Institutionalizing the Field of Expertise Studies and its Applications to Computer Science

Robert R. Hoffman, Ph.D., Research Scientist
Institute for Human and Machine Cognition
University of West Florida
40 Alcaniz St.
Pensacola, FL  32501
rhoffman@ai.uwf.edu

Abstract
This Workshop is a forum at which researchers who are interested in the study of expertise and its applications in computer science will gather to share ideas and generate collaborative projects. A number of world’s foremost “experts on expertise” have chosen to move to the northern ‘Bend’ region of Florida, which extends from the northern main peninsula across through the western panhandle. At few places in the world is there such a concentration of researchers and scientists focused on the goal of understanding the nature of expertise and then applying that knowledge to the development of new information technologies—a goal that is of immense value to society. Furthermore, it is noteworthy that The Bend includes not just a critical mass, but a complementarity in each research center has a topical focus (expert performance, expert teams, experts' cognition, computer science applications) and each center is interested in particular domains of expertise, such as music, sports, aviation, weather forecasting, and military command and control. At the Workshop, the Principals will present brief summaries of their research and interests, and then the group will engage in discussions aimed at (1) generating an action plan to facilitate research, (2) institutionalizing a process for training and education of researchers in Expertise Studies, and (3) generating new avenues for applications in computer science.

The Importance of Expertise Studies

Diverse businesses and government agencies have realized that high levels of expert performance and corporate knowledge need to be nurtured, that expertise needs to be preserved, and that scientific knowledge about expertise needs to be leveraged into new computer technologies. Countless horror stories can be told of the negative consequences of the loss of expert knowledge and proficient practitioners in many occupations and organizations.

Economic forces and changes in the last decades of the 20th century (e.g., downsizing) have led to a situation in which there is a large workforce of individuals who are about to retire, but in many instances there is no replacement workforce having comparable levels of expert performance and knowledge. Grumblings about the loss of expertise have echoed down the hallways of NASA, the National Weather Service, and many other agencies. In the private sector, many organizations have found a need to create “Knowledge Officers” whose job is to preserve corporate memory in for form of knowledge bases (e.g., Alee, 1997; Brooking, 1999; Choo, 1998; Davenport & Prusak, 1998; Nonaka & Takeuchi, 1995; O'Dell & Grayson, 1998; von Krogh, Ichijo, & Nonaka, 2000).

Converging on the notion of Expertise Studies is the fact that many psychologists have started to focus on the study of proficient performance. Traditionally, psychologists who studied such mental faculties as perception, decision-making, and learning, concentrated on the “everyday cognition” of college-age adults. It became clear, however, that theories of cognition would have to say something about the structure of experts’ superior performance, including their impressive knowledge and memory. There are now many scientists who study the development of expert performance in diverse domains, such as sports, music, dance and chess, as well as professional domains, such as electronics debugging, business decision-making, medical diagnostics, electric power management, and software engineering (e.g. Ericsson, 1996; Feltovich, Ford, & Hoffman, 1997; Hoffman, 1992).

Also converging on the notion of Expertise Studies have been developments in computer science. In the creation of expert systems and other forms of knowledge-based systems (KBS), it became clear that it often takes longer to elicit and represent expert knowledge than it actually takes to write the software. This came to be called the “knowledge acquisition bottleneck.” The solution lay in advancing our understanding of knowledge elicitation methodology—bringing the efforts of psychologists together with the efforts of computer scientists in the development of Knowledge Acquisition (KA) tools. Cognitive Psychology and Computer Science have thus converged on a perspective that regards knowledge acquisition as a modeling process (Agnew, Ford & Hayes, 1997; Ford & Bradshaw, 1993; Hayes, Ford, & Agnew, 1994).

With further studies of expert performers, such as airline pilots, medical doctors and chess masters, it...
became clear that expert performance requires more than just knowledge. Expert performers cannot simply apply past knowledge; they need to be able to plan and reason. They need to be able to evaluate new situations and develop new knowledge and skills. Furthermore, experts typically possess a great deal of "tacit" or "intuitive" knowledge—knowledge about their craft that they cannot easily articulate. Here too seemed to be a ripe avenue for the application of KA tools and KBS.

Studies of individuals who have reached the highest international levels in a wide range of domains show that they it takes at least ten years of motivated, "deliberate practice" focused on the gradual improvement of performance. The study of experts has revealed the nature of the kind of practice that allows individuals to reach the highest levels of performance. The knowledge of how teachers, coaches and mentors support the development of expert performance can be adapted to improve training and the creation of training support systems. Furthermore, the development of expert teams (airplane crews, astronaut crews, surgical teams) presents special challenges to training and development of the highest levels of performance. This too represents an area that is ripe for research and application.

Convergence

Over the past decade, a number of world's foremost "experts on expertise" have chosen to move to the northern "Bend" region of Florida, which extends from the northern region of the main peninsula over through the western Panhandle.

- Some have been attracted to the University of West Florida where the Institute for Human and Machine Cognition has been a magnet for world-class cognitive scientists and computer scientists.
- Some have been attracted to Florida State University, where the Endowment for the Conradi Eminent Scholar has supported the a group of researchers studying skill acquisition and expert performance.
- Some have been attracted to the University of Central Florida where the Program in Psychology and the Institute for Simulation and Training have attracted world-class experimental psychologists and human factors engineers.

Among these individuals are some research pioneers listed in Table 1.

Table 1. Participants in "The Bend."

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>K. Anders Ericsson</td>
<td>FSU</td>
</tr>
<tr>
<td>Neil Charness</td>
<td>FSU</td>
</tr>
<tr>
<td>Gershon Tenenbaum</td>
<td>FSU</td>
</tr>
<tr>
<td>Eduardo Salas</td>
<td>UCF</td>
</tr>
<tr>
<td>Peter Hancock</td>
<td>UCF</td>
</tr>
<tr>
<td>Ken Ford</td>
<td>UWF</td>
</tr>
<tr>
<td>Pat Hayes</td>
<td>UWF</td>
</tr>
</tbody>
</table>

K. Anders Ericsson (FSU)
Anders is known world-wide for significant advances to the methods of protocol analysis. In addition to major contributions to cognitive psychology, including the notion of long-term working memory, Anders is regarded as one of the world leaders in the study of expert performance in domains such as music and sports.

Neil Charness (FSU)
Neil is not only a cognitive psychologist known for his research on expertise in chess, but is also a gerontologist, specializing in the effect of aging on cognition and the use of computers by older adults.

Gershon Tenenbaum (FSU)
Gershon is Editor of International Journal of Sport Psychology. He has made pioneering contributions to the study of perceptual-motor and decision making processes in sports.

Eduardo Salas (UCF)
Eduardo is Editor of the journal, Human Factors, and is a pioneer in the study of "expert teams." Eduardo is also a leader in the emerging paradigm of "Naturalistic Decision Making."

Peter Hancock (UCF)
Peter is widely regarded as one of the world's leading experimental psychologists. He has made significant contributions to the psychology of perception and to human factors psychology. He has served as President of the Human Factors and Ergonomics Society.

Ken Ford (UWF)
Ken's work on theory-based knowledge acquisition tools and construing the KA process as a constructive modeling activity were important contributions to the KBS. Ken is also active in exploring and explaining foundational issues in AI. Ken is Director of the Institute for Human & Machine Cognition (UWF).

Pat Hayes (UWF)
Pat is one of the pioneers of AI and cognitive science. The focus of his work, much of it seminal, has been on the development and study of broad classes of knowledge representation formalisms, including those used by humans and by machines. This has several aspects, including the understanding of "diagrammatic" and "pictorial" representations; the use of formal notations to encode intuitive meanings, particularly in a social context involving human and machine agents; and the development of international standard formalisms for the emerging "semantic web."

(Table 1 continues)
William Clancey (UWF)

Bill is one of the pioneers in the field of expert systems and KA tools. His current research involves “work practice simulation,” in an effort to advance our scientific understanding of human behavior as it pertains to the design of work systems, viewed as interacting organizations, procedures, facilities, and tools. Work practices that are currently being simulated include scientists on field expeditions, astronauts on the International Space Station, and mission controllers remotely operating a rover on Mars.

Robert Hoffman (UWF)

In addition to creating new methods for knowledge elicitation and creating a framework for the KE process, Robert pioneered the experimental comparison and evaluation of KE methods. In addition, he has applied the methods of experimental psychology and human factors to the domain of weather forecasting. Robert is currently conducting research aimed at expanding the capabilities of the "Concept Mapping" approach to knowledge modeling.

Jeffrey M. Bradshaw (UWF)

Jeff’s work on KA tools played an important role in the development of the field, as did his theoretical contributions to understanding the process as once of constructive knowledge modeling. Jeff is currently one of the leading lights in software agents and adjustable autonomy.

Paul Feltovich (UWF)

Paul is widely regarded as one of the founders of Expertise Studies, by virtue of seminal research on expertise in physics problem solving. Paul also helped pioneer in the study of the cognition of expert and trainee physicians. His current efforts include the study of metacognition and "tough tasks" in military command and control contexts.

Research over the past decade conducted by these individuals has led to:

- Ideas about effective methodologies for eliciting and preserving the knowledge of experts, including their tacit knowledge,
- Ideas of effective methodologies for describing the reasoning and decision-making skills of experts and expert teams,
- Ideas of measuring the level of attained performance of highly skilled individuals and experts and methods for assessing the structure of their skills,
- Ideas about the necessary instruction and practice required for the development of expert levels of performance,
- Ideas about leveraging all of the above into new computer science applications.

With the addition of these new, world-class researchers to the faculties at Florida State, Central Florida, and West Florida Universities, The Bend has emerged as a prospective national focal point for Expertise Studies and its application in the creation of new information technologies. Indeed, it can be argued that nowhere else in the world is there such a concentration of researchers and scientists focused on a the goal of understanding the nature of expertise and then applying that understanding—a goal that is of immense value to society.

Furthermore, it is noteworthy that this triad of schools includes not just a critical mass, but a remarkable complementarity in that each school’s research staff has a particular topical focus and an interest in particular domains of expertise, as shown in Table 2.

Table 2. Interests and Focus

<table>
<thead>
<tr>
<th>FOCUS POINTS</th>
<th>APPLICATIONS</th>
<th>DOMAINS OF INTEREST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert performance</td>
<td>Training methods and instructional design; Learning support for aging populations</td>
<td>Music, sports</td>
</tr>
<tr>
<td>Expert teams</td>
<td>Methods to facilitate teamwork and collaboration; Methods for the mitigation of the effects of stress and mental workload</td>
<td>Aviation, Transportation</td>
</tr>
<tr>
<td>Expert cognition</td>
<td>Knowledge modeling and preservation for distance learning and collaboration; Performance support systems; Embedded training</td>
<td>Meteorology, Medicine, Aviation, Military command and control</td>
</tr>
<tr>
<td>KBS and other technologies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Proposal

This convergence of world-class researchers and the associated complementarity of topical interests and capabilities can be leveraged into a formal partnership. At the Workshop, the Principals will present brief summaries of their research and interests and then the group will engage in discussions aimed at generating an action plan to: (1) facilitate collaborative research, (2) institutionalize a process for training in Expertise Studies, and (3) generate new applications for computer science and information technology.
References


