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Six Dimensions of Expertise: A More Comprehensive Definition of Cognitive Expertise For Team Coordination

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Six dimensions of expertise: A more comprehensive definition of cognitive expertise for team coordination

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Running head: Six dimensions of expertise

Looking at expertise from the vantage point of many knowledge domains allows the observations and resulting definitions to be useful across a broad range of subject areas. A stable set of definitions that work on a higher, more comprehensive level than the current literature offers is needed for an integrated description of expertise. A cohesive cross-domain definition and explanation of expertise can be used to optimize group interactions. Since group performance incorporates additional components of expertise that are not present in individual performance situations, these additional components must be examined in order to see a full picture of the successful utilization of expertise in a group setting. This expanded expertise definition will allow group dynamics to be better understood, and will help break down the expertise components required to have successful group interactions.

Keywords: Expertise, Team coordination, Knowledge sharing, Supervisory coordination

1. Introduction

Each discipline that has approached the study of expertise brings its own background and focus, which has led to a variety of definitions that are difficult to generalize across domains and disciplines. Within the field of psychology; the definition of 'expertise' has encompassed a range of ideas, such as the 'extent and organization of knowledge and special reasoning processes to development and intelligence' (Hoffman et al. 1997: 544). A review of current literature reveals that most articles on expertise are contextually focused. There are relatively few studies that integrate different areas of expertise; each discipline has its own terminology, with limited discussion of convergence of terms. The limited amount of literature available on expertise that is not discussed from the standpoint of a specific discipline tends to divide expertise into categories.

The purpose of this paper is to look at expertise from a multi-disciplinary viewpoint. An expert is widely considered to be someone having extensive knowledge or experience in an area. We hold that there is even greater complexity in examining expertise shared across members of a group operating in a complex task environment. Prior researchers utilized categories, such as explicit and tacit, for determining a type of expertise, but this method gave little underlying information as to the make-up of the expertise. One issue that we describe in this paper is the nature of multiple forms and levels of expertise in a group or team.

Our theoretical perspective is that expertise has many overlapping and dependent dimensions. The difference between categories and dimensions is that categories tend to be mutually exclusive. Conversely, dimensions describe the composition of expertise. It is our belief that coordinated, applied expertise is made up of combinations of these dimensions.

Rather than attempting to list domains of expertise as individual elements, this paper posits that there can be substantial gains made by considering how differing underlying aspects of expertise can be combined to unify the previous discussions of expertise domains.

Individual dimensions of expertise take several forms, and may be generally described as classes of skilled performance across physical and cognitive domains (Bailey 1996, Caldwell 1997). The range of performance being described in this paper spans from detection through the execution stage in the SCOPE model, as illustrated by Caldwell and Kapp (1996). As the study of expertise moves from an individual to a group perspective, the coordination of different forms of skilled performance can no longer be assumed to take place within a single person, or from a single perspective of skilled performance. Although specific classes of individual skilled performance are necessary, they are not sufficient to describe effective coordination and performance in a group task environment.

The original consideration of dimensions of expertise was derived in the context of the above attempt to integrate discussions of physical and cognitive skilled performance, as well as how individual experts collaborated to demonstrate team level expertise. The following sections describe contributing areas of literature, our own prior research, and the rationale for our six-dimensional expertise framework.

2. Review of current literature

Scardamalia and Bereiter (1991) found that the definitions of 'expertise' established in literature were incomplete, and therefore created a new definition based on their discussion of expertise in writing. At that time, the current definition of an expert as being capable of recalling 'complex, task specific patterns and the ease of which they gain access to just the right information' (Scardamalia and Bereiter 1991: 172) did not fully take into account the different ways a novice and expert approach a problem. Scardamalia and Bereiter describe the distinction between novices and experts as not based on the amount of knowledge that one has accumulated in a specific domain, but rather on the interaction between general domain knowledge and a specific case.

This interaction between forms of knowledge is a very important distinction because it helps explain not only how the process of problem solving in novices and experts differs, but also how the development of new understanding advances a field or area of human activity. Scardamalia and Bereiter's definition points to the fact that expertise is not as simple as a quantity on a single continuum, but rather a process based on how differing abilities interact. They illustrate this point by discussing how a literate expert must be an expert in both reading and writing within some domain, and that this expertise draws not from these skills individually but in the 'productive interaction between these activities' (Scardamalia and Bereiter 1991: 175).

2.1. Experts, expertise, and experience

Scribner views expertise as a function of experience, and further introduces the concept of working intelligence (Mieg 2001). Expertise as experience was also used to support the hypothesis that experts have a complex knowledge organization (Seifert et al. 1997). This complex organization of knowledge is supposedly due to the experience that is only acquired over time, and this differentiates experts from novices.

Mieg (2001: 4) discusses a concept of expertise that is quite different: ‘experts as specialists having specialized knowledge’. He also makes a case that an ‘expert-by-experience must be an expert in the field’, while an ‘expert-by-knowledge can be an expert about the field, while lacking personal experience in the field’ (Meig 2001: 4). When Clancey’s theory of *situated cognition*, as cited in Mieg’s (2001) book, is taken into account, this concept of an expert *about* the field versus *in* the field takes on even more importance. At the very least, this distinction suggests that declarative domain knowledge is a different type of expertise than recognition of situational and experiential factors that affect the application of that knowledge.

Clancey claims ‘that human activity, including knowledge, basically routes [*sic*] in an adaptation to the environment constraints: every human thought and action is adapted to the environment, that is, *situated*, because what people *perceive*, how they *conceive of their activity*, and what they physically do develop together’ (Mieg 2001: 6-7). This illustrates another example of why it is important to understand what makes up expertise; otherwise, it becomes extremely difficult to evaluate whether one or both of these types of experts would be able to perform a given job.

Experts and highly skilled operators have a greater ability to determine what information is relevant in a given situation and utilize more sources of relevant information during a task than less skilled operators. In settings where operators are required to utilize complex technologies, experience with, and recognition of, the capabilities and constraints of the human-technology interfaces suggest a different type of skill than knowledge about what task needs to be accomplished.

In a study by Fujita, Kamata and Miyata (2005) it was found that highly skilled operators were able to utilize and integrate multiple sources of work information to achieve better performance results than less skilled operators. Thus, the expertise needed to integrate a variety of information during a work task can be attributed as a skill of expert operators and therefore a component of the expertise needed for a specific type of job. For instance, the discussion of situation awareness, as elaborated by Endsley and colleagues (Endsley 1988, Endsley, Bolte, and Jones 2003, Endsley et al. 2003) explicitly addresses the effective application of knowledge subject to environmental factors and projections of performance requirements into the future.

Since the mid 1980s, a number of authors have attempted to summarize and integrate distinct aspects or elements of expertise across domains (Caldwell 1997, Hoffman et al. 1997). Different research perspectives represent a variety of views on expertise (Hoffman et al. 1997; Sternberg as cited in Hoffman et al. 1997):

- Experts solve problems differently than others (reasoning differences);
- Experts process more quickly than others due to practice and skill (automaticity);
- Experts know more than others and can access that knowledge better (domain completeness, knowledge organization)
- Experts are more ‘intelligent’ than others (where intelligence is measured as mental ability and / or creativity)
- Experts have more experience to help organize knowledge (developmental or experiential integration).

However, the vast majority of research on expertise focuses on individual expertise, since individual cognition is the overwhelming focus of the cognitive science domain. As a result, interpersonal and social aspects of expertise (knowing how to get others to do as one intends, or how to coordinate the activities of others) are usually downplayed (Caldwell 1997, Hoffman et al. 1997). Extensive research literature traditions exist for both leadership and persuasion as those capabilities to coordinate or convince others, and that those capabilities differ between individuals. Our perspective is that, according to the general definition of expertise, these interpersonal skills therefore represent a social aspect, or dimension, of expertise that is distinct from individual aspects of expertise.

2.2. Group level expertise

The literature on group dynamics confirms that the performance of an individual differs from the performance of a group (McGrath 1984, Shaw 1981). On the other hand, the expertise literature is often not focused on social and contextual issues that help define expertise, and the coordination of expertise among members of groups (Mieg 2001, Chi et al. 1988, Posner 1988, Stein 1991). Hoffman et al. (1997: 553) argue that the determination of expertise is context dependent; therefore, the 'minimum unit of analysis would be the "expert-in-context"'.

Further, Shaw (1981) mentions that groups have different problems than individuals do when working. According to Shaw (1981), the products obtained by a group result from the contributions of the individuals forming the group. In order to work efficiently, the group needs to coordinate the effort of its members. A group generates a structure in order to coordinate efforts. If a proper structure is not established, the group may fail to complete its task. Stanton (2003) mentions the existence of a relationship between coordination and team performance. 'Co-ordination refers to the formal structural aspects of the team: how tasks, responsibilities and lines of communication are assigned' (Stanton 2003: 203).

In the case of group expertise, there is a need to develop and utilize a group structure that facilitates the identification of the varied skills and expertise levels available and useable within each group member. This facilitation is especially required in teams with interdependent, distinctive roles (such as specific positions in sports teams, or members of a surgical team with different technical areas of emphasis). These types of teams are seen as having different dynamics, including unique requirements for exchanging role-specific and role-general information, as well as coordinating different perspectives in order to achieve shared goals (McGrath 1984, Sundstrom et al. 1990). As a result, effective teams conducting complex tasks must integrate both the ‘taskwork’ and ‘teamwork’ functions of task coordination (Cooke 2001). This concept has been recently expanded in settings relying on information and communication technology based coordination, to include ‘pathwork’ as a required focus in maintaining communication path availability (Caldwell 2005a). In such complex, technology-rich environments, then, the issue of skill in utilizing technical interfaces becomes a more visible and explicit area of expertise.

3. Significance of framework

Based on the above literature, including studies by the two primary authors of this paper examining team performance in highly complex task settings such as spaceflight (Caldwell 2005a, Garrett and Caldwell 2001), this paper emphasizes the need to integrate different examinations of expertise and skilled performance in the analysis and improvement of complex task settings. Our analysis of expertise incorporates different types of distribution: geographical, temporal and functional. A need for well-defined and structured coordination becomes imperative in both geographically-distributed teams and teams composed of members with heterogeneous subject matter expertise, in order for them to achieve optimal functionality. This structured coordination is necessary to minimize the process losses associated with teamwork without face-to-face communication, as is found in geographical distribution. Temporal distribution and asynchronous coordination adds another level of complexity because of the lag in communication feedback. Finally, coordination between individuals with different functional specialties needs to be well-defined in order to reduce the probability of miscommunication and misunderstanding of domain specific concepts and vocabularies. The dimensions of expertise suggested in this paper would be instrumental in coordinating distributed experts and managing expertise by providing a configuration to this distributed expertise, and would help in formulating structural relationships within the distribution.

Though literature has made attempts to refer to different categories of expertise, there has been limited success in clarifying relationships among these categories. For instance, in the case of knowledge transmission, for Scardamalia and Bereiter (1991: 180) it is clear that 'it is possible to become skillful at knowledge telling'. Nonetheless, they maintain that the named skill differs from expertise based on a definition of expertise focused on domain knowledge (1991). A dimensional approach allows an individual to have expertise in either communication, a specific subject domain, or both, since they are not exclusive.

Our analysis of expertise also supports the social perspective described in Stein's argument that the 'construct of expertise is seen as jointly determined by individual skills and knowledge, and the needs, perceptions, and activities of the members of the social system with whom the experts interact' (1997: 182). We are approaching expertise from a *socio-technical* perspective, taking into consideration variables such as teams, context and subject matter. Stanton (1996: 199-200) points out that, 'system elements cannot be constructed as separate, self-contained elements. All elements of the system are interrelated and interconnected. Therefore, changes in one element will have an effect upon the entire system'.

The central focus of this paper, then, is to describe how a multi-dimensional description of expertise can help integrate concepts of expert behavior in the context of cognitive group processes and task performance. We propose the following six dimensions of expertise, based on integration of the types of research studies and concerns described above. These six dimensions include:

- subject matter (the most classic form of domain knowledge identified as expertise);
- situational context (a recognition of environmental and situational demands, as emphasized in situation awareness and situated cognition literature);
- interface tools (based on training and human-computer interaction literature examining development of user skill in manipulating complex technological systems);
- expert identification (following Gladwell's and Harryson's discussions of "know-who" networks);
- communication skill (thereby integrating communication, leadership, and persuasion literature traditions)
- information flow path expertise (based on NASA and other applications requiring use of complex information and communication technologies to support physically and temporally distributed teams)

Although other theoretical perspectives may define or organize these dimensions differently, an operational problem helped to define this six-dimensional framework. The driving operational concern was to describe the nature of effective team performance of NASA mission control center operations (Caldwell 2005a, 2005b, Garrett and Caldwell 2001). In this setting, each flight controller can be seen as an ‘expert’ functioning as a critical system element within a distributed group environment. In order to effectively construct and quantitatively describe the behavior of such a system, it is necessary to identify the expertise level within each expertise dimension for the individuals that interact in that group environment.

4. Six dimensions of expertise

In order to utilize expertise as a multidimensional construct, each dimension needs to be well-defined, both individually and in contrast to each of the other dimensions. These dimensions need not be exhaustive, but they should represent a coordinated logical structure, and should be conceptually as well as operationally distinct. It must be recognized that prior authors have laid out very similar dimensional structures, but have not in fact described them as such. For example, Sundstrom (1990) used the example of a skilled surgical team to describe the “expert team” concept. The surgeon must possess more than just expertise about human physiology in order to successfully perform a complex operation. The surgeon must also know the correct surgical instruments to use, how to use those tools, how to communicate with the other operation team members, and also be aware of how the patient’s current condition is changing and how that affects what measures must be carried out next. Likewise, other members of the surgical team must be aware of the surgeon’s actions and how to apply that information to their responsibilities. Thus, attending nurses and anesthesiologists also have relevant physiology domain knowledge, as well as knowledge about the tools that the surgeon will need and situational awareness for when specific procedures are appropriate. We suggest that this example describes the multi-dimensional aspect of expertise, and that these interrelated dimensions work in concert to describe the ‘expert-in-context’.

This paper proposes that the framework described in the six-dimensional description presented here is a more comprehensive description of the expertise construct. The following paragraphs promote a more detailed definition of each of these dimensions and how they are characterized. In brief, these dimensions can be considered as descriptions of the *content* of knowledge required to complete a task at the individual or group level; the operational *context* for which that knowledge is useful; and the *process* by which that knowledge is utilized. In addition, the descriptions below can be thought of as answers to questions of *what* task gets done, by *who* (which people), *when* and *where* (addressing time and space considerations), and *why* (for which strategic goals).

4.1. Subject matter expertise

Probably the most often considered type of expertise, subject matter expertise is defined as knowledge in a specific subject area. Examples of subject matter expertise would include the understanding of electrical engineering, micro-economics or botany. This dimension does cover a very wide range of sub-domains; however, it is still appropriate to look at this aspect globally, due to its parsimonious relation to the other expertise dimensions at this level. Subject matter expertise can be used to answer the question of ‘what’ and ‘how’ something works in a specific knowledge domain. This dimension of expertise emphasizes the task *content* of information flow among team members.

4.2. Situational context expertise

Situational context expertise is the ability to identify and understand the current and changing context (inclusive of both circumstances and the environment) and how it affects goal-oriented strategic performance. The main focus of this dimension is how the context affects the current tasks being done -- knowing 'when', 'where' and 'why' certain topics and stimuli are relevant. It is also important to be aware of 'how fast' the environment is changing (the event rate of the context affecting performance, rather than simply the rate of task performance), since this information has a direct effect on how long the current environmental awareness will apply. The concept of the rate at which current information becomes invalid due to changes in the environment can be also considered as the 'freshness' of current information / awareness. This emphasis on the *context* of information flow highlights the range of conditions under which information has valid use.

The awareness of contextual relevance and event change is closely related to 'situation awareness', which Endsley (1988: 97; emphasis added) has defined as 'the perception of the elements in the environment *within a volume of time and space*, the comprehension of their meaning, and *the projection of their status in the near future*'. In addition, she contends that it is the most difficult part of many jobs (Endsley 2003). An example of how awareness of the situational context affects a person's ability to do a task would be a pilot flying through a storm. If the pilot does not have a clear understanding of the effect the storm will have on the plane, a crash may result. In a study of accidents among major air carriers, 88% of those involving human error could be attributed to problems with situational awareness (Endsley 2003).

4.3. Interface tool expertise

Expertise with a specific interface tool is the understanding of how to utilize that tool to achieve relevant task goals. It often describes someone's ability to interact with the tools necessary to apply their subject matter expertise; however, just being able to utilize an interface may not encapsulate a full understanding of the system being manipulated through that interface. Supervision of power plant operations is a good example of the need for interface tool expertise. Due to the variety of information that is needed to maintain such a complex system, it would be virtually impossible for a person to be aware of all of the important variables without automation of some kind. This means that the supervisor must be an expert in interpreting the interface outputs from the automation systems in order to successfully fulfill his or her responsibilities (Hansen 1995). As stated elsewhere in this paper, many of the dimensions of expertise must be used in conjunction with other dimensions to produce constructive performance; expertise in the interface tool dimension alone is not very useful in most settings. Interface tool expertise represents an emphasis on *process* of information flow, usually between the human and system interfaces.

4.4. Expert identification expertise

Expert identification expertise has been previously described in literature as 'know-who' (Harryson 2002). This dimension incorporates knowing who has what level of expertise in a specific area. It can be thought of as the ability to create a network map of other individuals' expertise levels. This form of expertise is needed when trying to determine who to ask a specific question or who to choose to complete a specific project. In order to correctly identify experts, one must know not only the people, but how to accurately assess the cues / signals of expertise (Subramani et al. 2003). A ‘know-who’ expert must also know which cues are the most useful to give in order to establish credibility about their own and others’ expertise.

Another important task of expert identification expertise is to increase the amount and quality of information available during a discussion or decision-making process. Stasser et al. (1995) find that unshared information often remains hidden during group discussion unless the group is aware of the expert roles of each individual. When an individual knows which group member has additional information about a specific topic, it facilitates the discussion and dissemination of otherwise unshared information (Stasser et al. 1995).

The expert identification dimension relies heavily on social awareness and is indispensable for the coordination of teamwork. Gladwell (2002) also discusses the ability to make social connections, to see the interconnectedness of a social system. The authors maintain that this ability to ‘collect people’ is a skill, which means that it can be honed and improved (Gladwell 2002: 42). This skill is one of the underlying elements of people who have expert identification expertise. The knowledge of specific individuals and their expertise configuration is social or teamwork *content* information about properties of the distributed expert network.

4.5. Communication expertise

Communication expertise is the ability to transmit knowledge and information effectively via appropriate media. This social process encapsulates both the knowledge of what and how to communicate. According to the National Speakers Association, ‘the ability to demonstrate and make tangible the value of one’s unique expertise is essential’, and in the changing marketplace, the ability to ‘develop, demonstrate and enhance expertise and then communicate it effectively and powerfully is key’ (Parisse et al. 2003: 2-3). Effective communication is vital to team performance. If members of a group cannot successfully communicate with each other, their ability to execute any group level task is degraded. Thompson’s (2001) meta-analysis of 55 articles on collaboration in technical communication (published between 1990 and 1999 in five major journals) determines that there is a relationship between effective communication and successful collaboration. The study of effective communication activity is clearly a *process* analysis of information flow.

4.6. Information flow path expertise

Expertise in the information flow path dimension includes the technical knowledge of what communication paths exist and which is most appropriate to use, within specific task and situational constraints. This dimension is dependent on the situational context, in that some information paths may not always be available in a dynamic environment. An expert in this dimension knows when a communication path is available and what alternatives should be used if the optimal path becomes unavailable. Situational constraints and activity, availability access, and effective throughput via information flow paths indicate their *context*-sensitive appropriateness for task performance (Caldwell 2005b).

Thus, the six dimensions of expertise presented here are an attempt to provide a coordinated approach to the study of how expertise functions in individuals and groups, and what combinations of skills are required to enable successful task performance. As shown in Table 1, the six dimensions provide an integrated framework of content, context, and process factors affecting performance, and address the issues of expertise implementation to achieve complex task performance goals. One worked example of this framework, that of NASA mission control center flight controllers, follows in the next section.

[Insert Table 1 here]

5. An example of experts in action: NASA's Mission Control Center

The context of complex, cognitive group processes is an interesting and useful area in which to illustrate how these different dimensions are interrelated and overlap within differing individuals' key job functions. As was described briefly in the example of a surgical team, any one individual must be able to perform well on multiple dimensions at the same time; however, it is likely that a specific individual's job functionality will require more expertise in some dimensions than others.

Effective team performance in a time-critical task environment requires coordination across dimensions of expertise, and complementary integration of expertise dimensions within the specific team members (Caldwell 2005a, Caldwell 2005b). Complex distributed group coordination with complementary expertise integration can be seen in NASA Mission Control Center (MCC) operations. In order to successfully manage a space mission, multiple individuals must work together as supervisory controllers to oversee and coordinate the various components of the space vehicle. The MCC environment (and vehicle as controlled system) is much too complex for any one flight controller to be able to attend to (or troubleshoot) all systems at once. Supervisory oversight of specific vehicle subsystems is distributed to teams of flight controllers and support personnel; other controllers have dedicated responsibility for maintaining communication and coordination between these vehicle subsystem teams (Garrett and Caldwell 2001). Three such job functions will be described here in detail to illustrate how various flight controller positions require different levels of expertise in each of these six dimensions. For simplicity, only the dimensions in which a specific controller is expected to have extensive expertise will be discussed in relation to that flight controller's job functionality.

The Flight Director's main responsibility is to monitor and coordinate the decisions and actions of the other flight controllers working in Mission Control. In effect, this job position achieves task orientation through facilitating the teamwork of others. In order to be able to accomplish this task, the Flight Director must 'know who' to ask about specific events as they occur, which is designated as 'expert identification expertise'. In this extremely time-sensitive environment, successful group coordination also requires a high level of 'communication expertise' to ensure that knowledge and information is being effectively exchanged without loss, delay, or degradation. Since the Flight Director's role is central to much of the high-level collaboration in the MCC, effective communication is essential to fill that role. Finally, because the Flight Director is also ultimately responsible for coordinating the final decisions of the front room flight controllers, he or she must be acutely aware of the current 'situational context' and mission status, to know how that will affect the appropriate actions to take in any given situation.

Each front room flight controller is responsible for a different set of specific technical systems, which are divided by console. Many of the consoles, which manage technical sub-domains on the vehicle, require expertise in the same dimensions, with the obvious exception of which technical domain their ‘subject matter expertise’ would be. An example of one of these consoles is EGIL, the Electrical Generation and ILlumination engineer. EGIL’s main responsibility is to monitor the vehicle’s electrical systems for any unusual occurrences, and to maintain support for those systems. Therefore, the flight controller who works the EGIL console would need to be a ‘subject matter expert’ in electrical systems engineering and possibly other related technical areas. In addition, EGIL would need to know how to interact with the ‘interface for the tools’ and console-specific software to monitor and correct the electrical systems. And once again, EGIL must maintain awareness of the current ‘situational context’ as that will affect the decisions of how to prioritize different activities and determine what actions should be carried out.

One front room console that maintains a very different functionality from that of the other flight controllers is that of the Ground Controller (GC). It is GC’s responsibility to help synchronize knowledge and situational awareness through determining what information to display on the three main projections in the front of the Flight Control Room (FCR). Clearly then, the GC must also be very aware of the ‘context in the current situation’. Another one of GC’s main duties is to monitor the different ‘information flow paths’ to ensure that the channels for communication are available. He or she must know when a path becomes unavailable, how to redirect information that would normally be exchanged via that medium, and begin trying to make that path available again. In order to monitor path availability and to facilitate a shared awareness through the common displays at the front of the FCR, the GC must also be proficient in utilizing the different ‘interface tools’ available within the FCR and at that console. A summary of these flight controller positions and responsibilities can be seen in Table 2.

It should be apparent that even though specific dimensions may not have been described for a specific position within the MCC, some level of ability is needed in each of the six areas for effective group coordination. For example, all flight controllers must be able to communicate information clearly with their support staff and the other flight controllers (however, since that would be a general and secondary aspect of their job it is not specifically discussed for each position). The dimensions described above are only the areas of highest expertise demand for each of those positions and therefore are used to distinguish how different functions within the MCC operate in concert with each other.

[Insert table 2 here]

6. Conclusion

Many disciplines and researchers have approached the study of expertise from within a particular research perspective and tradition. As a result, it is difficult to translate many of the definitions across research domains or fields of application (what types of experts are studied). Therefore, this paper has presented a set of descriptions of expertise as being composed of an interrelated set of dimensions that integrate discussions of physical and cognitive skilled performance. The proposed framework for expertise uses six dimensions to structure the distribution of expertise within a team as well as the relevant social and contextual issues. These six dimensions include: subject matter, situational context, interface tools, expert identification, communication, and information flow path expertise. The framework presented here provides a comprehensive description of expertise that may effectively enable a generalized study of expertise comparing human performance across a wide range of context areas.

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Table 1: Framework for the six dimensions of expertise

Dimension	Content/ Context/ Process	Questions answered
Subject matter	Content	What, (How)
Situational context	Context	When, Where, (Why)
Interface tools	Process	How
Expert identification	Content	Who (When)
Communication	Process	What, How
Information flow paths	Context	Which, When, (How)

Table 2: NASA expert example task summary (NASA 2001)

Console Position	Task Responsibility	Expertise Emphasis Dimensions
Flight Director	Overall mission operations and decisions	Expert Identification, Communication, Situational Context
EGIL	Monitors fuel cells, electrical systems, and vehicle lighting	Subject Matter, Interface Tools, Situational Context
Ground Controller	Maintenance and operation for hardware, coordinates spaceflight tracking, data network and data relay satellite system	Situational Context, Information Flow Paths, Interface Tools

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