CHAPTER 10 Science and Engineering

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This chapter examines various aspects of performance support within the domain of science and engineering. The important characteristics of performance-enhancing task-execution environments are reviewed and a unified support model is presented in order to describe them. Activities in science and engineering involve different degrees of information processing. Information and knowledge support are therefore a crucial aspect of the work undertaken by modern science and engineering professionals. The engineering domain is further complicated by the need to provide performance support facilities that meet the requirements of a wide spectrum of skills and expertise on the part of their users. For this purpose a broad range of support tools and technologies are available to facilitate effective and efficient performance. Various examples of performance enhancement are described and a short case study is presented.

Introduction

In recent years, computers and communication technologies have been increasingly used to facilitate and automate many common tasks that people perform. In fact, nowadays, technology has become almost ubiquitous and people are often unaware of its underlying utility. Consider, for example, the everyday task of withdrawing cash from a bank. Instead of going into a particular branch of the bank and embarking on a face-to-face transaction with a bank clerk, many people now use an ATM – that is, an 'automated teller machine'. This involves inserting an appropriate personal identity card into the machine, using a keypad to enter the access code for the account to be debited and then specifying the amount of cash required. Provided that the access code the customer enters is correct and sufficient funds are available in the customer's account (and in the ATM), the required amount of cash is dispensed almost immediately. In this example, many of the tasks that were previously performed manually by a clerk in the bank have now been replaced by equivalent tasks involving the use of ATM technology. Originally, these tasks involved: using a customer's signature (for identity and account verification), checking and updating the balance in the customer's account and the manual 'handover' of cash to the customer. Nowadays, these operations are all performed automatically using computer and communication technologies. The ATM-based transaction system has removed the need for any face-to-face human interaction (between the bank clerk and the customer) by making the cash withdrawal process an automated self-service activity. One of the advantages of the ATM automation process is the reduction in errors that can arise as a result of shortcomings in unaided human performance (in terms of the mistakes that might be made by the bank clerk). Furthermore, the automated system has enhanced the level of convenience for its customers as a result of increased accessibility – by enabling them to withdraw cash at any time of day and at a wider range of service locations.

The ATM example described above illustrates how the deployment of computer and communication technologies can be used to enhance the performance of both a banking organisation and its customers. This is an important type of application in business and commerce; further examples of applications in these areas are discussed in Chapters 11 and 12. In contrast, this chapter deals with performance support applications in science and engineering. Applications in these areas are becoming more involved and demanding. This has therefore had a significant impact on the performance of the researchers and engineers involved in these areas. Bearing this in mind, the underlying goals of this chapter are: (1) to explore the processes involved in the application of science and then identify possible computer-supported activities where performance support techniques may be applied, and (2) to discuss computer support in engineering processes – particularly those used in industrial contexts. Because of their importance, this chapter describes examples of performance support within each of the above types of application area. It also describes their advantages and offers suggestions for developing appropriate technology-based support facilities within science and engineering settings.

The Unified Model of Performance Support

Originally, the concept of *performance support* was introduced to address problems associated with: improving the ease-of-use of technology-based systems, providing support for task performance and helping to facilitate learning processes. Keeping these requirements in mind, it is widely agreed that performance support systems should have three primary characteristics (Barker and Banerji, 1995):

- they should enable people to perform tasks quickly (because performance-enhancing tools should be able to provide integrated task structuring, data, knowledge and tools at the time of need);
- they should not tax the performer's memory, nor should they require performers to manipulate too many variables; and
- they should enable task completion with learning as a secondary consequence.

Based on the notion of a human-activity system (as described in Chapter 1 of this book), a *unified model of performance support* has been proposed (Banerji, 1999). A fundamental assumption that is inherent in this model is that the tasks to which it refers are all computer mediated. That is, the human activities involved are all 'routed' through appropriate computer and communication facilities. Bearing this in mind, it is important to realise that successful task completion depends on the permeability of the barriers that exist between the person involved in executing a task and the actual task that is being executed (see Figure 10.1).

To improve the permeability to the barriers depicted in this figure, effective performance support will invariably employ a broad range of processes, technologies and methods to support its users. Undoubtedly, the most effective performance support systems will be

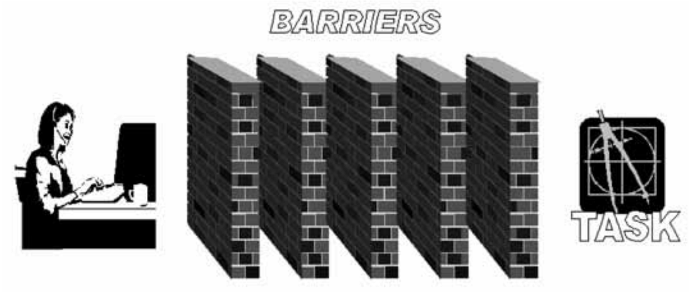

Figure 10.1 Barriers to performance

those that are designed around their users' needs and will thus involve user-centred design principles. Furthermore, such systems will embed processes of incremental improvement which enable continuous ongoing refinement – as a result of feedback relating to the target system's performance.

In a performance support system, many of the constraints imposed by the performance barriers described above can be reduced (if not entirely removed) by 'scaffolding' – that is, the provision of appropriate support infrastructures. Examples of these can be found in use in many diverse disciplines. Typical examples include business systems development, data modelling and processing, management information system design, executive information system design, decision support, expert systems, artificial intelligence, computer-based learning systems, multimedia systems, process modelling/re-engineering, and virtual representation – to name just a few. Generic support tools typically generated by these disciplines include the examples listed in Table 10.1. Within this table each column (A through F) represents a particular generic approach to providing a performance support solution. These six categories do, in fact, represent the complete performance support spectrum – from training to task-automation tools.

Table 10.1 The spectrum of performance support possibilities

A	B	C	D	E	F
Training, e-learning and just-in-time learning facilities	Infobases/ Reference/ Hypertext	Knowledge Management Systems	Workflow Management/ Process Support Tools	Decision Support Tools/Expert Systems	Process automation tools/ Job aids/ Wizards

Within the unified model, the concept of 'performance deficiency' is introduced. This is defined, for any given task-execution process, as the difference between the *ideal state* (excellent task completion) and the *actual state* (which a performer happens to be in during task execution):

performance deficiency = {ideal state – actual state}

Measuring the quantity (*ideal state – actual state*) is central to performance-problem analysis and identifying performance gaps. This requires monitoring the performance of those who solve problems and, where applicable, measuring the effect that their solutions have on overall organisational performance. In this context, the gap (and therefore performance deficiency) can be measured both in quantitative terms (*time*, *quality*, *error count*, *accident or failure rates* and *cost*) and in qualitative terms (*convenience* and *satisfaction level*) – both from the perspective of an employee/problem-solver and an employer/client. Of course, it is also important to consider the *resultant state* that arises after task execution. If, for some reason, it is not possible to achieve the *ideal state*, then the difference between the *resultant* and *ideal* states will reflect a shortfall in performance that may show up as a reduction in quality of the final outcome of task performance. For example, a swimmer who is not able to achieve a previously attained 'personal best' represents a shortfall in performance.

The barriers to performance depicted in Figure 10.1 can arise from a number of sources, for example:

- the gaps that exist in a person's knowledge of the work/problem space;
- a lack of access to relevant information and data;
- an inability to make accurate/correct decisions;
- a lack of understanding of workplace processes;
- an inability to establish personal/organisational goals; and
- an inability to solve problems within the work domain.

Within the context of a human-activity system, performance support can be thought of as a set of processes that are designed to improve the permeability of the performance barriers (see Figure 10.1) which a person encounters as they attempt to accomplish a problem-solving task. In most situations, effective performance support will depend critically upon a designer's ability to: (1) model the task in question; (2) build a profile of the person involved in performing the task; and (3) identify an appropriate performance-improvement intervention. It also involves measuring key performance indicators and using the results of these observations to provide continuously applied corrective actions that support the overall performance of the person who is executing the task. Naturally, improving the permeability of the performance barriers involves continuously measuring a problem-solver's state with respect to their position within the relevant task space. This may require, for example, measuring the time it takes for the person involved to discover a solution (to the problem in hand) plus the time it takes in order for that person to execute the actual solution that has been selected. During the task execution process, the support system must continually compare the actual current system state (at any particular time) with the ideal (target or sought-after) state – and then respond in an appropriate way by providing the information that is needed for emerging states of the system to map on to the ideal state – if indeed, this is feasible.

In many performance improvement situations, corrective action has to be applied in order to realise an improvement in behaviour – this is essentially a 'control situation' from the perspective of using an Electronic Performance Support System (EPSS). In most control situations, positive feedback is used to reinforce the direction of progress to which it refers. Similarly, negative feedback is used to inhibit progress in an incorrect direction. As depicted in Figure 10.2, negative feedback is used to prevent the onset of undesirable states. In this situation, negative feedback leads to corrective action.

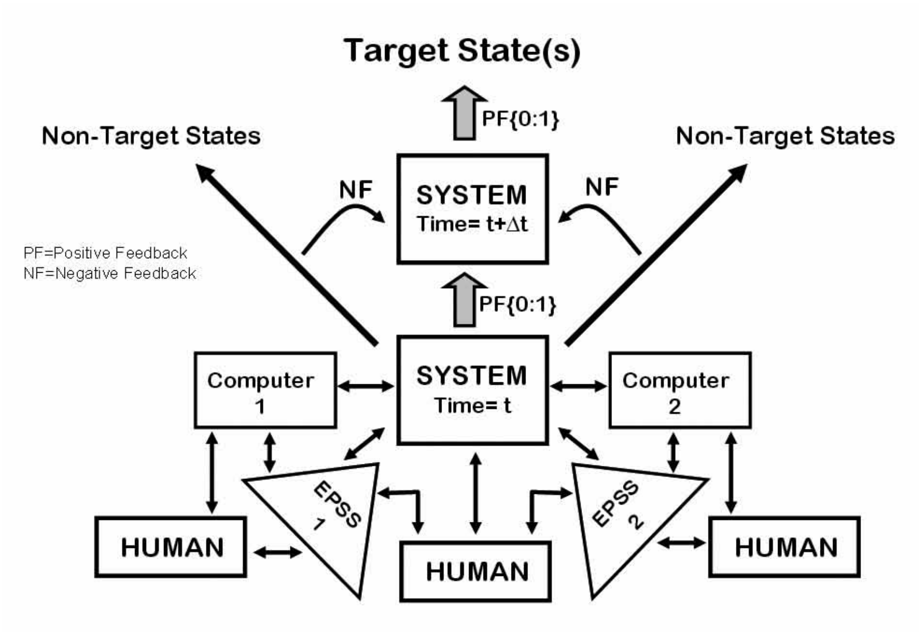

Figure 10.2 Human activity and the unified model of EPSS

Within any human-activity system to which performance support is being applied, it is important to consider the roles played by both the human and the computer components in relation to the realisation of the overall system goals. Thus, in a performance support situation, the human and computer components each represent resources that are available to augment the underlying host system. The ability of the augmented 'system' to complete tasks more accurately and efficiently depends on monitoring, feedback and the application of appropriately designed interventions. Therefore, performance support can be viewed as having been enacted by the unification of human and computer components. Of course, it is assumed that the human component is not fully competent in completing the task in an unaided way. The feedback loop helps to increase competence continuously. The *total* system performance therefore improves continuously – which means that the system's performance improves continuously. In this sense, the Unified Model is an adaptive model, with the human being a variable component. The human-computer collaboration inherent in Figure 10.2 (sometimes this is referred to as human-computer symbiosis) combines the strengths of both human and computer components (as listed in Table 10.2) to optimal advantage.

The forgoing discussion of the unified model of performance support is particularly relevant for the domain of science and engineering. In the following sections of this chapter, the underlying processes involved in science and engineering activities will be examined – with a view to discussing how these can be supported within the unified framework presented earlier in this section. The focus in these sections will therefore be to explore the aspects of performance problems relevant to science and engineering activities. Broadly, the performance problems for each of these domains are more or less similar – as shown in Figure 10.3. This diagram will be the starting point to investigate and reveal the aspects of support required for scientific activities.

Table 10.2 The properties of the primitive components of an EPSS system

	Strengths	Weaknesses
Humans	Pattern recognition Selective attention Capacity to learn Infinite LTM[b] capacity Multiple type data in LTM	Low STM[a] capacity Decaying memory Slow processing Error prone Unreliable access to LTM
Computers	High-capacity memory Permanent memory Fast processing Error-free processing Reliable memory access	Weak even in simple template matching Limited learning capacity Limited capacity LTM Limited data integration in decision making Inefficient pattern recognition

*Sour*ce: Adapted from Banerji and Ghosh, 2010.

[a] Short-Term Memory; [b] Long-Term Memory.

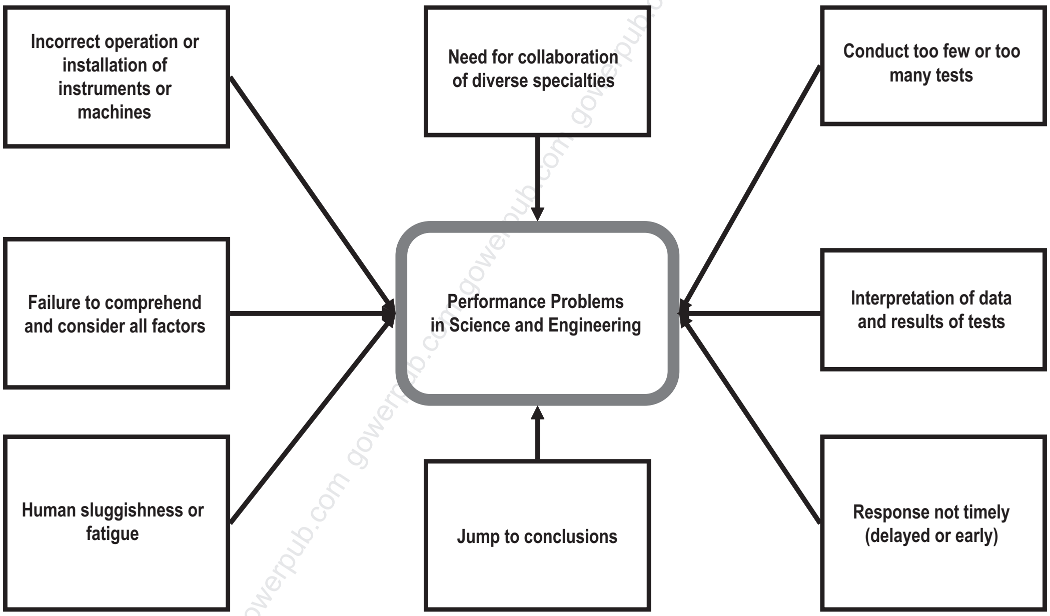

Figure 10.3 Performance problems in science and engineering practices

Performance Support in the Science Domain

Science is a branch of knowledge or study dealing with a body of facts or truths systematically arranged and showing the operation of general laws. It is systematic knowledge of the physical or material world gained through observation and experimentation.[1] Scientists create knowledge. They study the world and seek to understand and explain natural

1 Useful definitions of the terms 'science' and 'scientific method' can be found in online resources such as *http://dictionary.com* and *http://www.reference.com*.

phenomena. Thus scientists are trained in scientific methods which involve the design of experiments to test theories. This is a complex process because it does not always follow any fixed path. There are many possible strategies in any scientific investigation. However, it is evident that scientists build on previous work and current knowledge. For this reason, open communication among scientists is very important. In fact, three of the remarkable approaches and technologies developed in the last century were basically targeted at meeting this need. These involved: first, the concept of hypertext – proposed by Vannevar Bush (1945) – which evolved out of the need to promote information access between scientists engaged in nuclear research in the USA during the Second World War; second, the development of the Internet (Internet Society, 2007); and third; the subsequent creation of the World Wide Web. These latter two developments[2] also evolved out of the need to support collaborative communication between researchers and scientists (Berners-Lee, 1989).

Scientific activity usually involves searching for a cause for a given effect or phenomenon. The key steps involved in the process of science are: (a) making observations; (b) asking questions; (c) forming hypotheses; (d) making predictions; and (e) conducting tests or experiments. Often the first step in the scientific process is an observation of some phenomenon. The observation process then leads to a question such as 'Why did it do that?' or, 'What made that happen?' These questions might suggest an answer or an explanation. Any possible explanation is called a hypothesis. This process is often called inductive reasoning. Quite often a number of specific observations may lead to the formulation of a general hypothesis. If the hypothesis is sound, it should allow 'predictions' to be made. Thereafter, tests and/or experiments are performed to confirm the hypothesis or refine it further – based on the generalised results of the tests that are made. Finally, theories or laws can be formulated. The method of scientific investigation described above involves the application of five basic categories of scientific skill. These are listed in Table 10.3. The skills (and tasks) listed in this table form the foundation of problem solving in science and the underlying scientific methods that are employed.

Table 10.3 Categories of scientific skill and their associated tasks

Acquisitive	Organisational	Creative	Manipulative	Communicative
Listening	Recording	Planning ahead	Using instruments	Questioning
Observing	Comparing	Designing	Demonstrating	Discussing
Searching	Contrasting	Inventing	Experimenting	Explaining
Inquiring	Classifying	Synthesising	Constructing	Reporting
Investigating	Organising	Inferring	Calibrating	Writing
Gathering data	Outlining	Predicting	Measuring	Criticising
Researching	Reviewing	Hypothesising	Interpreting	Graphing
	Evaluating			Teaching
	Analysing			

Source: Adapted from Trowbridge et al., 2000; Bobrowsky, 2007.

2 The Internet is the name given to an international network of computer systems. Running on top of this underlying hardware/software configuration is a whole range of applications – one of which is the World Wide Web.

Communication among scientific communities is an essential part of the inquiry process. The values of independent thinking and reporting the results of observations and measurements are essential in this regard. Mental models of the thinking processes are an integral aspect of scientific inquiry. These processes include inductive reasoning, formulating hypotheses and theories, deductive reasoning – as well as the use of analogy, extrapolation, synthesis and evaluation. The choice of experiments (or models for exploration) and subsequent data collection, ordering, structuring and analysis of data are just some of the essential processes that can be facilitated through the appropriate use of the performance support techniques described in this chapter and elsewhere in this book. Indeed, computer-based support has become necessary for most of the tasks presented in Table 10.3 due to the increasing complexity of the science domain. Figure 10.4 illustrates some of the typical classes of performance problem that scientists often face. It also shows some of the possible causes of these problems and the types of support needed for solving performance problems in this area.

Information access, support for collaboration, decision support and experimental support for testing and calculation are the main areas of science where computers can be used to aid and facilitate the scientific skills and tasks shown in Table 10.3. The way in which scientific inference and decision making can be supported is illustrated by websites such as '*Which Test?*' (*http://www.whichtest.info/index.html*) and '*The How To Guides*' (*http://www.statsguides.bham.ac.uk/HTG/HTG_Home.htm*). These examples of performance support for statistical data analysis have been described earlier in Chapter 2 of this book.

Another example of how computers have become an essential tool in scientific exploration is the Human Genome Project (Braun et al., 2003). The objective of this project was to determine the complete nucleotide sequence of the human genome. This process involved approximately three billion nucleotides of the human genome. Addressing these challenges required the use of high-performance computing techniques (Braun et al., 2003). As a result of widespread international cooperation and advances in the field of genomics (especially in sequence analysis), as well as major advances in computing technology, a 'rough draft' of the genome was finished in the year 2000. There are currently hundreds of databases containing biological information that may contain data relevant to the identification of disease-causing genes. Interested readers will find detailed discussion of the computational process in the paper by Swidan et al. (2006). The genetic sequence of human DNA is now stored in databases that are available to anyone who has Internet access (see, for example, *http://www.ncbi.nlm.nih.gov*). These have been used in developing useful performance-enhancing tools that are now within easy reach of researchers in this area. An example of such a tool is the electronic Polymerase Chain Reaction (e-PCR). This PCR technique is now an absolutely routine component of practically every molecular-biology laboratory. e-PCR empowers scientists by providing them with a flexible alternative for the conventional method. It is a computational procedure that is used to identify Sequence-Tagged Sites (STSs) within DNA sequences (*http://www.ncbi.nlm.nih.gov/sutils/e-pcr/*). The *NCBI GenBank* is an excellent example of computer support for biologists and genetic scientists. Naturally, knowledge discovery using these databases holds enormous potential.

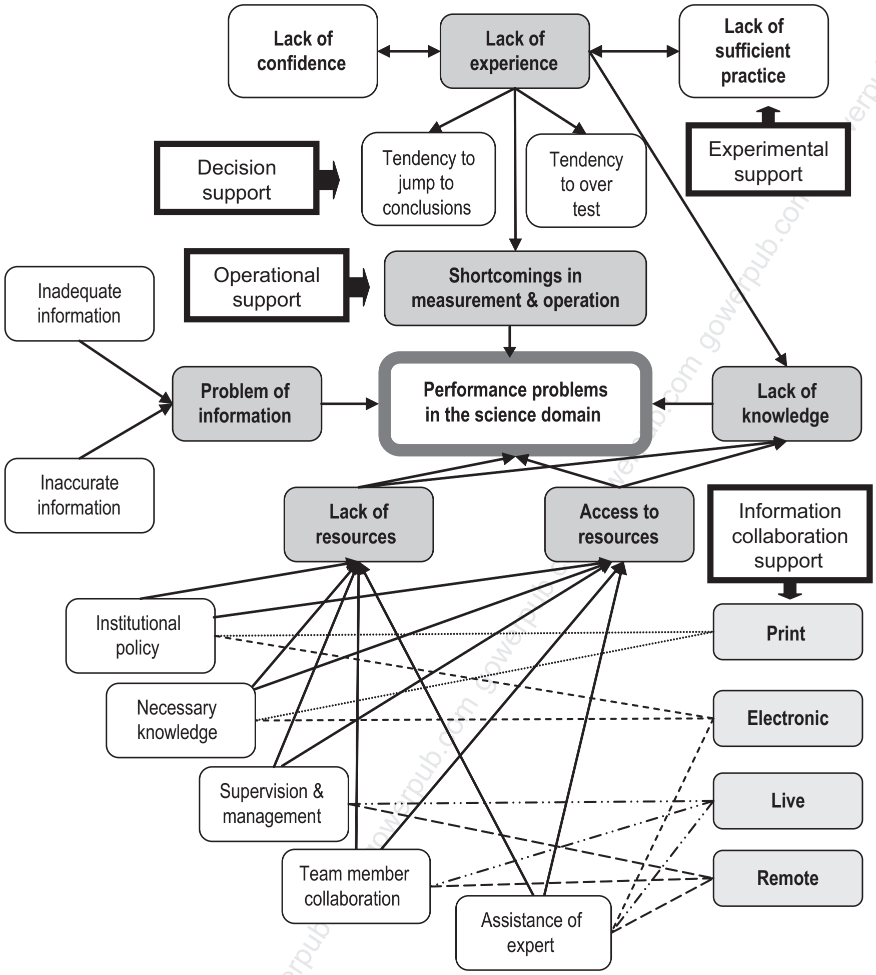

Figure 10.4 Typical performance problems arising in the science domain

Performance Support in the Engineering Domain

Originally, engineering meant the art of managing engines. In its modern and extended sense, engineering is the art and science by which the mechanical properties of matter are made useful to humans in structures and machines.[3] Indeed, according to Barker,[4] '*In its very broadest sense, the discipline of engineering is concerned with that body of knowledge (both theory and practice) that is relevant to the design and fabrication of real-world artefacts arising from human endeavour.*'

Engineering is a problem-driven discipline. Engineers apply the knowledge created by scientists and create engineering knowledge. They design and build devices or machines

3 A useful definition of the term 'engineering' and a description of the methods it employs can be found in online resources such as *http://dictionary.com* and *http://www.reference.com*.

4 This definition is based on a personal communication entitled 'On the Nature of Engineering' that was sent to Bani Battacharya and which was reproduced in a paper that was published in 2008 in the journal *Innovations in Education and Teaching International*, 45(2), p. 93.

and operate these for improving the quality of human life in general. With the development of human knowledge-engineering, engineering processes are also getting complex. In many situations, this has necessitated the use of human-computer symbiosis as well as computer-based process automation. In fact, the early references to performance support systems were concerned with supporting engineering processes such as: the Integrated Circuit (IC) chip manufacturing processes in Intel (Gery, 1991), the Service Diagnostic System in the Ford Motor Company (Bielawski and Lewand, 1991), just-in-time help in Renault (Pring, 1992) and the creation of simulation-based performance support tools for the marine industry (Banerji and Bhandari, 1997).

Broadly, engineering processes that often require support include activities such as design, development, operation, testing, fault diagnosis, repair and maintenance. In all these areas the chief concern is usually reducing the probabilities of error. Within many systems, errors can arise as a result of the inherent weaknesses of the human components of the system, for example, a lack of responsiveness ('sluggishness'), forgetfulness, inability to comprehend, and many others (such as those listed in Table 10.2). In particular, limitations in a human's ability to perceive, attend to, remember, process and act on information are all potential sources of error within systems in which there is a human element. Stranks (2006) outlines a number of factors which can contribute to human error. These include: *inadequate information, lack of understanding, inadequate design, lapses of attention, mistaken actions, misperceptions, mistaken priorities* and *wilfulness*. A diagram that illustrates some of the different types of performance problems that can arise within engineering systems is presented in Figure 10.5.

An appreciation of the causes of error is important because they are significant sources of performance problems, performance shortcomings and accidents in the workplace. It

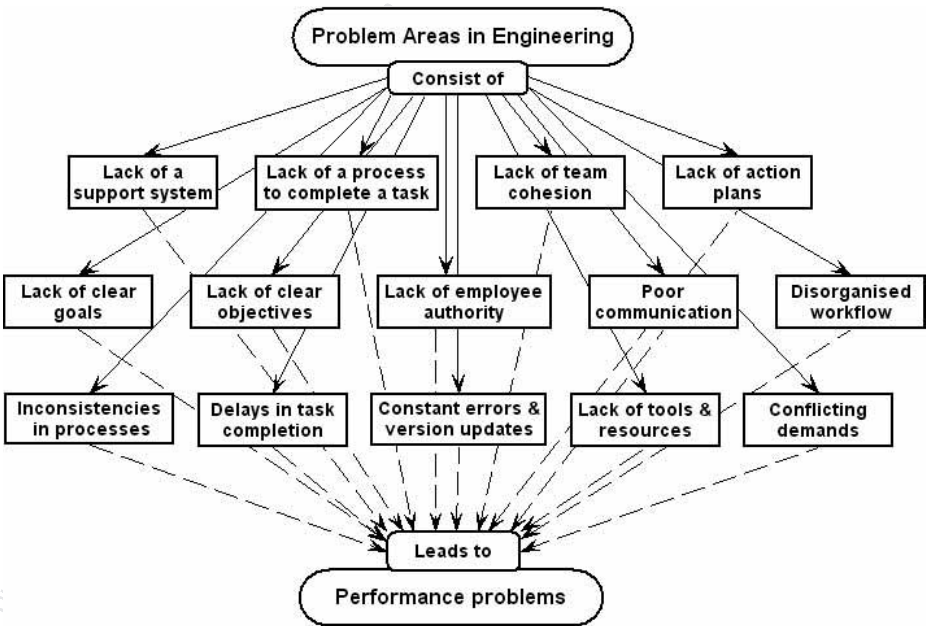

Figure 10.5 Potential application areas for performance support in engineering

has been estimated that up to 90 per cent of all workplace accidents arise as a result of human error (Feyer and Williamson, 1998). Bearing this in mind, performance support interventions for engineering processes will usually include strategies for reducing errors that arise from the following six sources: (1) learning-gap; (2) memory-gap; (3) inconsistency; (4) application; (5) decision making; and (6) omission. Performance support interventions for use in an engineering context could include appropriate combinations of the generic types of tool that were previously listed in Table 10.1.

Various computer-based performance-enhancing support systems for engineering applications are available from a number of different sources. For example, simulation tools like *MATLAB*[5] *(http://www.mathworks.com/)* and *LabVIEW* (*http://www.ni.com/labview*) and design tools such as *AutoCAD* (*http://www.autodesk.com*), and many others, now greatly simplify the *design* process within engineering projects. In addition, many of these tools allow engineers to visualise new products and test their performance before actually building them. Another example, the *Supervisory Control And Data Acquisition* (SCADA) system greatly simplifies engineering-plant *operation*. Such systems collect data from various sensors at a factory, plant or other remote location and then send this data to a central computer which then manages and controls the plant while displaying data at a supervisory control desk. Engineering *maintenance* tasks are aided by *monitoring* the state of the equipment. For example, computer-based vibration analysis of rotating equipment alerts the operator about the possible need for preventive maintenance when the vibration goes beyond a set limit.

Fault diagnosis and repair is another class of problem that often challenges engineers. A typical fault diagnosis process is presented schematically in the diagram shown in Figure 10.6.

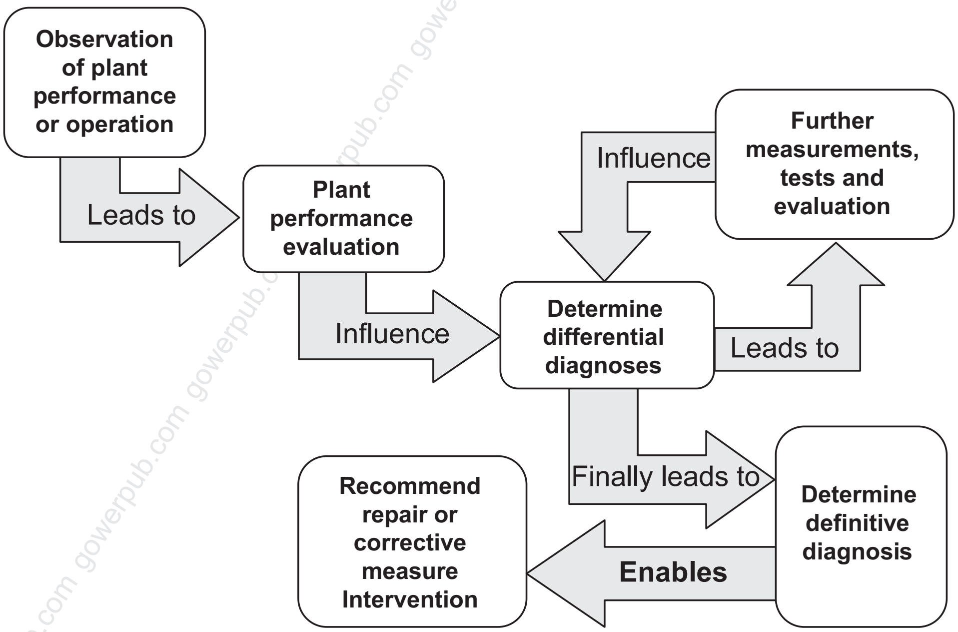

Figure 10.6 Flow diagram to facilitate problem diagnosis in a process plant

5 Please see also Chapter 13 in this volume for further details about applying performance support techniques when using MATLAB.

Depending upon the level of sophistication of the equipment involved, the diagnostic processes that need to be applied can become quite complex. In order to combat this complexity, most of the functions depicted in Figure 10.6 would be augmented through the use of appropriate performance support tools. As a way of facilitating this, a considerable amount of effort has been devoted to developing computer-based maintenance systems. One example of such a system is the *Advanced Integrated Maintenance Support System* (AIMSS) from Raytheon (*http://www.raytheon.com/capabilities/products/aimss/index.html*). AMISS is an Interactive Electronic Technical Manual (IETM) authoring tool set. It uses an object-oriented database that can store, retrieve and display information, data and documentation relating to the particular engineering systems for which it is being used. Diagnostic information that is needed by an engineer can be displayed on a workstation or on an engineer's personal computer. Systems of this sort can also be augmented by the use of an expert system, a decision support system, knowledge management tools and case-based reasoning techniques to create an integrated fault diagnosis system. Such a system could be based on the use of the unified performance support model that was described earlier in this chapter. The case study described in the next section will elaborate on this.

Case Study – Battery Maintenance

This case study illustrates how the ideas discussed in the previous parts of this chapter can be brought together to create an operational performance support system. The case study is based on the work of Gerald Damschen (2008) as related to the author of this chapter, while Damschen was a student at Jones International University.[6]

BACKGROUND

As a young petty officer in the Navy, Damschen was assigned responsibility for the maintenance of the back-up batteries on a nuclear submarine. The availability of a reliable back-up power source is critical for ships of this sort. Back-up power is provided by large powerful storage batteries that are carried on-board the ship. These batteries require continuous monitoring and maintenance so that they stay at peak capacity. They are frequently charged and discharged to prevent their capacity loss. The underlying reason for this is similar to the 'memory' effect (that is commonly seen in rechargeable laptop batteries) which causes severe reduction in their capacity. Each charge and discharge cycle of the submarine's batteries requires numerous calculations to characterise their condition.

DEVELOPING A JOB AID

When Damschen took over the duties, the calculations were performed manually and recorded in a log book. He followed the procedure like many of the petty officers before him but soon he began looking for an alternative way to perform the tedious calculation

6 Further details about the history and current role of Jones International University are given in the *Wikipedia* online encyclopaedia at: *http://en.wikipedia.org/wiki/Jones_International_University*. [Accessed: 29th January, 2009].

tasks that sometimes had to be carried out multiple times a day. As a solution he wrote a simple computer program to do the calculations on a personal computer. This allowed him to enter all of the measurements that had been taken; it would then display them on the computer's screen so that he could verify their correctness. Thereafter, the computer program performed various calculations which were previously done manually. Thus he off-loaded the calculation tasks to the computer. This decreased the possibility of calculation errors, freed him of the time that was earlier required for calculations and made him more efficient since the task could be completed more quickly. Thus, in its first incarnation, Damschen's battery calculation program was a simple procedural *job aid* serving as a performance support tool.

AN INFORMATION MANAGEMENT TOOL

As the ship's batteries were nearing the end of their normal life, he had to monitor them more closely. Often he had to respond to the Captain's critical questions and submit details of the batteries' conditions and their performance trends. Answering these questions required going through historical data, searching through the battery log and performing additional calculations. To simplify these tasks he wrote another computer program to store the results of the calculations to a disk and display the data as graphs for easy visualisation of the trends. This allowed him to retrieve data as needed for whatever period, present these in the required format and observe the trend. Thus, in its second incarnation the battery calculation *job aid* became a simple *information management system* that stored information about the ship's batteries and helped in task performance.

A KNOWLEDGE MANAGEMENT SYSTEM

Satisfied with the results of the battery monitoring program and its ability to easily identify trends, Damschen began to look for reasons for the trends. At one point he found that part of the battery was not performing as well as the rest. While looking for the reason he could not make sense of the readings. Finally, he realised that the information about the different battery blocks as recorded and displayed on the screen of his computer was actually different from the way the batteries were physically installed. The discrepancy looked somewhat similar to the location arrangement shown in Figure 10.7 (a) and (b).

Thus, correspondence of the physical location of the batteries with those used for analysis caused confusion. To solve this problem, Damschen added another component to his program; this created three-dimensional graphs of the parameters ordered in the way the battery parts were physically installed in the ship (Figure 10.7b). With this revision, the location and cause of reduced capacity became visually clear – there was a problem with the part of the system that kept the battery acid mixed. The graph showed the exact location of the problem and indicated which one needed to be fixed. In addition to the revised display, he added another component to the program for storing notes, observations and experiences. So, in the third incarnation, the *information management system* evolved into a *knowledge management system* supporting the battery maintenance and monitoring task.

1	2	3	4	5
6	7	8	9	10

(a)

1	2	8	7	5
10	9	3	4	6

(b)

Figure 10.7 (a) Location arrangement of batteries as recorded and displayed on the computer screen and (b) the actual physical location arrangement of the batteries

THE FINAL ELECTRONIC PERFORMANCE SUPPORT SYSTEM

Eventually, when it was time for Damschen to leave the ship he gave the final touch to the system by adding additional components to the program. He knew that his replacement would not have much time to learn about the battery system before taking over the duties so he made a digital battery manual which could be easily searched and referred to; it could also provide a quick 'newcomer' orientation. Damschen also converted the troubleshooting section of the manual into electronic form and linked it to the calculation program. He created triggers in the program to alert its user to any out-of-specification readings discovered during the calculations. The software could then 'step' the user through the appropriate troubleshooting process to correct the problem. So finally, the knowledge management and performance support system became a full-featured *EPSS* that incorporated information support, procedural support and support for decision making, coaching, learning and job aids.

The benefit of the program was acknowledged by the ship's Captain who remarked that the battery maintenance system had added several months to the life of the ship's batteries and allowed the submarine to meet additional commitments that would not have been possible otherwise. The improved performance saved the Navy several million dollars by not having to take the vessel out of service prematurely in order to replace its batteries.

EPILOGUE

The system worked very well for Damschen because it was designed to perform tasks he needed to do – in the way that he preferred to do them. He visited the ship a little over a year after his transfer. He enquired how his successor was using the battery maintenance system – a system that he developed so elaborately. To his surprise the reply was that his replacement had not used it because he was not comfortable with computers. Moreover, he did not have time to learn how to use it, and he did not really see much use for it anyway. Thus, a very well-developed performance support system was left unused!

The EPSS was designed by the user around his work process but it was not made a part of the work-process policy. The subsequent user did not have any input into the design of the software, therefore, he did not understand how it could help him. Also, he was not motivated to work differently, unlike his predecessor. The software was not designed around its user, and in the absence of management policy, it went unused and was discarded. By not involving all the possible users, the design was not user-centered.

Thus a successful system had fallen victim to the common problem of EPSS design and implementation.

THE MORAL OF THE STORY

When planning for the integration of an EPSS into the daily life of workers, it is crucial to begin with a user-centred approach and involve users early and often in the process of designing the EPSS. Adopting such an approach is likely to minimise misconceptions about the intended uses and roles of the EPSS.

Conclusion

Great breakthroughs in science are made through systems of scientific enquiry. These have led to new ways of thinking about and understanding both the natural and artificial systems that make up the Universe. Undoubtedly, advances in science have helped to address many of the problems encountered in (and have contributed to) the development of engineering and technological practices. As the complexities of both science and engineering processes have increased, the need for computer support – both as a means of understanding them and of controlling them – has become very evident. Indeed, without the synergy that exists between computers and human minds, many of the scientific and engineering feats that have been achieved in the modern world would not have been accomplished. However, most of these developments have evolved as a consequence of attempting to use available technology in an ad-hoc way to meet performance needs. These developments have lacked a coherent and integrated design framework – similar to that which is embedded in the unified model of performance support that has been outlined in this chapter.

Because of the potential that it has as a basis for designing EPSS, this chapter has reviewed the unified model of the performance support concept and has illustrated areas in which the model may be used. In order to do this, the characteristic processes involved in scientific investigations have been identified and examples have been given of how computer-based performance support tools may contribute to the different activities involved in this domain. A similar approach was then adopted for the characteristic activities involved in the engineering domain. Finally, a simple case study was then presented to illustrate the way in which an EPSS can evolve in an incremental fashion using a step-by-step engineering approach.

Of course, it is important to realise that the type of performance support that is used in the science domain is fundamentally different from that required in engineering. This is due to the nature of the activities involved and the people who participate in them. Scientific activities mainly require knowledge and information support. However, the activities involved in engineering often require a wider range of support functions – because the target users range from 'white collar' to 'blue collar' – each varying in knowledge and skill levels. Naturally, in situations of this sort, appropriate performance support design would benefit from the application of the unified support model together with a judicious mix of the toolsets listed in Table 10.1 (p. 195). To facilitate this objective, the set of ten EPSS design principles identified by Barker and Banerji (1995) and Banerji and Scales (2005) may prove useful. Eventually, this may lead to the vision of HAL (Clarke,

1968) as a ubiquitous performance support environment, reducing, if not eliminating, every possible performance gap within a given target system.

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References

Banerji, A. (1999). Performance Support in Perspective. *Performance Improvement Quarterly*, 38(7), 6–9. Available online at: h*ttp://www.pcd-innovations.com/piaug99/PSinPerspective.pdf*. [Accessed on: 27th January, 2009].

Banerji, A. and Bhandari, R. (1997). Designing EPSS for the Marine Industry. *International Conference on Computers in Education*, December 2–6, 1997, Kuching, Sarawak, Malayasia. Available online at: *http://www.sp.edu.sg/resources/images/schools/sma/papers/epss.pdf* [Accessed on: 29th January, 2009].

Banerji, A. and Ghosh, A.M. (2010). *Multimedia Technologies* (Chapter 13). New Delhi, India: Tata McGraw Hill.

Banerji, A. and Scales, G.R. (2005). Interactive Multimedia for Learning and Performance. In S. Mishra and R.C. Sharma (eds), *Interactive Multimedia in Education and Training* (pp 47–59). Hershey, PA: IGI Publishing.

Barker, P. and Banerji, A. (1995). Designing Electronic Performance Support Systems. *Innovations in Training Technology International*, 32(1), 4–12.

Berners-Lee, T. (1990). Information Management: A Proposal. CERN March 1989, May 1990, W3 Archive. Available online at: *http://www.nic.funet.fi/index/FUNET/history/internet/w3c/proposal.html*. [Accessed on: 29th January, 2009].

Bielawski, L. and Lewand, R. (1991). *Intelligent Systems Design – Integrating Expert Systems, Hypermedia, and Database Technologies*. New York, NY: John Wiley and Sons.

Bobrowsky, M. (2007). *The Process of Science and its Interaction with Non-Scientific Ideas*. Washington DC: The American Astronomical Society. Available online at: *http://aas.org/files/The_Process_of_Science.pdf* . [Accessed on: 29th January, 2009].

Braun, T.A., Scheetz, T.E., Webster, G., Clark, A., Stone, E.M., Sheffield, V.C. and Casavant, T.L. (2003). Identifying Candidate Disease Genes with High-Performance Computing. *The Journal of Supercomputing*, 26(1), 7–24.

Bush, V. (1945). As We May Think. *Atlantic Monthly*, July issue. Available online at: *http://www.theatlantic.com/doc/194507/bush* [Accessed on: 29th January, 2009].

Clarke, A.C. (1968). *2001: A Space Odyssey*. New York, NY: The New American Library.

Damschen, G.A. (2008). *Designing Information and Performance Support Systems*. EDU652 Course project for the M.Ed programme. Centennial, CO: Jones International University.

Feyer, A.M. and Williamson, A.M. (1998). Human Factors in Accident Modelling. In Stellman, J.M. (ed.), *Encyclopaedia of Occupational Health and Safety, Fourth Edition.* Geneva: International Labour Organisation.

Gery, G.J. (1991). *Electronic Performance Support Systems – How and Why to Remake the Workplace Through Strategic Application of Technology*. Boston, MA: Weingarten Publications.

Internet Society (2007). Histories of the Internet. Available online at: *http://www.isoc.org/internet/history/* [Accessed on: 30th January, 2009].

National Center for Biotechnology Information (NCBI) Details available online at: *http://www.ncbi.nlm.nih.gov/*. [Accessed on: 30th January, 2009].

Pring, I. (1992). *Digital Vision DVI Project Directory*. London, UK: Digital Vision International.

Stranks, J. (2006). *Health and Safety Handbook: A Practical Guide to Health and Safety Law, Management Policies and Procedures*. London: Kogan Page.

Swidan, F., Rocha, E., Shmoish, M. and Pinter, R. (2006). An Integrative Method for Accurate Comparative Genome Mapping. *PLoS Computational Biology*, 2(8): e75. Available online at: *http://www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.0020075*. [Accessed on: 26th September, 2009].

Trowbridge, L., Bybee, R. and Powell, J. (2000). *Teaching Secondary School Science: Strategies for Developing Scientific Literacy*. UpperSaddle River, NJ: Prentice-Hall. [Cited in *Building Science Process Skills* by A.V. DeFina, The Science Teacher, January 2006, 36–41.]