where technology is so pervasive that we may have lost control. Unlike previous centuries, machines are now used to make other machines; some devices are so small that the human hand cannot possibly manufacture them. We have also reached a point where digital information has become the basic unit of communication (supplanting the printing press), and technology is contributing to changes in nearly all aspects of society (Apple, 1986).

In general terms, technology can be defined as "the systematic application of knowledge to practical tasks" (Galbraith, as cited in Heinich, Molenda, Russell, & Smaldino, 1999, p. 18). In this sense, various technologies might be classified as either "hard" or "soft" (Heinich, Molenda, Russell, & Smaldino, 1999), or as "resources" and "processes" (Seels & Richey, 1994). Hard technologies are developed through the application of physical science and engineering concepts, resulting in new devices meant to accomplish practical tasks (Saettler, 1968). Planes, trains, and automobiles, as well as devices utilized in education such as computers, televisions, and chalkboards, are all examples of hard technologies. Soft technologies are process oriented, applying research from the behavioral sciences to improve human performance (Saettler, 1968). Methods such as needs assessment and task analysis, or various instructional strategies and tactics, are examples of soft technologies used in education and training.

When the practical task is instruction, we try to apply knowledge about learning and teaching so learners might attain specific outcomes after experiencing the series of teaching/learning events that we design and implement. Just as technology can be classified as hard or soft, instructional technology has long struggled with an identity that divides the field along lines that distinguish media from method. For much of its history, instructional technology has been associated in the minds of many people with audiovisual instruction. Decades of research focused on media and its resulting effects on learning (see Clark, 1983; Kozma, 1991). Early attempts to define the field of Instructional Technology incorporated the media/method distinction, characterizing Instructional Technology as "the efficient utilization of every medium and method to promote learning" (Ely, 1963, p.19), or as the "media born of the communications revolution which can be used for instructional purposes," along with a "systematic way of designing, carrying out, and evaluating the total process of learning and teaching" (Commission on Instructional Technology, 1970, p. 21). Gagné also noted these distinctions in identifying the knowledge sources, resources, and activities that constitute the field of Instructional Technology. His definition focuses on a concern for the "conditions necessary for effective learning" (Gagné, 1987, p. 3), including both communications to the learners that are "frequently delivered by equipment and its associated procedures, commonly referred to as media" (p. 6), as well as concern for the techniques of instruction that "systematically aim for effective learning, whether or not they involve the use of media" (p. 7).

The most recent definition of Instructional Technology provided by the Association for Educational Communications and Technology (Seels & Richey, 1994) is now more comprehensive, reflecting the maturity of the field. Instead of distinguishing between media and method, Instructional Technology is now seen as "the theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning" (Seels & Richey, 1994, p. 9). This new definition allows the present discussion of Gagné's impact on the newer technologies of instruction to include not only resources and processes (hardware and software), but also the knowledge sources and practices of the people who design, develop, utilize, manage and evaluate instruction. The significant contributions to the knowledge and practice of Instructional Technology made by Gagné have been well documented. This chapter will focus on how Gagné's work informs the utilization of hardware and the design of software for instruction that incorporates some of the newer technologies.

Knowledge Sources

It would be arrogant to imply that all of the knowledge utilized in Instructional Technology was produced by people closely involved with the field. Much of the knowledge applied by practicing instructional technologists has been derived from other disciplines including engineering, computer science, cognitive science and communications. While it is not possible to address all of these areas here, a small subset of the knowledge base of Instructional Technology will be examined. The aim of this discussion is to help understand the relationship of Gagné's work to the current state of the knowledge being applied to solve today's instructional design problems, in particular the domains of artificial intelligence, psychology, and learning theories. All of these areas have made a strong impact on the practice of instructional design, including the ways that software is designed and hardware is utilized for instruction.

Gagné's career has coincided with some major revolutions in theoretical descriptions of learning. Beginning with a somewhat behavioral orientation, Gagné has consistently revised one of his major works, *The Conditions of Learning*, to incorporate advances in learning theory as the information processing model of cognition has evolved (Gagné, 1985). The information processing model provides a comprehensive description of how information is acquired and retained in the human mind, as well as how expertise develops. Gagné's instructional design model (Gagné, Briggs, & Wager, 1992) is based on the prevailing view of cognition that assumes thinking involves processing of information within memory structures in the brain. Given this explanation as a basis, Gagné has proposed instructional prescriptions designed to facilitate learning in the various categories of learned capabilities that he has identified (Gagné, 1985; Gagné & Glaser, 1987). According to Gagné, learning some of these skills can be facilitated if instruction is organized hierarchically, so that prerequisite skills are learned in the appropriate order.

Considerable guidance is also provided for direct instruction through Gagné's prescription of events for instruction. He suggests that a particular sequence of events should occur in order to facilitate learning (Gagne, Briggs & Wager, 1992). These events serve to orient the learner to the learning task, focus attention on pertinent information, and elicit performance with guided practice. Whether the instruction is traditional or computer-based, the events are essentially the same (Gagné, Wager & Rojas, 1981). This model for direct instruction is very similar to other models of direct teaching, especially that of Madeline Hunter (Hunter, 1982, 1984).

Much of the theoretical progress made in the area of human information processing has been achieved by modeling with computers the symbolic computation involved in human cognition. As a result, a field of research in computer science has emerged that is concerned with the development of artificial intelligence (Wenger, 1987). Significant progress has been made in vision processing, language processing, knowledge representation and reasoning, knowledge engineering, and intelligent tutoring systems, but we are far from the point where the complete range of human intelligence can be achieved by devices such as computers. One of the major tasks facing researchers in this area is to find ways to represent knowledge in structures that computers can utilize for reasoning. Many of the techniques and procedures utilized for artificial intelligence knowledge acquisition, representation and reasoning can also be employed in the instructional design and development process (Nelson, 1989). Recent activities in Instructional Technology research are taking advantage of the techniques of artificial intelligence, especially knowledge engineering, to streamline the instructional design process and allow more direct participation by subject matter experts (Jonassen & Wilson, 1990; Richey & Nelson, 1996).

Recently, a challenge to the dominant information processing paradigm in psychology has been proposed by those interested in situated cognition and constructivism (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991; Suchman, 1987). Situated cognition poses a radically different explanation of learning, conceiving it as a largely social phenomenon. Rather than occurring within the mind of the individual, learning is instead described as a characteristic of many social interactions that take place within a framework of participation (Hanks, 1991). Indeed, from this perspective learning requires a rich repertoire of essential actors and participatory relationships beyond those commonly found in education and training as now practiced, emphasizing instead the participation in social groups that is characteristic of learning in a variety of settings and cultures outside of formal education. Situated cognition also proposes a different philosophy of knowledge as it relates to the learning process, suggesting that knowledge is not an internal component of the mind, but rather is a relation between an individual and a social or physical situation (Greeno, 1989).

Constructivism is a parallel movement in psychology that suggests knowledge is constructed by learners in personal ways based on personal experiences (Paris & Byrnes, 1989). What is required for learning from a constructivist perspective is an environment that promotes discovery, reflection, negotiation of meaning among learners, and communication of knowledge between learners (Bednar, Cunningham, Duffy, & Perry, 1990). Instruction from the constructivist perspective should be a self-regulated process engaged in by a learner who is motivated to explore problems and situations. Technology can be employed to provide the kinds of environments appropriate for constructivist learning (Duffy & Jonassen, 1992), and a great deal of recent research and speculation has focused on the design of these learning environments (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Hannafin, 1992; Jonassen, Peck, Wilson, & Pfeiffer, 1998; Rieber, 1992)

These new conceptions of learning propose viable alternatives to current cognitive theories, and will require new approaches and procedures for the design and development of instruction (Orey & Nelson, 1997; Young, 1993). Instructional design has traditionally focused on the variables and conditions necessary to improve learning in settings that feature intentional learning and direct instruction. While Gagné has not directly addressed the issues of constructivism and situated cognition in his writing, his concern for keeping his instructional theories current is evident in one of his more recent publications. Proposing a new cognitive structure termed “enterprise schema,” Gagné and Merrill (1990) attempt to broaden the analysis of content and learning tasks in order to identify “integrative goals” for instruction (see Chapter 6). Others have followed this lead in suggesting that instructional design must consider broader issues than the learning task, such as the environment for learning (Tessmer, 1990), and the context for learning (Tessmer & Richey, 1997). This attention to new developments in learning theory, and the subsequent modification and extension of his own theoretical descriptions is a hallmark of Gagné’s work.

One other knowledge base utilized in Instructional Technology that has received little formal study is the personal knowledge and beliefs of practitioners. Little is known about how this knowledge might affect the processes and products of Instructional Technology. Some research has indicated that an instructional designer’s expertise greatly influences the kinds of decisions made at various stages of the design and development process (Nelson, 1988; Rowland, 1992). Designers tend to produce solutions for novel problems that are based on similar problems they experienced in the past. The knowledge acquired from previous projects may serve as a template for understanding the current problem, as well as generating solutions for the problem (Goel & Pirolli, 1988). Not only does prior knowledge and experience affect design solutions, but also the belief systems held by instructional designers can influence their practice (Shambaugh & Magliaro, 1997). Beliefs about learning and instruction that have been established through reflection on Gagné's work will probably serve the designer well.

Current Practice

The practice of Instructional Technology employs the knowledge and beliefs discussed above to design, develop, utilize, manage, and evaluate instruction. This practice includes models for designing and developing instruction along with procedures for working with these models. Of course, the current practice of Instructional Technology is influenced by the knowledge sources employed by the practitioner (both theoretical knowledge and life experiences), as well as constrained or enabled by the hardware and software to be employed as part of the instruction.

Design Models: The Design of Computer-Based Instruction

The process of designing computer-based instruction is very similar to the processes recommended by traditional models of instructional design and development that have been practiced for years. In fact, many texts on instructional software design advocate models that can be attributed to the work of Gagné and Briggs (Gagné, Briggs, & Wager, 1992; Briggs, Gustafson, & Tillman, 1991). For example, Allessi and Trollip (1991) recommend a process that includes traditional stages such as needs identification, goal specification, task and content analysis, and sequencing objectives. Hannafin and Peck (1988) organize their design model similarly, as do Soulier (1988), Price (1991), and Flouris (1987). What these models have in common is a concern for a systematic design process that emphasizes learner outcomes as a central element of the planning and authoring process.

Gagné's work, however, has influenced more than just the basic models employed for instructional software design. The application of his Events of Instruction model (see Chapter 4) has been discussed by numerous authors (Jonassen, 1991; Wager, 1981), and has been exemplified in an article by Gagné himself (Gagné, Wager, & Rojas, 1981). The advantage of applying this theory to instructional software design is that most authoring environments are atheoretical, that is, there is some provision for screen design and interaction strategies, but no guidance for incorporating sound instructional principles is provided. Therefore, it is imperative that the designer specify components for the instructional software that are based on design principles such as those suggested by Gagné.

Design Tools: The Automation of Instructional Design and Development

Systematic instructional design and development utilizes a variety of methods and techniques to organize and control a very complicated process, but even so, the process can be very time consuming and costly. Efforts to streamline the instructional design process have focused on the development of knowledge-based tools that assist designers to interpret problems, control design activities, and produce specifications (Richey & Nelson, 1996). Many of these tools employ artificial intelligence techniques to represent in computer systems the kinds of knowledge and reasoning necessary for instructional design. While a variety of approaches have been tested, work in this area tends to fall into one of three categories: individual tools for self-contained design tasks, integrated systems for decision support and process structure, and integrated systems that act as “drafting boards” for the design process.

Knowledge-based tools for instructional design and development activities have been employed for many years, at first as on-line job aids for novice instructional designers in the military (Schulz, 1979; Schulz & Wagner, 1981), then as expert system modules that could be accessed to provide guidance in such design tasks as classification of objectives, needs assessment (Kearsley, 1985), media selection (Gayeski, 1987), and job/task analysis (Hermanns, 1990). A more comprehensive system has been developed by Merrill (Li & Merrill, 1991; Merrill & Li, 1989) using expert systems technology to capture the knowledge and reasoning necessary to make decisions for all aspects of the design process, with special concentration on tools for acquiring and analyzing subject matter content (Jones, Li, & Merrill, 1990). Other researchers are pursuing the development of structured environments for instructional design that do not feature the system-controlled consultation sessions that are common to expert systems (Gustafson & Reeves, 1990; Munro & Towne, 1992; Russell, 1988). These systems tend to feature open-ended “workbenches" that provide numerous tools for structuring and managing the design process while allowing the designer the flexibility to complete tasks when desired, not under the control of an expert system interface.

Gagné’s attitude toward these efforts seemed neutral and cautious during an interview reported in *Educational Technology* (Twitchell, 1991). When asked if building expert systems for instructional design was a reasonable approach to evolving instructional design theory, Gagné expressed concern over the level of complexity already involved in the design process, but agreed to “wait and see what comes out” before forming a final judgment about the technology (Twitchell, 1991, p. 39). Since then, he has been involved in a similar project to “extract” his knowledge of instructional design and represent it in a knowledge-based instructional design system. It remains to be seen whether such systems will be used by practicing designers, as several problems in implementation and utilization have been identified (Locatis & Park, 1992; Gayeski, 1987).

Hardware

An interesting trend has surfaced in the development of hardware utilized for educational applications. The emerging technologies available for education are also converging technologies, that is, most of the newer hardware capabilities are converging on the computer as the central medium. Recent developments in interconnectivity provided by telecommunications networks such as the Internet have opened up countless opportunities for educational activities utilizing the vast information network that has developed around the World Wide Web (Khan, 1997; Reinhart, 1995). Improvements in storage capacity, processing speed, and memory have stimulated the emergence of digital multimedia, including compact disc storage devices and opportunities for two-way interactive learning over telecommunications networks. Advances in the design and construction of input/output devices have spurred the development of virtual reality technologies, allowing users to interact with the computer in high-fidelity simulations of electronic "worlds" that are digitally generated.

As previously noted, Gagné is not an engineer involved in the design and development of this hardware. Nonetheless, his research and theories can still provide considerable guidance in deciding how the available hardware should be used for instruction. First, we must better understand the role of video, audio, and pictorial information in the processes of learning and instruction. Gagné (1986) identified some of the important research questions that need to be addressed with respect to learning from a variety of media, whether the learning is incidental or intentional. Research is needed regarding what outcomes are achieved when people learn from pictures and diagrams, and how pictures (including video) can be designed to make learning more effective.

Second, as multimedia materials become easier and more cost effective to produce, and as computers with multimedia capabilities are becoming common in schools and other institutions, media selection for computer-based instructional software becomes more critical. The question is no longer "Can the computer provide an adequate and cost-effective instructional medium?", but instead, "How can the various media possibilities of which the computer is capable be integrated within this instructional software?" The guidance provided by Gagné's media selection procedures (Reiser & Gagné, 1982) are still applicable to the various components of instructional software, especially when considering the computer's capabilities for simulation and virtual reality.

Even though changes in hardware technologies will continue to provide new opportunities for Instructional Technology, it is still important that hardware capabilities do not "drive" the design of instruction. Too often, the field is influenced by possibilities suggested by new hardware, and a search is begun for an instructional problem for which the hardware solution already exists. As suggested by instructional design models, focus must be placed on the design of effective learning strategies and materials before selecting hardware. But designers must also know what hardware capabilities are available before designing instruction. As Gagné noted: "Hardware itself can only accomplish whatever the human imagination can invent for its use" (Gagné, 1986, p. 14).

Software

Advances in hardware enable, as well as constrain, the kinds of software that can be developed and utilized with any device. As hardware develops, so does the software necessary to utilize the hardware for a variety of purposes. Recent developments in software that make computer hardware more effective for instruction include hypermedia architectures for organization and presentation of information, along with methods for providing adaptive instruction in the form of intelligent tutoring systems. While Gagné has had little if any direct involvement with either of these software technologies, his theories and research continue to provide ample guidance for those interested in the technologies for instructional purposes.

Hypermedia

One of the most exciting developments in the area of "soft" technologies for computer systems has been the advent of hypermedia software architectures. The conceptualization of information "nodes" connected by "links" has significantly changed the ways that people interact with digital information, the ways that authors might organize and present information to people, and the options for designing and developing systems for computer-based instruction. As hypermedia systems have been implemented for educational use, confident predictions of a revolution in learning and instruction have been made (Heller, 1990), but progress is slow and many problems with using hypermedia architectures for instruction still remain unsolved (Marchionini & Shneiderman, 1988).

Hypermedia systems were originally developed out of ideas for information access proposed by Vannevar Bush (1945) and Ted Nelson (1981). Bush envisioned systems where individuals might organize information in personally meaningful ways, storing small amounts of text in files ("nodes" roughly corresponding to a screen of information) that were cross-referenced with electronic links. He developed an early system where a user could "browse" through text by selecting links from one node of information to another (links are typically indicated to the user by underlined or bold-faced words embedded in the text on the computer screen). Bush based his ideas of links on an associationist view of human memory organization, recommending that links be established between concepts that are related in some way in the reader's mind. This concept may provide a way to organize information outside of the mind that reflects how the information is organized in the human brain (Jonassen, 1991; Nelson & Palumbo, 1992).

Ted Nelson took Bush's ideas to another level, suggesting that some day a culture might exist where individuals organize and "publish" their ideas using a hypertext architecture to create a vast "web" of information that can be shared globally (Nelson, 1981). It has taken many years for computer hardware and software to develop to the point where hypermedia systems as envisioned by these early pioneers have become readily available, but the capabilities of current systems have surpassed the dreams and speculations of early proponents. Hypermedia systems are now commonplace, allowing for nodes of information that might include text, pictures, sound and motion video, and for delivery through the Internet.

Many of the hypermedia applications developed for education have focused on the information presentation capabilities of the medium, but hypermedia architectures also allow systems to be designed for knowledge representation and knowledge construction (Nelson & Palumbo, 1992). Hypermedia presentation systems provide databases of information that can be browsed or searched in order to read or view information that is associatively linked. Knowledge representation systems attempt to make explicit the nature of the relationships between the information contained in the nodes. Graphical browsers, knowledge maps, or links that are visually "coded" to indicate the structural relationships between concepts in the knowledge base are common in these type of systems. Knowledge construction systems support learners in their direct interaction with information, allowing them to author nodes, create links, annotate, or share ideas with others.

Simply allowing learners quick access to information through a learner-controlled, nonlinear organization may not ensure learning (Nelson & Palumbo, 1992). Additional instructional activities and knowledge base structures are needed to help learners acquire the necessary knowledge and skills (Kommers, Grabinger, & Dunlap, 1996; Locatis, Letourneau, & Banvard, 1989). Gagné's conception of learning hierarchies is directly applicable to hypermedia systems designed for instruction. Information organized hierarchically may allow learners to access nodes at elementary levels before moving upward, thereby ensuring that subordinate knowledge and skills are acquired before superordinate. Research suggests that learners who use hypermedia systems that are structured hierarchically tend to navigate initially through the information in systematic ways, rather than in non-linear patterns (Beasley & Waugh, 1997). Attempts to provide appropriate instructional events (Gagné, 1988) and other instructional strategies commonly used for printed text may also improve the instructional capabilities of hypermedia systems.

Intelligent Tutoring Systems

Intelligent tutoring systems have evolved from traditional computer-based instruction, but emphasize different theoretical perspectives and design principles. Intelligent tutoring systems encode knowledge to be used to make instructional decisions as the learner interacts with the system. On the other hand, traditional computer-based instruction encodes instructional decisions made before the learner interacts with the system (Wenger, 1987). Intelligent tutoring systems tend to separate subject matter from teaching method, emphasizing the idea that natural learning occurs through context-based performance. The software is designed to identify student misconceptions and provide appropriate instructional interventions through the interaction of four system components: the interface, the learner model, the expert model, and the pedagogical model (Orey & Nelson, 1993). Through the two-way communication provided by the interface, the learner engages in some activity while the system interprets the activity, passing the results of the interpretation along for diagnosis. By comparing the learner's current knowledge state and actions with the knowledge in the expert model, the intelligent tutoring system ascertains the nature of the learner's error and uses the knowledge in the pedagogical model to make decisions about what, when and how instruction for the learner should proceed.

Gagné has expressed some skepticism of intelligent tutoring systems (Twitchell, 1991). He feels that many interesting ideas are being tested, such as the notion that the knowledge of the learner must be considered in designing instruction, or that the basic difference between novices and experts is the knowledge they possess, or that experts tend to employ problem-specific strategies in problem solving. While all of these knowledge components are typically addressed in the design and development of intelligent tutoring systems, Gagné believes that it is necessary to go beyond merely embedding such knowledge within a computer program. However, he does not specify what additional components should be addressed in intelligent tutoring system research.

Despite his lack of direct participation, Gagné's ideas have had some influence in the area of intelligent tutoring system research. One of the difficult problems for intelligent tutoring systems is to structure a curriculum for each individual learner, and to do so dynamically while the learner is interacting with the software. A comprehensive review of procedures for curriculum planning in intelligent tutoring systems identified several methods for calculating paths through learning hierarchies (Capell & Dannenberg, 1993; Nesbit & Hunka, 1987) that can be directly related to Gagné's work. But the question remains whether learning is truly facilitated by a hierarchical curriculum. There is evidence that expert knowledge and performance is hierarchically structured (Dunn & Taylor, 1990; Stepich, 1991), but studies comparing instruction organized hierarchically with other organizational strategies have been largely inconclusive (Wedman & Smith, 1989; Yao, 1989).

Conclusions

The impact of technology on various aspects of society, and education in particular, is growing at a rapid pace. It is in this atmosphere of technological dependence that efforts to improve education and instruction continue. Predictions of the future of education within a technological society suggest basic systemic changes will continue as we expand existing communication and information networks, focus on curricular revision and accountability, restructure schools, and explore the implications of new learning theories and instructional methods (Perelman, 1992). The future may also see a continuation of more "superficial" technological changes that expand the utilization of artificial intelligence in education, the development of informal learning environments, and the expansion of information technologies and networks (Heinich, Molenda, Russell & Smaldino, 1999).

In order to meet the needs of subsequent generations of learners, it is necessary to base new developments in Instructional Technology on sound theoretical principles such as those provided by Gagné. This chapter has examined several areas in which Gagné's work has influenced the development and utilization of technology for instruction. Sometimes this was a direct influence brought about by his work in a particular area, and at other times it was an indirect influence based on his theoretical work. We should continue to explore these and other areas where Gagné's ideas might prove beneficial as new technologies emerge and as we devise new uses for existing technologies. But above all, it is necessary to avoid the "technology for technology's sake" mentality, and continue to employ technology as a means to improve and optimize the processes of learning and instruction.

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