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# COGNITIVE TECHNOLOGY EXTENDS THE WORK ENVIRONMENT AND ACCELERATES LEARNING IN COMPLEX JOBS

Sherrie P. Gott

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HUMAN RESOURCES DIRECTORATE
MANPOWER AND PERSONNEL RESEARCH DIVISION
7909 Lindbergh Drive
Brooks AFB, Texas 78235-5352

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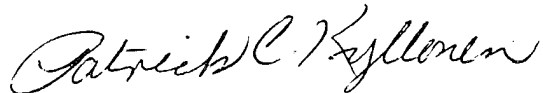
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SHERRIE P. GOTT, Ph.D.
Project Scientist
Manpower & Personnel Research Division

PATRICK C. KYLLONEN, Ph.D.
Technical Director
Manpower & Personnel Research Division


GARY D. ZANK, Colonel, USAF
Chief, Manpower & Personnel Research Division

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Instructional technology that is grounded in cognitive theory is used as the medium to accelerate the acquisition of complex problem solving skills. The use of an intelligent tutoring system to teach troubleshooting literally expands the learning environment by providing a simulated representation of the actual work environment where trainees work a graded series of troubleshooting scenarios. Scenarios are sequenced to promote successive approximations of mature practice as trainees work more and more difficult problems in the "forgiving" tutor environment, where they learn by doing and reflecting on their own solution vis-a-vis an exemplar master solution. In a controlled experiment, experimental apprentice subjects outperformed their control counterpart on the two Verbal Troubleshooting Posttests (t[39]= -4.04, p = .000; t[39] = -3.72, p = .001) and on the paper and pencil posttest (r[39] = -2.77, p = .009). After tutoring, scores obtained by apprentice subjects (having about 3 years' AF experience) rivaled those of Master technicians having over 10 years' experience in F15 avionics maintenance. The dramatic results are attributed to (a) cognitive models as input to instruction; (b) the sequence of instructional events; (c) situated learning in a constructivist instructional environment, and (d) the sociology surrounding the learning system. Topics (c) and (d) are discussed with special attention.

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# PREFACE

I am indebted to the hundreds of F15 avionics technicians at Langley AFB VA, Eglin AFB FL, Luke AFB AZ, and Nellis AFB NV whose expertise and conscientious dedication to their mission as aircraft maintainers have made this work possible. I am especially indebted to the three among their number who came to work with us in our Laboratory on this project: MSgt Mark Gallaway, MSgt Ron Kane, and TSgt Dennis Collins. They quickly became valued scientific colleagues as well as subject matter experts. Thanks is due as well to the HQ TAC/LG (now HQ ACC/LG) staff for their long-term support of the Basic Job Skills (BJS) scientific enterprise.

The quality of the science in this and every other BJS product has been immeasurably enhanced by contributions from our troika of eminent scientific advisors: Dr. Robert Glaser (chair), University of Pittsburgh; Dr. David Kieras, University of Michigan; and Dr. Robert Linn, University of Colorado.

Finally, we dedicate this report and others in the BJS series to Gen. Henry Viccellio, Jr., without whose vision and stalwart support this work would have never reached fruition and made the difference it has in the Air Force maintenance community.

# Cognitive Technology Extends the Work Environment and Accelerates Learning in Complex Jobs

## INTRODUCTION

Scientists at the Air Force Human Resources Directorate of the Armstrong Laboratory recently completed a long-term program of research and development (10+ years) investigating issues of technical competence in modern Air Force workcenters. We directed our investigation at examining human problem solvers in real-world, machine-laden work environments -- our goal being to improve our understanding of the man-machine interaction that results in technical expertise. The premise is that with greater understanding, we can build better training and make personnel resource-related decisions that are more responsive to high-tech performance demands. Better training has the potential to accelerate the rate of complex skill acquisition, and further, if training focuses on the components of skill that are common to a range of complex tasks, it becomes possible to equip technicians with generalizable skills -- i.e., a technical flexibility that greatly increases the value of human capital in an era of rapid technological change and diminishing resources.

## Background

Our research strategy unfolded in four stages of investigation, as follows: (a) during a pilot testing phase, we observed and interviewed F15 avionics technicians/troubleshooters at varying levels of proficiency and selected a separate sample of airmen to participate in a proof of concept experiment; (b) based on preliminary findings, we developed, tested, refined and applied a formal cognitive task analysis (CTA) methodology to use in eliciting from experts the components of skill needed for this domain (Gott, 1987; Gott, Bennett, & Gillet, 1986; Hall, Gott, & Pokorny, in press; Means & Gott, 1988); (c) we codified the output of the task analysis and then used it as input to the development of an intelligent tutoring system for avionics troubleshooting; and (d) we evaluated the tutor in a controlled experiment at three operational F15 flying wings (Gott 1989; Gott, Pokorny, Kane, Alley, & Dibble, in preparation).

The results of the cognitive task analysis studies, which involved hundreds of airmen, revealed patterns in realistic problem solving performance across a range of troubleshooting tasks and human proficiency levels. With these data we were able to formulate a *model* of technical performance that has guided our intelligent tutor development. An abstracted representation of the model is shown in Figure 1. The model highlights the important interplay among (a) strategy, (b) tactics (procedures) and (c) conceptual (system) knowledge. The **Strategic Knowledge** component sits on top of and controls the two remaining interactive components -- **Procedures** (tactics or operations) and **System Knowledge.** This configuration as a model of technical performance posits that a top-level plan or strategy deploys pieces of system knowledge and procedural

subroutines as needed and as driven by strategic decision factors such as time, effort, payoff, and resource efficiency. Troubleshooting is thereby represented as multilevel, complex decision making, which involves choices among various top-level and intermediate-level strategies, tactics, and system views.
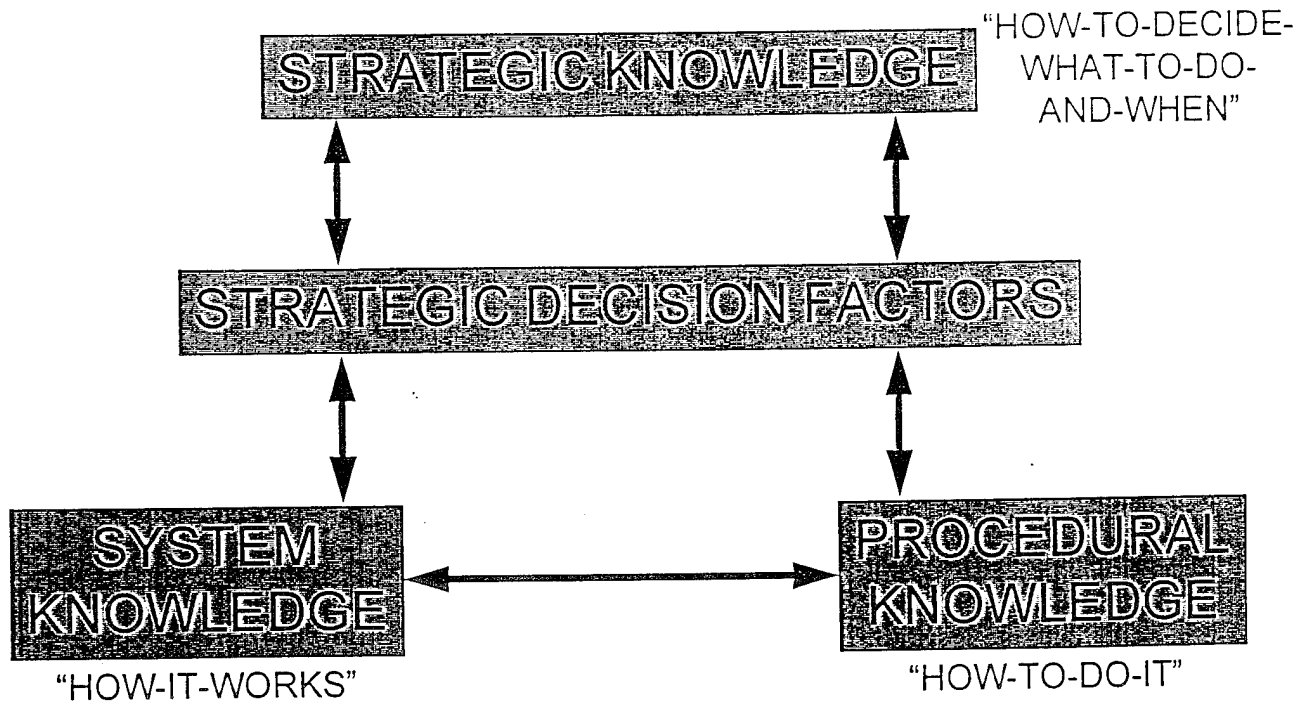


**Figure 1. Cognitive Skills Architecture**

## Method

*Tutor Development*

Given the targeted models of expertise revealed by the cognitive task analysis, i.e., electronic troubleshooting as multi-component, complex decision making, we knew that to be effective instructionally, the learning environment had to be robust. (In the real world, expertise of this type takes 8 to 10 years to develop.) We adopted the following multifaceted principle of learning as the foundation for instructional design: in complex diagnostic tasks, mental models (system knowledge) as well as procedural and strategic knowledge are **constructed** as students interact with the full context of the work environment, practicing shop procedures and fault isolation operations in response to realistic troubleshooting scenarios. Trainees receive support from coaching, which they access as needed. To culminate the process, learners **reflect upon** their solutions considering their strengths, diagnosing their weaknesses, and contemplating **model**

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solutions of Masters. In short, this principle calls for a situated, supported learning environment, which we have termed **coached apprenticeship.**

Pedagogically, the tutor (called Sherlock) functions as a coached, practice environment where students "learn by doing" electronic troubleshooting. They encounter high difficulty fault isolation tasks which they pursue in a computer learning environment that is an extension of their real world work environment (situated learning.) In the real world, technicians in this domain repair and maintain electronic subsystems and selected test equipment for the F15 aircraft. When a line replaceable unit (LRU or black box) is removed from the aircraft on the flightline because of a suspected malfunction, it is sent to technicians in the repair shops. Upon arrival it is attached via connecting cables (or similar apparatus, referred to as the Test Package) to a large piece of test equipment known as a Test Station. The LRU is then referred to as a Unit Under Test, or UUT. Figure 2a shows a top level diagrammatic view of the complete equipment system.
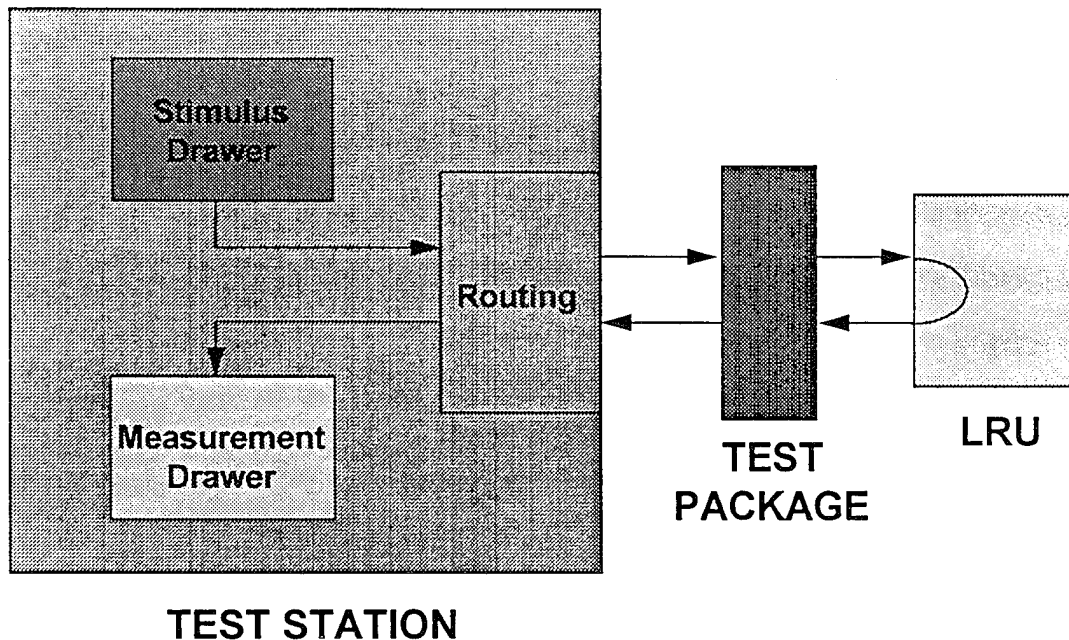


**Figure 2a. Top-Level Mental Model of Avionics Equipment System**

The test station has a wide range of functions in accomplishing its job of (a) simulating the electronic signals (from a stimulus drawer) that the unit would receive if it were in the airplane and (b) measuring the signals the unit produces in response (via a measurement drawer in the station). Hence the station performs a tremendous array of signal generation, signal routing, and signal measurement functions. Further, troubleshooting is complicated by the fact that very little of what the test station does is visible to the technician. (A digitized picture of the station is shown in Figure 2b.) The opaqueness and complexity of the test station not only increase device knowledge demands on the performer but also heighten associated procedural and strategic knowledge requirements as well. To address those performance demands, the tutor includes a simulation of the actual equipment system and all the functionalities available to

technicians in the shop to investigate the equipment. The goal is to make the opaque functionality "visible" via direct manipulations. For example, technicians can swap components, measure resistance and voltage levels, and so forth (see an example of the interface in Figure 3). Coaching is available to students as they work the graded, progressively harder series of fault isolation tasks, but eventually the supportive coaching fades.
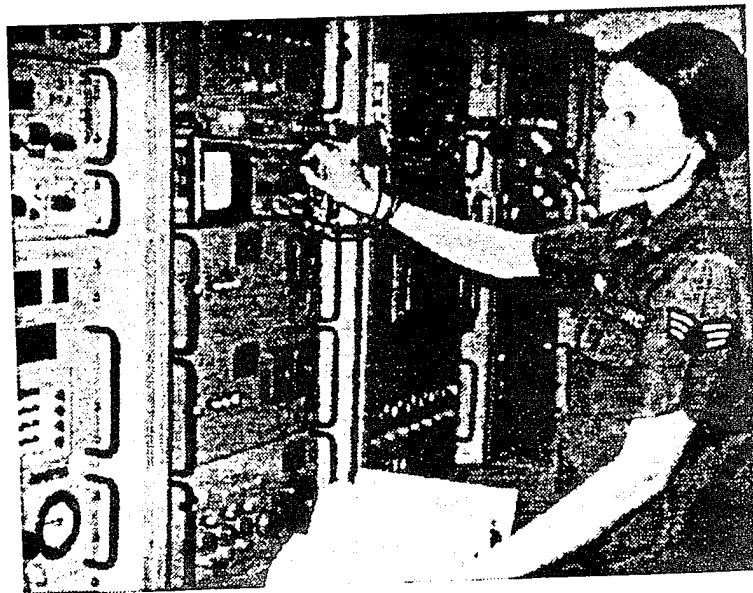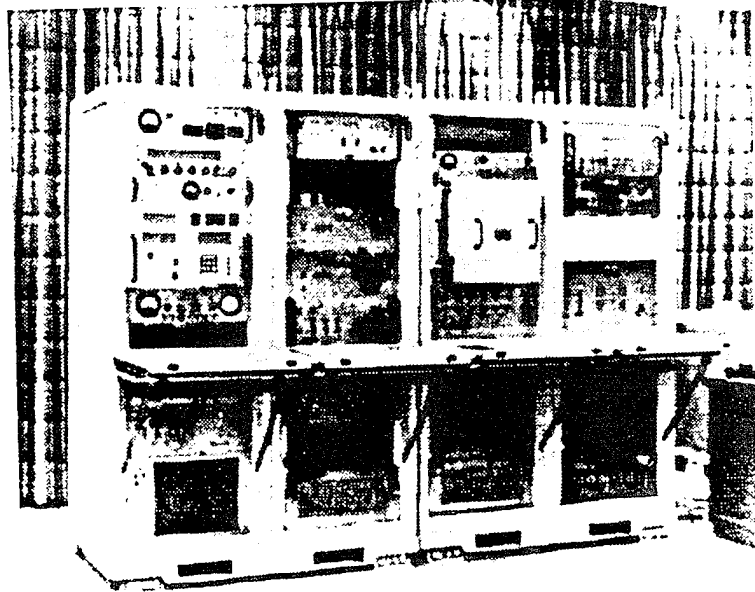


**Figure 2b. Actual Avionics Test Station**
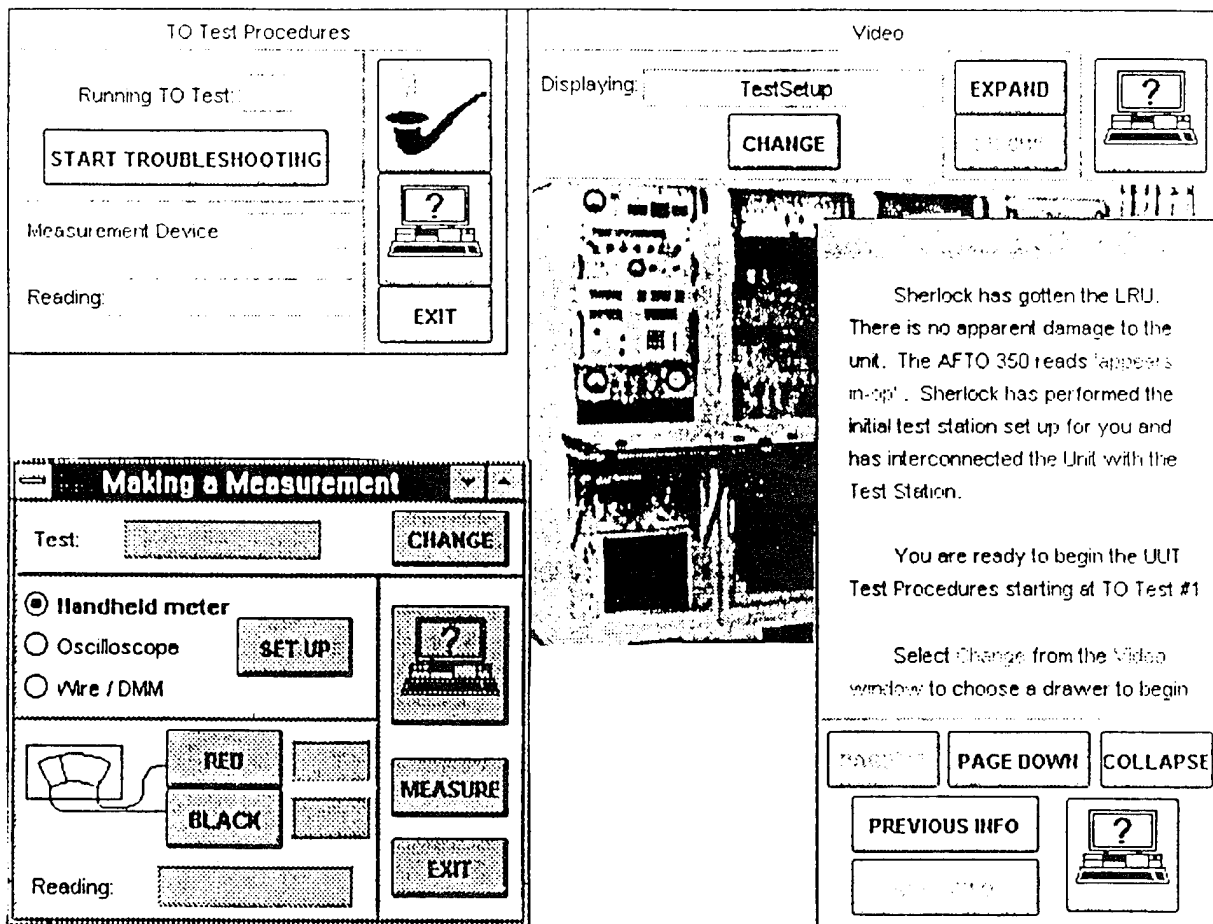
**Figure 3. Sherlock Interface**

In sum, the following critical features of learning environments for complex skill acquisition/generality provide the cornerstone for Sherlock:

- A pedagogical approach of **learning by doing** and **learning through reflection** in a situated, supported learning environment is indicated.

- Situated learning supplies the needed context for learners to execute tasks in an environment that reveals the use of their knowledge.

- Supported learning enables a master-apprentice instructional relationship to form, whereby the master (or coach) can model, assist, and review problem solving performances as well as sequence learning activities that promote successive approximations of mature practice.

- Detailed cognitive models and authentic problem solving scenarios are essential as inputs to the instruction of complex problem solving skills.

-- Cognitive models make the targeted expertise explicit, precise, and complete (e.g., tacit strategic knowledge is revealed).

-- Authentic scenarios give the instruction validity and vigor, with their realism, and they promote the culture of expert practice in the work environment.

- Given the multi-component nature of troubleshooting, all components should be treated in some integrated form instructionally. Further, a logical progression of models of proficiency is needed to inform the sequencing of instructional events.

-- Historically, troubleshooting training has focused on a single component (typically, the observable procedures); however, knowing the steps of procedures is a primitive, early approximation of expertise. Naked, brittle actions have very limited utility (Rouse, 1982).

-- Similarly, device knowledge has been typically taught with a focus on formal theoretical principles, without giving students direct manipulation experiences with the phenomenon. Training that has focused on formal theoretical principles without attention to their application has repeatedly failed. Direct manipulation experiences with devices promote qualitative causal reasoning skills (Morris & Rouse, 1985).

-- What's needed for complex problem solving is instruction where, at the minimum, device topology and procedural knowledge are coordinated into robust conceptual device knowledge, from which procedures may be inferred if necessary.

-- In addition, for the ill-structured problems of the real world, the explicit plans and goals of strategic knowledge need to be coordinated with the two other components to provide the glue that integrates the steps of complex performances.

To summarize, Sherlock followed the pedagogical tenets of (a) learning by doing in a situated, supported learning environment; (b) using detailed cognitive models as the primary input to instruction; and (c) coordinating the multiple components of troubleshooting expertise instructionally.

*Tutor Evaluation: Subjects & Instruments*

Fifty-four apprentice, journeyman, and master avionics technicians participated in the evaluation study, which was conducted as a controlled experiment at three geographically separated sites -- Langley AFB VA, Eglin AFB FL, and Nellis AFB NV. The apprentice and journeyman technicians had an average of 33 months experience on the job; the Masters averaged 124 months (10 years, 4 months) experience. Two types of instruments were used to assess learning and provide measures for pre to post intervention comparisons. To access and measure the covert processes and structures that comprise troubleshooting, we developed

Verbal Troubleshooting Tests (VTTs) as the principal learning assessments to evaluate tutor effectiveness. A VTT can be conceived as a structured thinking aloud protocol form of assessment. It allows a close approximation of hands-on troubleshooting performance, without the costly and inefficient utilization of actual equipment. The second instrument is a Noninteractive Troubleshooting (NIT) Test, which is a paper-and-pencil instrument designed to complement the VTT. The NIT's paper and pencil format eliminates the requirement for verbal responses, limits the involvement as well as any biases of the examiner in a VTT, and offsets the potential biasing influence of the low number of VTT problems (two pretest and three posttest.)

## Results

*Experimental and Control Group Comparisons (Post Intervention)*

As predicted, VTT and NIT scores revealed large and statistically significant differences in favor of the experimental group over the controls (Table 1): VTT Posttest #3 ($t$ [39] = -4.04, $p$ = .000); VTT Posttest #4 ($t$ [39] = -3.72, $p$ = .001); NIT Posttest ($t$ [39] = -2.77, $p$ = .009). The pre- to posttest differences for both tests are illustrated in Figure 4. Comparisons on both tests for all three groups (Master Group included) are illustrated in Figure 5.

Also, as predicted, the VTT and NIT posttest scores on a piece of novel equipment (called Frankenstation) revealed statistically significant differences in favor of the experimental group over the controls (Table 2): VTT Posttest ($t$ [36] = -2.93, $p$ = .006); NIT posttest ($t$ [36] = -2.34, $p$ = .025). The differences are illustrated in Figure 6.

**Table 1. Posttest Measures of Troubleshooting Proficiency (Sherlock 2)**

| Group | N | Sherlock 2 Posttests | | |
| --- | --- | --- | --- | --- |
| | | VTT 3 | VTT 4 | NIT |
| Novices | | | | |
| Control | 23 | | | |
| M | | 59 | 58 | 75 |
| SD | | 37 | 37 | 14 |
| Experimental | 18 | | | |
| M | | 95 | 91 | 87 |
| SD | | 5 | 7 | 12 |
| Masters | 13 | | | |
| M | | 85 | 86 | 86 |
| SD | | 12 | 11 | 11 |
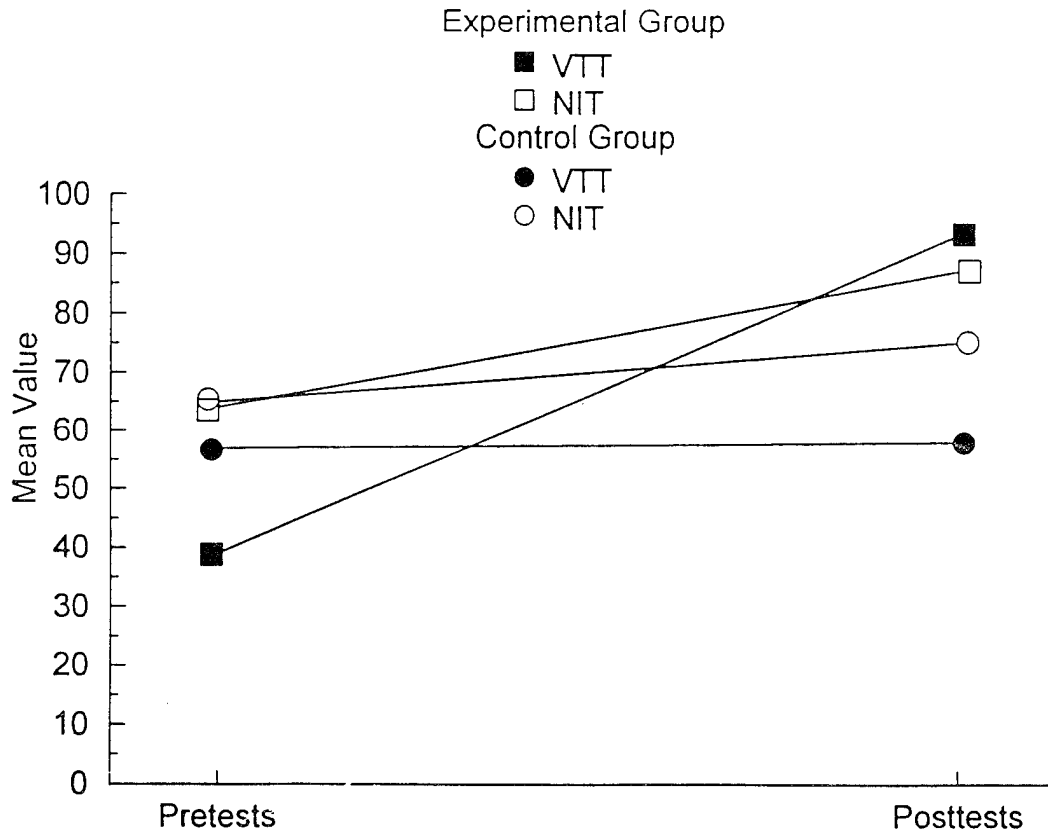
**Figure 4. Pre to Posttest Changes: Sherlock Tests**
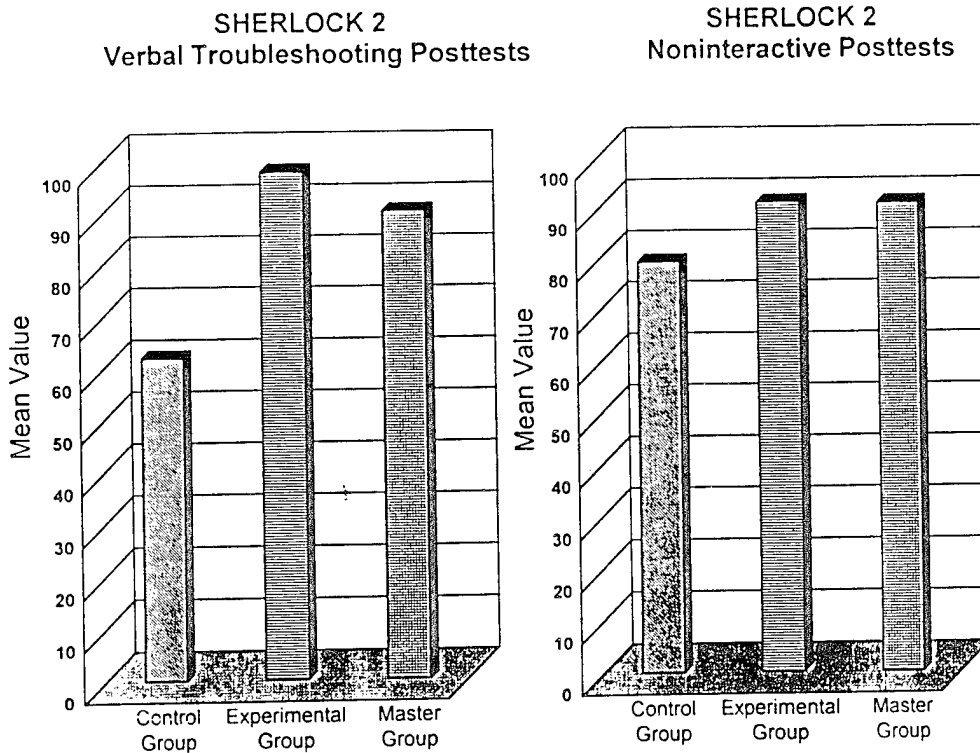


**Figure 5. Sherlock Posttest Scores Across Groups**

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**Table 2. Posttest Measures of Transfer**
**(Frankenstation)**

| Group | N | Frankenstation Posttests | |
| | | VTT | NIT |
| --- | --- | --- | --- |
| **Novices** | | | |
| Control | 21 | | |
| M | | 55 | 72 |
| SD | | 31 | 4 |
| | | | |
| Experimental | 17 | | |
| M | | 82 | 80 |
| SD | | 23 | 10 |
| | | | |
| **Masters** | 12 | | |
| M | | 91 | 88 |
| SD | | 22 | 12 |



**Figure 6. Frankenstation Test Scores Across Groups**

The effect size for each of the posttest measures is shown in Table 3. The range is from .76 to 1.27 standard deviations. As a basis for comparison, the average effect size for new science and math curriculum in U.S. schools is reported to be .30 standard deviation (Bloom, 1984).

**Table 3. Effect Size for Posttest Measures**

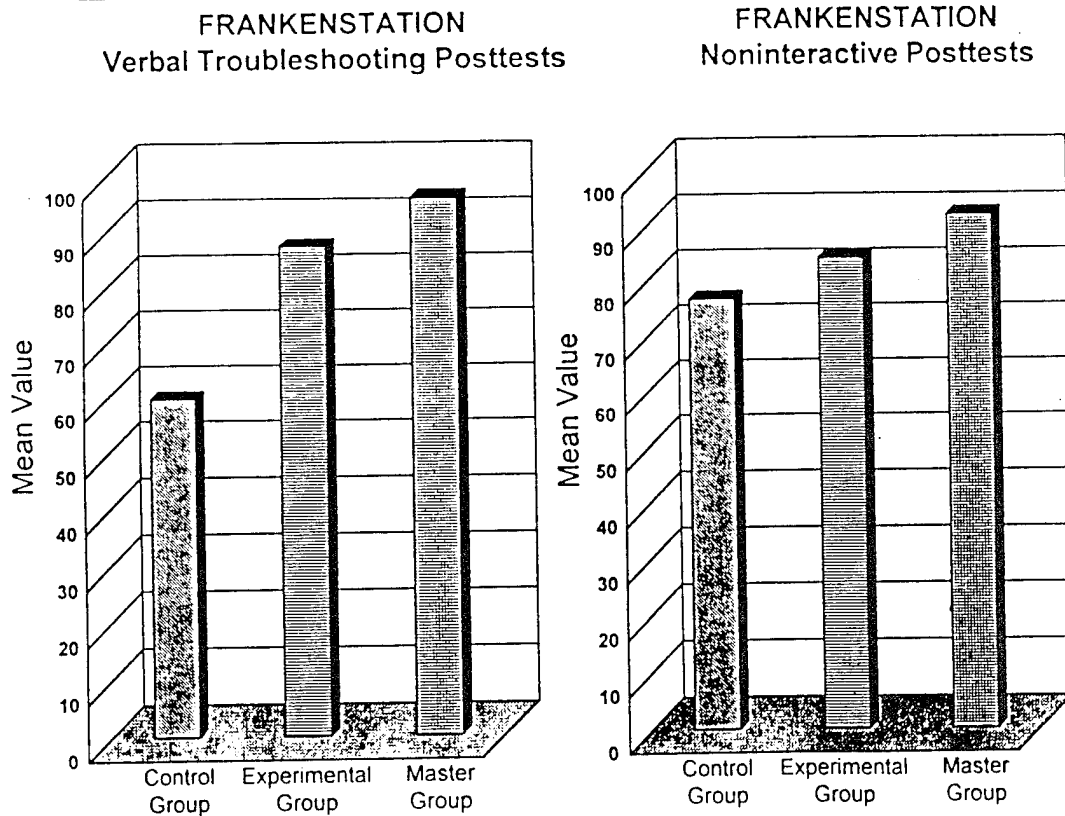| Measure | Group | | | | | | Effect Size |
| | Control | | | Experimental | | | |
| | N | M | SD | N | M | SD | |
|---|---|---|---|---|---|---|---|
| VTT 3 (Sherlock) | 23 | 59 | 37 | 18 | 95 | 5 | 1.27 SDS |
| VTT 4 (Sherlock) | 23 | 58 | 37 | 18 | 91 | 7 | 1.17 SDS |
| NIT (Sherlock) | 23 | 75 | 14 | 18 | 87 | 12 | .87 SDS |
| VTT (Frank'tn) | 21 | 55 | 31 | 17 | 82 | 23 | .96 SDS |
| NIT (Frank'tn) | 21 | 72 | 11 | 17 | 80 | 10 | .76 SDS |

*Qualitative Analyses of Sherlock 2 VTT Data*

While the significant differences in VTT and NIT posttest scores (Experimentals vs. Controls) provide solid evidence of the intervention effect, it only tells us that the overall troubleshooting performance of the tutored airmen improved after the tutoring sessions. The particular ways in which their performance improved -- particularly vis-à-vis the guiding troubleshooting principles embedded in the tutor -- provides a performance profile that is much more informative. Toward that end, we performed a componential analysis of the two VTT posttest protocols, focusing on the following components of troubleshooting skill (which correspond to the troubleshooting principles advocated by experts and emphasized in the tutor) (Gott et al, in preparation):

(1) Safety of procedures
(2) Accuracy of investigating **active** components in electronic test
(3) Accuracy of measurements performed
(4) Thoroughness of component testing
(5) Verification of faulty component prior to swapping
(6) Logic of sequence in which functional areas investigated
(7) Accuracy of inferences based on test results

We also analyzed **six** other performance components of interest:

(1)  Total number of troubleshooting steps
(2)  Number of measurements made
(3)  Number of ohms measurements made
(4)  Number of voltage measurements made
(5)  Number of swaps
(6)  Number of components investigated.

Results from these analyses are shown in Figures 7 and 8.
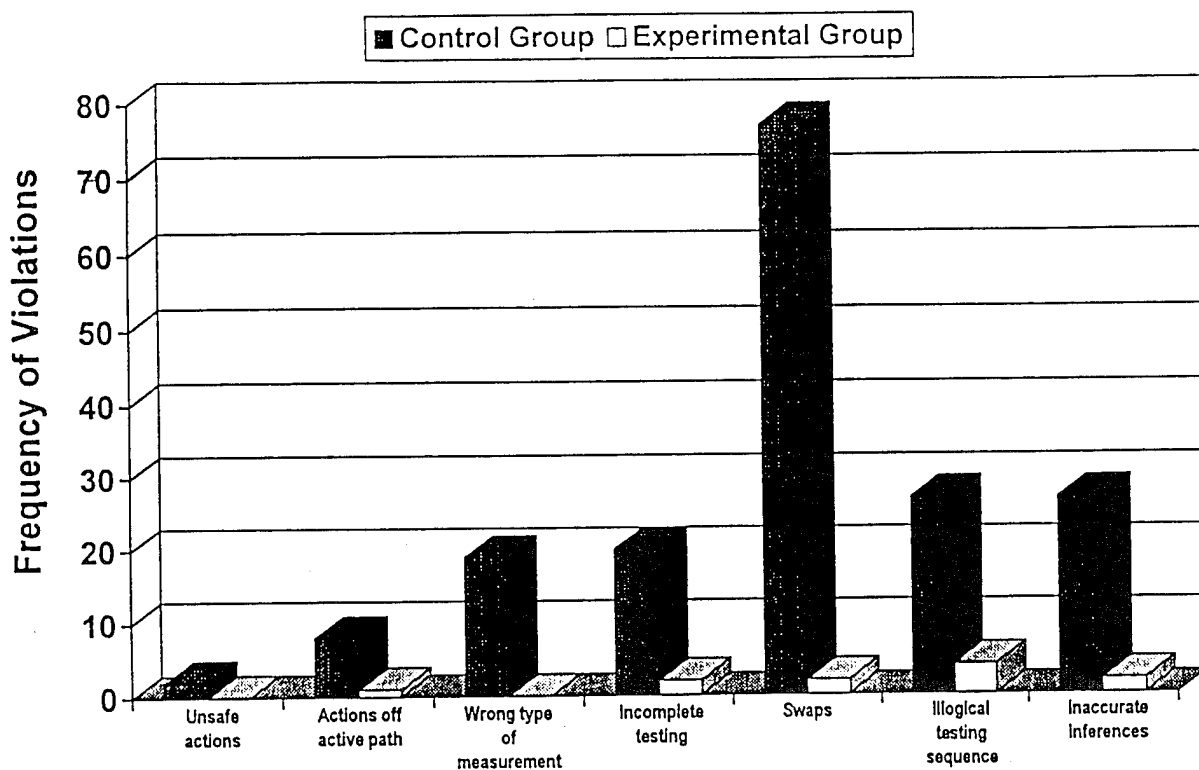


**Figure 7. Violations of Sherlock Troubleshooting Principles
by Group**

The experimental group performed significantly better than controls on every troubleshooting principle, with the exception of unsafe actions (Figure 7). The difference is especially dramatic on the much lower frequency of swaps by experimentals, which is essentially a *default action* executed by technicians when they have no productive action to take. Other experimental-control comparisons (Figure 8) reveal (a) no difference in mean number of actions taken but (b) fewer components and circuits investigated by experimentals,

and (c) significantly more voltage measurements (more difficult measurements to execute and interpret) taken by experimental subjects.



**Figure 8. Comparisons on Additional Sherlock Components**

## Discussion

How has Sherlock 2 been able to achieve this level of effectiveness? Although our study did not include conditions where instructional features were manipulated to gauge the power of individual instructional attributes, past 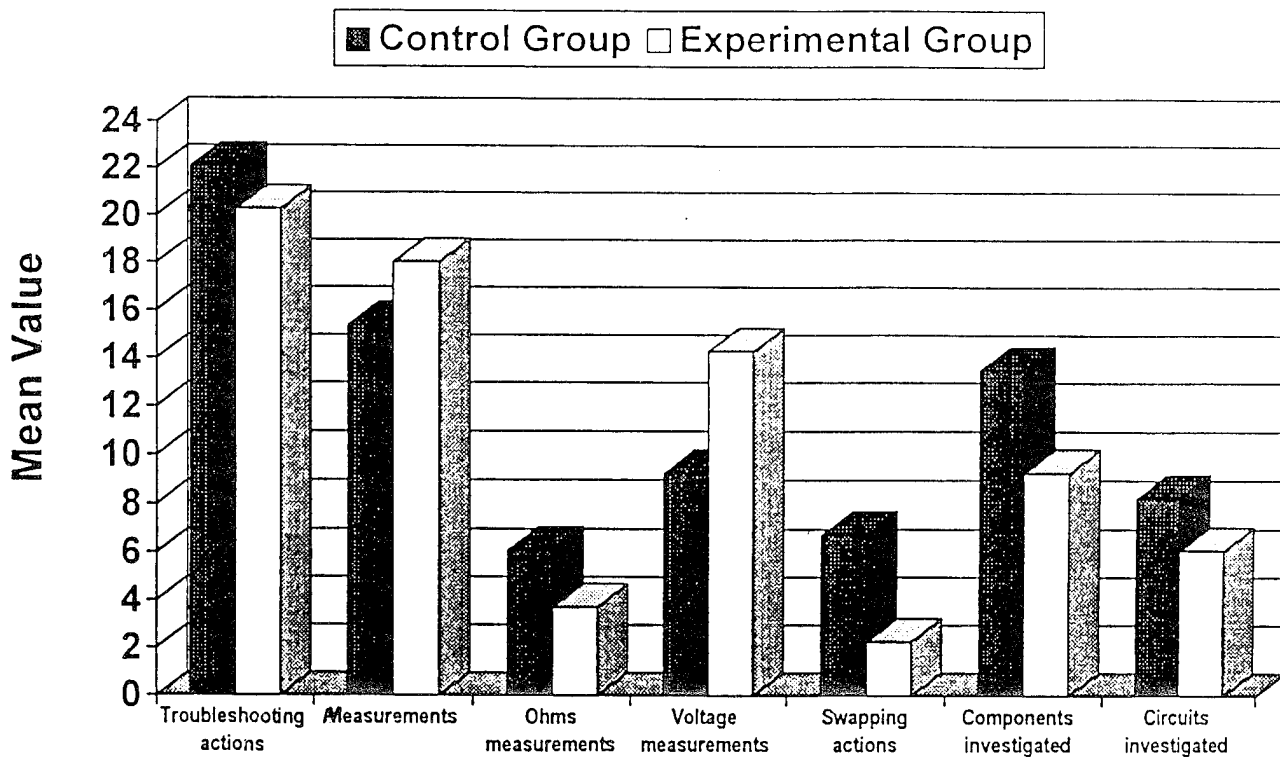research in the training of complex problem solving skills lends support to certain speculative explanations regarding Sherlock's effectiveness. The support centers around (a) cognitive models as input to instruction; (b) the sequencing of instructional events; (c) situated learning in a constructivist instructional environment, and (d) the sociology of a learning system. Topics (c) and (d) fall within the scope of this paper.

*Situated Learning in a Constructivist Environment*

Following Dewey and in accord with the current constructivist movement (Perkins, 1991), the general principle of **learning by doing** is the touchstone of the Sherlock design. The tutor is an extension of the trainee's actual work environment. Authentic fault isolation problems are selected and presented to students as holistic scenarios to solve as they actively construct their understanding of the equipment and of the troubleshooting task. Working in

Sherlock is like doing one's job in the real world -- objects in the environment are acted upon to achieve certain goals. There are, however, several nontrivial bonuses in Sherlock that do not exist in the real world.

First, in the actual shop environment, trainees must learn about test station troubleshooting as opportunities present themselves. Unfortunately, the opportunities are infrequent, because the frequency of station malfunction is relatively low. However, being able to successfully troubleshoot the test station is a critical skill for this specialty, commanding high training emphasis. Further, since malfunctions occur essentially at random, learning is driven by whatever breaks. Instruction cannot be sequenced in the manner just described where movement through upwardly compatible models of understanding and performance can be fostered. Finally, it is possible in Sherlock to time-compress the routine activities that may take an inordinate amount of time in the real world so that valuable instructional time is devoted to the challenging part of the task.

The second bonus is that the Sherlock environment is forgiving; mistakes can be made without dire consequences, plus, expert coaching is always available as scaffolding, when needed. Scaffolding in a learning environment supports trainees as they try to make sense of the domain -- with hints, explanations, even missing pieces of knowledge. In Sherlock , the scaffolding appears as coaching during problem solving, and additional support is provided in reflective followup (RFU) activities.

In the Sherlock RFU, students engage in four activities designed to foster learning through **reflection**: (a) they view a replay of the solution steps they just executed; (b) they see their solution juxtaposed to an exemplar Master solution; (c) they can view a more elaborated replay of a Master solution; and (d) they are asked to diagnose their own solution trace using the principles of good troubleshooting. Their self-diagnosis is then compared to the computer coach's diagnosis, for validation. The RFU culminates the problem solving session, and, we believe, provides a considerable value-added element to the Sherlock 1 system where there was no post-performance review capability.

By enhancing earlier **learning-by-doing pedagogy** with a **learning-by-reflection component,** we believe the instructional impact has been heightened. As Collins and Brown (1988) and Collins, Brown, & Newman (1989) have argued, learning through reflection in a computational environment such as Sherlock achieves the following objectives:

(1) The student's solution trace becomes a useful object of study, especially since the computer can represent the **process** of the solution and thereby externalize decisions for interpretation from a variety of perspectives.

(2) By having access to an exemplar solution from a Master (including the Master's normally tacit reasons for each action), the student can observe and even discover expert strategies and reasoning that subsequently can improve the trainee's own solution.

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(3) After viewing a number of problem-specific traces in the RFU, the student can derive abstractions from the patterns of actions and underlying reasons.

(4) By treating each of his traces as useful objects of study, the student can come to view learning as an "incrementally staged process" that happens over time, not all at once (Collins, Brown, & Newman, 1987). Further, the self-diagnosis activity provides the student with concrete benchmarks of his own progress along the skill continuum.

(5) The self diagnosis that occurs can then become internalized by the student as a form of self-correction, self-monitoring capability. These are metacognitive skills the trainee may not have possessed before the Sherlock experience.

*Sociology of the Learning Environment*

Above all else, instruction must be viewed as valid to trainees. It must serve their needs, profit them directly. "Drawing students into a culture of expert practice in cognitive domains involves teaching them to think like experts" (Collins, Brown, & Newman, 1989, p. 488). In effect, Sherlock seeks to do just that -- draw students into a culture of expert practice, enable them to reach the mature levels of proficiency they observe being practiced by the masters who are the acknowledged leaders in the shop.

On a daily basis during the field trials we observed the tutored subjects make strides in becoming a part of the community of expert practice. They shared with us conversations they had with their Team Leaders when malfunction problems arose on the actual equipment that were covered in Sherlock. They sometimes consulted the acknowledged masters in the shop (after a tutoring session) when they needed and wanted more elaboration about a Sherlock scenario than was available in the tutor. There were also occasions during tutoring sessions when trainees would want to get an opinion from one of the shop 7-levels because they thought the tutor's interpretation or suggestion was too narrow or incomplete.

For some of the more experienced apprentice subjects, they sometimes opted to use the device simulation in the tutor as a way to **discover** the equipment's functionality and observe general cause and effect relationships. They did this by making additional measurements during a Sherlock scenario (i.e., more than needed to solve the problem) just because they wanted to verify or expand their device knowledge. They explained that when they first started working on another test station, e.g., the Electronic Warfare Station, they would do just that -- take a lot of measurements as a way of figuring out how the system worked.

These observations provide one measure of Sherlock's effectiveness in socializing apprentices into the expert culture. On the Tutor Report Card, trainees also reported increased confidence in performing the hardest tasks in their job. The argument can be made then that Sherlock was viewed as valid instruction by trainees. They were learning to perform tasks that they recognized as having value in the shop, in their culture. Moreover, the acquiring of skill and knowledge from Sherlock was enabling them to be more conversant with shop Masters

about the domain. In short, their status in their culture was on the rise and it is reasonable to assume they attributed some of that ascendance to Sherlock.

## Summation

In considering the acquisition of complex skills on real world tasks, we have posed two major premises as foundation. First, skill acquisition in practical domains depends upon purposeful learning experiences where knowledge connects with its uses in the world. (Cognitive technology makes that nexus possible.) Secondly, cognitive modeling makes explicit the forms and utilities of knowledge that may otherwise go unobserved, untaught, and therefore unlearned. These premises have come to the forefront of practical skills training as a result of several significant educational and technological trends. Educational systems at all levels appear to have gradually weakened the ties between the knowledge/skills (that are the province of formal schooling) and their uses in the world. A renewed interest in apprenticeship instruction and related empirical work in learning suggest that the pedagogical principles that characterize classic apprenticeship methods can help to remedy this discontinuity.

Further, as rapidly advancing technologies increase the number of mental (vs. manual) tasks, critical elements of the expert's performance are correspondingly more likely to become unobservable to the apprentice. Mental processes and features of knowledge often remain tacit, that is, unarticulated and therefore unknowable. Cognitive models of real-world task performance make the elements and processes of modern-day expertise explicit, observable and therefore potentially learnable.

In practical domains, the modeled expertise has revealed the multiple sources and levels of knowledge that experts bring to bear on the types of complex, ill-structured problems that are commonly encountered in modern-day workplaces. A major finding concerns the expert's capability to engage in adaptive, opportunistic reasoning that involves the coordination of three major sources of knowledge: procedural, device (or system), and strategic control knowledge. For each type of knowledge, the expert has access to elaborate abstraction hierarchies that range from specific knowledge instantiations to abstractly stated principles.

A second major conclusion, which is supported by a growing body of empirical evidence, is that skill acquisition occurs through successive approximations of the targeted expertise. The progression is characterized by movement from partial to more complete (and thus complex) (a) **understandings** of domain phenomena, (b) **procedural** subroutines, and (c) **strategic control structures,** including goals, plans, and decision factors. The apprentice achieves various levels of incomplete knowledge and capability on the way to mastery. Principles and methods from classic apprenticeship training are proving useful in fostering this progression. **Situated, supported,** and carefully devised and **sequenced** learning experiences have been shown to foster development in veridical learning environments that cognitive technology has borne.

Concordant with these premises, I report results from the recent controlled experiment conducted to evaluate a piece of U.S. Air Force cognitive technology -- the avionics

troubleshooting tutor called Sherlock. Outcomes of **situated and supported learning** in this tutor show dramatic gains in fault isolation proficiency, as well as in skill generality by apprentice technicians. With the Sherlock (computer tutor) system, authentic fault isolation scenarios are presented in a computer environment that is an extension of the airman's real work environment. Learning is meaningful because the trainee works on problems he sees the acknowledged experts in his culture confront every day. He observes his own incremental growth and eventual movement into this same community of expert practice. He even gains confidence he can transfer what he knows to novel equipment systems. A victory for successful learning in the modern workplace using cognitive technology can be declared.

Three advances in cognitive science have been central to the realization of this instructional system: (a) **cognitive performance models,** which Newell and Simon (1972) said over 20 years ago must be given precedence in research (over studies of learning processes) so that a more complete and successful theory of learning and development can ultimately emerge; (b) a **cognitive task analysis methodology** robust enough to codify the expert performance models, as well as the successive approximations of expertise encountered along the way; and (c) **the "mental experiments"** that experts run to simulate explanatory models ("in the mind's eye") during diagnostic and procedural tasks. The confluence of these and other advances have taken us a step forward in fostering learning in the real world via engaging applications of cognitive technology.

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