Electronic Performance Support Systems and Technological Literacy

George R. Maughan

Abstract

Electronic performance support systems (EPSS) can provide alternative learning opportunities to supplement traditional classroom or training strategies. Today's students may benefit from educational settings and strategies that they will use in the future. In using EPSS to nurture the development of technological literacy, workers and students can achieve higher level cognition skills while they perform tasks. Although there are unique challenges to the development and use of EPSS, efforts to overcome these challenges are becoming more widespread.

Introduction

Whether it is planning new highway construction, calibrating a stamping machine, or assembling a tricycle, humans cannot escape using information, tools, energy, and materials when performing a task. Technology has become a powerful force in the world, forming a totality that is difficult to understand as a whole (Ellul, 1954; Winner, 1977; Postman, 1993; Sismondo, 2004). The nature of modern work and rapidly changing conditions in the workplace demand that workers to be very agile in their use of information, tools, energy and materials, and continuously engage in learning.

It is because of this evolving and complex nature of technology that work in advanced technological societies frequently requires skill and knowledge development beyond the scope of standard education and training programs. As tasks become more systemic and highly integrated within a complex workflow, traditional training fails to adequately prepare workers. While traditional training and job aids predominate, increasingly Electronic Performance Support Systems (EPSS) are employed to support skill and knowledge development in real-time and at the work station (Gery, 1995). An EPSS is a configuration of hardware, software, and content accessible by employees or students and structured to provide users with information to permit them to do their jobs or perform tasks with minimal intervention by others. EPSS are an important link between task support, the acquisition of new knowledge and skills, and the development of broader technological literacy (Wittmann & Süß, 1999).

Traditional pre-work and on-the-job training have evolved in such a way that in some cases training is embedded in the work process itself. In the past decade the promise of cost savings and more efficient labor initially provided the impetus for EPSS (Gery, 1995). By eliminating much of the traditional training of workers and providing a smart electronic coach, individuals can use performance support systems to learn while working, and at the same time have instant access to vital support information such as conversion tables, schematics, and flow diagrams. By harnessing computer systems to accumulate information, coach, and respond to user requests, contemporary EPSS are beginning to fulfill their promise of efficiently supporting the performance of tasks. EPSS may deliver even greater benefits than first imagined as these systems actually learn through individual user interaction.

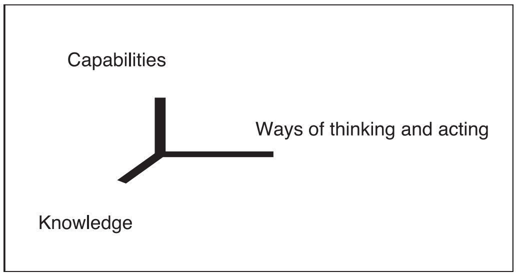
In EPSS, information regarding the performance of technical work is cumulative, expansive, and, as the task is performed, contributes to knowledge constructed by the user. These features are frequently observed in journeymen and master technicians. Performance support systems provide prescriptive information to enable a user to accomplish a task such as locking-up a piece of stock in a vertical milling machine. Expanded information in the form of troubleshooting rubrics, case studies, workflow summaries, and calculation wizards are also provided in the context of the specific task. A user's interaction with this information can lead to higher level thinking and the construction of knowledge enabling the user to realize concrete and abstract concepts and principles (Hambrick, Kane & Engle, 2005). When blended with social learning, scaffolding can contribute to new technical as well as technological literacy both in the workplace and the classroom.

This article explores the relationship between EPSS used to assist workers in the performance of complex tasks and the contributions these systems can make to the development of overall technological literacy. Several themes are discussed. First, the nature of technological literacy is described. Second, electronic performance support systems and how they are used to support work is explored. Third, the role of theoretical constructs within cognition and constructivism and their relationship to the development of technological literacy is discussed. Finally, the challenges faced by trainers and technical educators as they integrate these themes into their work is considered.

Technological Literacy

The National Academy of Engineering and the National Research Council's jointly published book *Technically Speaking*, opens the executive summary by describing "an unacknowledged paradox" (Pearson & Young, 2002, p.1). This paradox is the current low level of technological literacy in the midst of the widespread use of technology. The authors challenge K-12, higher education and adult education to do their part to address this situation. One of the most intriguing aspects of the work is the manner in which technological literacy is described. Three axis: knowledge, ways of thinking and acting, and capabilities are conceptualized. (See Figure 1.) Knowledge represents "knowing about" and being able to recognize the numerous ways technology is represented in our society, including both devices and techniques and large systems, as well as their impacts. Ways of thinking and acting refers to one's participation in asking questions, seeking information and making decisions about the use of technology. Finally, capabilities refer to skills and abilities to recognize and use tools, including such diverse examples as cell phones and programmable control units. This also includes the ability to apply theories and principles.

Figure 1. Dimensions of technological literacy (p.15)



It is within these dimensions that technological literacy develops. Constructivist learning theory suggests that when a user is engaging technology and actively questioning and learning, it is quite likely that knowledge and ways of thinking and acting will develop (Fox, 2001). Through the use of EPSS, employees may construct knowledge necessary to perform complex tasks in the workplace (Wittmann & Süß, 1999). When coupled with social learning, EPSS may assist learners in gaining new ways of thinking and provide greater insight into the larger technological world.

Electronic Performance Support Systems

EPSS exists as **stand-alone** systems or as systems **embedded** in the work process. **Stand-alone** electronic performance support is made available to the user while the work is on-going but requires the user to seek or pull information by querying. Many times this information is displayed alongside work information. A device such as the scan-tool marketed by Snap-on is a good example. This device functions like most scan tools used in automobile service settings by providing troubleshooting codes for malfunctioning engine, transmission, and ABS systems. Yet, this tool goes a step further by providing "troubleshooting" advice to technicians and work-context answers to questions about problems and possible solutions. These functions operate in real-time and can also provide live instrumentation on the actual system in question.

In another example of a stand-alone EPSS application, many Sears service technicians use laptop computers when servicing home appliances. Although the laptop is networked to an external database, the laptop does not directly interface with the malfunctioning appliance. It is quite common to see a technician referring to his/her laptop while diagnosing or repairing an appliance. The laptop communicates wirelessly with the service vehicle parked in the driveway. There the signal is transmitted to a comprehensive database via a satellite link. This communication illustrates the networking of the user's access device with external information. Technicians can check model numbers against parts lists, inventory and price information as well as view diagrams and illustrations.

Finally, another example of a stand-alone EPSS is that of a European automobile manufacturer that employs a "guided fault-finding" system used by service technicians. A laptop computer provides decision-branches for the technician to follow in order to ensure consistency in diagnostic efforts across dealerships. This support system also provides documentation of the technician's work. The system is based on a prompt-and-response procedure that requires the technician to respond at each stage of the guided process thereby tracking workflow. The documentation is then transferred to the technician's memory stick and presented to the service manager for analysis or payment calculations.

Embedded electronic performance support is provided by devices that are interfaced into the work process. They provide suggestions and relevant information to the user during the performance of work by pushing some information to the user as well as responding to user queries. A simple example of an embedded EPSS system is the ubiquitous word processing software that corrects or underlines misspelled words as one types on the computer. Another type of support is the feature that recognizes the task one is performing and offers to provide support via an intelligent agent. For example, when beginning a new word processing document with "Dear Sir," the intelligent agent may query you to offer assistance by displaying a text box that reads, "It looks like you're writing a letter. Would you like help?"

Intuit's Turbo Tax is another example of a user-friendly embedded support system that prompts users for information and is capable of running complex calculations. An on-line example of a relatively powerful embedded system is found at www.expedia.com. Here, the system responds to information the user provides and seeks clarification when necessary before launching a search for airlines or hotels. A complete "vacation wizard" is also available to provide assistance to those who are "vacation challenged."

A unique aspect of stand-alone or embedded EPSS is the wearable feature. Demonstrated in science fiction and action movies, wearable EPSS devices have been portrayed as miniature display panels in glasses or headbands that provide text and imagery along with tiny ear pieces and microphones that provide voice activated commands or instructions. For these systems to qualify as EPSS as described in this article, they would provide only pre-created information, learned information, or real-time information without the intervention of people.

Wearable EPSS systems are no longer relegated to the movies. A few years ago, researchers at Georgia Tech studied the use of stand-alone wearable computers for task guidance in aircraft inspection. The equipment configuration consisted of very small computer with data storage and voice recognition software worn on a belt, a head strap with monochrome display and a microphone. The task performed by subjects using the EPSS was the external preflight inspection of a Cessna 172. Three experimental groups performed the task from memory, using text, or using photographs taken from the operating manual of the aircraft. Although no significant difference was found among the groups, the observable lack of physical contact with the aircraft by the pilots, who seemed to rely heavily on the EPSS to guide their preflight inspection, prompted researchers to suggest additional study of the task context and environmental context when using EPSS so that users will be able to discriminate between interacting with the EPSS and performing the work task (triton.cc.gatech.edu/ubicomp/614).

Regardless of the degree of embeddedness, EPSS consists of twelve possible support structures for workers. Each is tailored to a related set of work tasks, the level of task complexity varying for each. Imagine each of the following being used to support the multi-step task of replacing a residential hot water heater or performing a pre-flight inspection of a single engine aircraft. These structures, adapted from Gery (1995, p. 52), include:

Cue Cards. Single ideas or small sets of facts.

Explanations or Demonstrations. Mini lessons that explain concepts or processes, or graphical presentations of the effect of variables (heat, pressure, time, etc) on materials.

Wizards, Assistants, or Helpers. Sets of queries and prompts that enable the system to perform relatively complex plans or solutions.

Coaches or Guides. Step by step instructors to perform a task.

Searchable Reference. Presentations of glossary, safety precautions, specification charts, tables, and graphs.

Checklist. Mini check lists of flow charts or processes.

Process Map. Graphical representation of flow charts or decision trees.

Examples. Mini cases representing solutions to similar problems.

Templates. Pre-existing solutions to design or process problems.

Tips. Hints to optimize efficiency, avoid problems or to alert users to unique situations.

Practice Activities. Sample problems or exercises to develop skills.

Assessments. Clusters of questions to be used as self-assessment and/or to engage in some type of pin-point diagnostic.

It is apparent that a great deal of effort goes into the creation of EPSS. Of course, more than a single task-set is supported; related tasks may also be supported. The hot water tank replacement task support would probably be accompanied with support structures for related home maintenance tasks such as replacing a kitchen sink and replacing windows. The variety of support structures provides flexibility for individuals who require specific information, yet can accommodate the individual needs of a number of workers.

The degree to which EPSS can support workers or students is influenced by the means of access a user has to the system, and the level of intelligence built into it. Access is influenced by the type of work the system is supporting and the manner through which the user interfaces and navigates within the system. Devices such as optical scanners, keypads, touch-screens, visual displays or voice controlled devices have unique impacts on navigation within the EPSS. Graphical user interfaces that provide alternative views, multiple reference and access points and contextual feedback - all with text and imagery, is desirable. A “text only” default is rarely adequate. Access points and strategies can vary between novice and experienced users frequently requiring multiple pathways to the same information. For example, if an EPSS were available for diagnosing drivability problems on a motorcycle, it could be embedded into a dynamometer (Maughan, 2005) and provide real-time graphical displays of engine performance while identifying faults when the engine is under different loads and supplying the technician with possible repair strategies.

Levels of intelligence built into EPSS determine how adaptable the interface can be and how the system can acquire new knowledge. According to Janet Cichelli, Chief Technologist, SI International, Inc., five levels of intelligence have been described: static, maintained, standardized, dynamic and intelligent (Cichelli, 2004). A static level of information may be information about specifications, procedures, or frequently asked questions/answers associated with the task. As systems are given the capacity to learn, they progress in sophistication by updating changes in the basic information available and creating more standardized task scenarios of “if this, then this.” These features are very useful to typical users. However, it is the top two levels, dynamic and intelligent, that represent the power of EPSS to adjust to various users’ entry levels and link learned information about the user’s experience in relation to the specific task as well as universal task issues. Truly intelligent EPSS may acquire sufficient knowledge to provide suggestions to overall workflow, previous unconsidered efficiencies, as well as simple task completion information.

Constructed Knowledge and Cognition

Training and education activities are informed by various theories of learning. Although a number of theories may apply, the theory that relates most to the fundamental practice of using EPSS to support the performance of workers and develop a broader technological literacy is constructivism. Constructivists view the learner as actively constructing new knowledge drawing upon pre-existing information and past experiences. As experience is gained and knowledge is built, learning opportunities produce new concepts or ideas (Maughan & Anderson, 2005). Most workers are actively engaged in the learning experience. In addition to engagement through doing, reading, calculating and viewing, collaboration with other learners provides alternate perspectives to consider and adds meaning to new knowledge. In addition, learners bring experiences as consumers or hobbyists to the learning process, helping fill in gaps with new knowledge and facilitating higher order thinking.

Fox (2001) explains that learning constructed by the individual can be achieved in many ways and that the paths to learning are not always compatible. The learner may realize the path they decide to take is incorrect and learn from this mistake; thus, the experience of the mistake has assisted in the learning process. Multiple pathways to information need to be provided for different learners. Facilitating the learner's demand for information, when and in what form the learner prefers, is an important function of EPSS.

Learning requires activity and is best facilitated through action. For example, one can better understand the concept of torque if he/she has turned a torque wrench on a bolt and felt the tension while watching the pointer move across the scale. Technology education and vocational and career tech programs have long recognized the importance of this type of active learning. Most industry training programs are also based on a praxis or doing model. EPSS engages the learner by providing highly relevant information while tasks are performed.

The process of turning information as a commodity into knowledge as it is conceptualized by cognitive scientists involves stringent analysis. On a conceptual level, Brown and Duguid (2000) offer three distinctions: 1. knowledge is associated with an individual, 2. knowledge transfer is not easy, and 3. knowledge acquisition requires assimilation based on the knower's "understanding and some degree of commitment" (p. 120). Obviously, to benefit an organization, knowledge must inform practice. In the workplace, that means that knowledge must contribute to the act of work by an individual or through collaboration with workgroups. The third distinction relates to a direct benefit of the use of EPSS since the learner's assimilation occurs within, and because of, the work situation in which the learner is committed to learning en-route to successful completion.

The potential of achieving higher-level cognition from the use of EPSS is probably dependent on the relationship among working memory, short-term memory (STM), and long-term memory (LTM) (Wittmann & Süß, 1999; Hambrick, Kane, & Engle, 2005). STM is influenced by sensory input of information in the common domains of language, text, sights, sounds and smells. This information remains available to the individual for only a matter of seconds or minutes. The variance among individuals may be influenced by their ability to attend and the nature of what is to be learned (Hambrick, Kane, & Engle, 2005).

Repetition or scaffolding techniques applied to information in STM may cause it to become stored as LTM. Once there, LTM is generally not influenced by time – in fact, it can be theorized that once information is accumulated into LTM it may reside there indefinitely. Problems with LTM usually relate to accessing information and integrating smaller bits of information into larger concepts and principles from which higher-order thinking might occur. Furthermore, the cognitive capacity to plan how to apply information from memory to perform a task, known as executive functioning, can influence the overall effectiveness of using EPSS. These cognitive processes become very important to consider in their relationship to the development of technological literacy through the use of EPSS.

One way LTM may be accessed and integrated is through interaction with others. By communicating across the workgroup, the assimilation of information can result in the evolution of various levels of knowledge (Lave & Wenger, 1993). In their recent book, Salas & Fiore (2004) postulate that a key to understanding work process and performance is team cognition, the collective level of thinking within a group. Recent evidence supports that there exists "direct and indirect relationships between team effectiveness and various operationalizations of common cognitions among team members (Rentsch & Woehr, 2004, p.11).

The construction of technological literacy through the use of EPSS requires an understanding of work tasks, cognitive functioning, and design principles for electronic performance support devices, software, and interfaces. The social learning that occurs in a work or learning environment contributes to individual high-level thinking and team knowledge. Although these variables and subsequent systems are often considered in the workplace, it is important to recognize the potential of EPSS in schools. Most certainly the development of performance systems in business would look different than those in schools (Sleight, 1992). Educators are encouraged to think about the comprehensive nature of EPSS development and select those features and systems that can be created and used in settings that do not have the resources or infrastructure for fully developed systems.

Challenges

Although the challenges to trainers and teachers developing and using EPSS are many, the following describes four categories.

Communication and computer infrastructure

The creation of a seamless EPSS information infrastructure comprised of user access devices, networks, developer skills, application policy, and financial support is a challenge to many organizations (Maughan, 2001). The provision of access terminals or nodes may vary from cabled bench-top computers to wearable wireless devices. Network capacity could range from delivering text-based information to full-motion video warehoused in multi-layered databases and connected to real-time process data. In most cases, the speed of data transfer is very high in order to accommodate multiple simultaneous users. This capability is best served in large organizations by their enterprise system. In such cases EPSS users must undergo training to be able to access the system at a level of proficiency necessary to acquire support for the tasks they perform. In addition, if voice interface is a feature of the EPSS, the user must teach the system to recognize his/her voice.

EPSS development generally requires a multidisciplinary team approach. The situation and degree of use of EPSS must be clarified through policy in order to optimize the potential symbiosis between the EPSS and the user, so that inappropriate application will not result in decreased efficiency in the work process. Structural changes in an organization may occur as trainers and teachers move from a linear paradigm of instruction (training followed by application to work), to a paradigm that includes the traditional linear model as well as models where employees or students also construct knowledge through experience or with the support of performance systems while doing work. Financial resources must be in place for the purchase, development, and maintenance of the system. Alternatives to fully integrated communication and information systems are available to most trainers and teachers. The most fundamental of these are hand held and desktop computers.

Knowledge management

Knowledge management is also a challenge to organizations moving towards the integration of EPSS. EPSS requires that relatively large amounts of knowledge be sorted and organized into smaller chunks and placed in the appropriate contexts of particular work processes. This can be difficult for trainers and teachers. Traditional industry and school curricula tend to treat content in an abstract or formal epistemological fashion independent of applications or work settings. Knowledge management in the support of task performance must be derived from the activity and involves identifying and capturing knowledge, indexing knowledge, and making knowledge available to users in flexible and useful ways (Siemens, 2004). Furthermore, it must be acknowledged that the practice of communicating knowledge across an organization depends on the varying communication patterns of workgroups, that in practice, also vary greatly from organization to organization.

Usability

Trainers and teachers tend to develop an unscientific assessment of the knowledge learners bring to the task of learning advanced or relatively new content. For any task, learners can be categorized in terms of possessing prerequisite knowledge as basic, intermediate, or advanced. This assessment can be verified with pre-test or screening instruments, although this is rarely done in education or industry environments. The task for developers of EPSS is to envision multiple access points within the process during which task support is offered – some at very basic levels, continuing in hierarchical fashion to very advanced levels of entry skills, knowledge and ability. In many cases this is not merely an investigation into a linear continuum of difficulty, but often requires the integration of related attributes and concepts fundamental to achieve success. Ideally, as workers or students perform iterative tasks, information corrections as well as new information needs should be provided to developers so that the support structures can be improved for the next execution cycle (Darling, Parry & Moore, 2005).

Presentation

Performance specialists frequently refer to “The Performance Zone” when developing EPSS (Dickelman, 1995; Degler & Battle, 2001). This zone is the center of a venn diagram that consists of three slightly overlapping circles. These three critical elements enable performance: information appropriate to the task, information appropriate to the person and information containing critical features of the world. By ensuring that each of these features are integrated through the means of a graphical user interface, an EPSS can optimize the efficiency of the support provided to workers or learners. EPSS developers must create a virtual world of work without omitting major human attributes (Dickelman, 1995). As sophisticated as a cleverly designed screen may look, the integrating of information needed to enable a worker to make a decision boils down to presenting the totality of the task, not just bits of information. In essence, the EPSS must process information based on the immediate task and the demands of the user.

Conclusions

Certainly the improvement of organization and individual performance requires a focus on the structure of work and workforce training. Because work task performance generally requires the application of specific skills and knowledge, training often focuses on this level of employee learning at the expense of developing a broader technological literacy. Some argue that this approach might limit decision-making and innovation. Improving human performance through the development of specific skills and knowledge, in addition to broader technological literacy has been a major goal of practioners and researchers. Furthermore, efforts to understand the relationship between support structures for the development of specific skills and knowledge to perform tasks and the development of high cognition levels are on-going. The many disparate attempts to characterize learning organizations and high performance workplaces illustrate this point.

Traditional approaches to developing technological literacy through formal education and training programs must continue and expand. However, EPSS can provide alternative learning opportunities to supplement traditional classroom or training strategies. Today's students may benefit from educational settings and strategies that they will use in the future. In using EPSS to nurture the development of technological literacy, workers and students can achieve higher level cognition skills while they perform tasks. Although there are unique challenges to the development and use of EPSS, efforts to overcome these challenges are becoming more widespread. Additional research in this area could provide trainers and educators with new strategies and tools for performance enhancement.

Dr. George R. Maughan is Professor of Industrial Technology Education at Indiana State University, Terre Haute.

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