Knowledge Sharing at NASA: Extending Social Constructivism to Space Exploration

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Social constructivism provides the framework for exploring communities of practice and storytelling at the National Aeronautics and Space Administration (NASA) in this applied theory paper. A brief overview of traditional learning and development efforts as well as the current knowledge sharing initiative is offered. In addition, a conceptual plan for incorporating information and communication technologies (ICT) to sustain communities and foster storytelling is introduced.

Keywords: Social Constructivism, Community of Practice, Storytelling

The mission of the National Aeronautics and Space Administration (NASA) is to pioneer the future in space exploration, scientific discovery, and aeronautics research. To do that, thousands of people, belonging to hundreds of communities of practice, have been working around the world — and off of it — for nearly 50 years, trying to answer some basic questions. What's out there in space? How do we get there? What will we find? What can we learn there, or learn just by trying to get there, that will make life better here on Earth? To answer these questions, NASA is currently engaged in efforts to maximize human capital, including using storytelling for sharing tacit, situated knowledge within and across communities of practice.

Social constructivism provides the framework for exploring communities of practice and storytelling at NASA. In this applied theory paper, a brief overview of traditional learning and development efforts and the current knowledge sharing initiative are provided. Finally, the approach for incorporating information and communication technologies (ICT) to foster storytelling and sustain communities is introduced.

Background and Significance

NASA was founded in 1958 and has consistently been identified as a leading producer of—and a significant contributor to—scientific and technological feats in aeronautics and aerospace. The organization employs approximately 18,000 civil servants and 160,000 contractors in a variety of positions such as scientists, engineers, technicians, administrators, contract officers, educators, and outreach specialists (APPEL, 2006; Chindgren & Hoffman, 2006). The personnel are generally stationed either at NASA's headquarters in Washington, D.C., one of the ten centers, or at the numerous field facilities, laboratories, air fields, wind tunnels, and control rooms across the United States.

Located within NASA is the human resource development organization called, "Academy of Program/Project and Engineering Leadership," or APPEL. This academy is responsible for developing the practitioners who serve in core positions at NASA, the program and project managers and engineers. A brief overview of the evolution of learning and development activities will establish a context for the current effort to foster communities of practice. This historical perspective reflects NASA's growing awareness of the dynamics of learning and knowledge sharing in the workplace as the Agency confronts evolving challenges.

When it was launched in 1988, the organizational predecessor to APPEL focused on program and project management training that would provide foundational knowledge to future generations of NASA project managers. NASA also understood that training could not replace two critical sources of learning: time spent gaining professional experience in the real world of projects; and an unstated but essential reliance on a previous generation of project talent who would naturally serve as mentors, coaches, and expert guides (APPEL, 2006). At the time, NASA was managing large, expensive, long-duration programs like Apollo and the Space Shuttle, both of which generated numerous organizational learning opportunities.

Five years into the program, in 1993, NASA embarked on a new era of revitalization with projects that were *smaller, faster, and cheaper* (APPEL, 2006). It was during this era that NASA emphasized *doing more with less*; the Agency began to significantly increase the volume of its project work. It did so in a way that emphasized safety, innovation, low cost, speed, and quality. Such a demanding vision dramatically altered the nature of NASA's project management practice and the way it developed its talent. NASA began relying on curriculum-driven programs. It implemented a major effort to identify the core competencies that program and project managers would need to achieve success at different career stages. In developing a competency-driven project management practice, the

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organization attempted to link critical project competencies to NASA-sanctioned learning and education. As a result, by the mid-1990s, the academy increasingly emphasized career development, curriculum certification, benchmarking and research, and job aids and tools. It was during those years that NASA laid the groundwork that would enable it to significantly broaden and diversify its developmental organization beyond what was originally envisioned (APPEL, 2006).

During the same time, tremendous changes also occurred within NASA's business environment. Many of these changes were driven by federally mandated directives and programs, such as the President's Management Agenda and the Human Capital Plan. Other changes included the increasing focus on operating as a business, using competition to increase productivity, shrinking budgets, and developing new technologies. These strategic, administrative, social, and technical changes were largely the responsibility of the project management workforce. In a short span of time, the responsibility of project managers had shifted from a pure focus on mission success (i.e., technical, business, safety, and customer satisfaction) to responsibility for business management, commercialization, new technology identification and development, customer satisfaction, strategy, and much more (APPEL, 2006). The question then confronting NASA was how does it meet the challenges involved in managing its current project portfolio as safely, efficiently, and effectively as possible?

In response to this query, APPEL enhanced the capability of program and project managers and engineers with the creation of four business lines: career development, performance enhancement, research and advanced concepts, and knowledge sharing. Career Development provides products and services around professional development competencies and training and development. Performance Enhancement brings world-class experts and learning directly to NASA's programs and project teams when they need it and how they need it. Research and Advanced Concepts engages universities in world-class research and conducts workshops designed to foster the exchange of ideas between NASA program/project leaders and university researchers. Knowledge Sharing focuses on building and supporting NASA communities of practice for the express purpose of promoting leadership development through mentoring and teaching, encouraging open communication and dialogue, and capturing and communicating knowledge and wisdom from the best program and project leaders. Storytelling is used to give practitioners a sense of the context in which experience has been developed and help them to grasp the tacit nature of some of the knowledge being communicated. The influence of social constructivism theory on knowledge sharing is particularly evident and the question, "What are the implications of using social constructivism and storytelling at NASA?" will be explored in the remainder of this paper.

Methodology

The methods used to respond to this question were a literature review, author observations and content analysis. The literature on social constructivism was largely drawn from the adult learning/human resource development research because of the learning thrust of the APPEL Knowledge Sharing activities. A literature search was also conducted within the knowledge management scholarly and practitioner literature on storytelling, because the philosophy that undergirds the Knowledge Sharing effort is highly influenced by knowledge management. The author then observed the use of storytelling at NASA forums, as well as reviewed publications containing stories provided by seasoned NASA program/project managers and engineers. This applied theory paper is intended to inform human resource development researchers and practitioners about a current organizational initiative.

Framework

Social Constructivism

Social constructivism served as a framework for developing the NASA program/project manager and engineering professionals. Constructivism is the perspective that learning is a process of constructing meaning and building knowledge; it is how people make sense of their experience (Matthews 2002; Merriam & Caffarella, 1999). The adult learning perspective of social constructivism has prospered by proposing Piaget's theory of cognitive development and Dewey's assumptions about knowledge and experience. Piaget laid the foundation for our understanding of cognitive development and he emphasized the importance of the learner constructing knowledge through activity. Dewey addressed the underlying concept that learning is cumulative and examined the connections between life experience and learning. To this end, he underscored the importance of the situated nature of experience in learning.

Constructivism emphasizes the learners' personal interactions with physical experience within their daily lives (Piaget, 1970); whereas a social constructivist perspective recognizes that human beings require the assistance from others to learn. Learning entails involvement with the symbolic world, in that it consists of conceptually organized, rule-bound belief systems about what exists, how to get to goals, and what is to be valued (Bruner, 1985).

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Driver, Asoko, Leach, Mortimer, and Scott (1994) define social constructivism by reporting that knowledge is "constructed when individuals engage socially in talk and activity about shared problems or tasks. Making meaning is thus a dialogic process involving persons-in-conversation, and learning is seen as the process by which individuals are introduced to a culture by more skilled members" (p.7). Candy (1991 p. 275) adds that, "Becoming knowledgeable involves acquiring the symbolic meaning structures appropriate to one's society, and, since knowledge is socially constructed, individual members of society may be able to add to or change the general pool of knowledge. Teaching and learning...is a process of negotiation, involving the construction and exchange of personally relevant and viable meanings."

Berger and Luckmann (1967) depict social constructivism as a blend of symbolic interaction and social reality. The social reality of learners entails integrating an existing reality with a new generation of reality and results in *legitimation* (Berger & Luckmann, 1967 p. 86). Legitimation is the process by which people construct explanations and justifications for the fundamental elements of their collective, institutionalized tradition. There is a cluster of literature that examines the linkage between socially constructed realities with organizational storytelling. The linkage suggests that storytelling is useful in expressing the experience of organizational members, socializing new members, building commitment, amending the organizational reality, and developing a renewed sense of purpose (Boyce, 1996). Put simply, stories and storytelling reflect organizational culture, with culture defined as a shared set of beliefs that shape people's behavior, judgments, and understanding of the world. Although storytelling is an ancient medium for creating meaning and sharing knowledge, it is increasingly used in organizations, including NASA, as a part of learning and development interventions.

The approach to learning and knowledge sharing explored in this paper will reflect an understanding that knowledge is embedded in and constructed from relationships and through social interactions. With this framework, knowledge is recreated and reconstituted through dynamic, interactive, social networking activities. This approach is a contrast to the more frequently accepted cognitive, information-processing perspective that thinks of knowledge creation as individual absorption and interpretation of information. According to Newell, Robertson, Scarbrough, and Swan (2002), the community model, which is socially constructed and based on experience, may be transferred through participation in social interactions including communities of practice, and is largely built on trust and collaboration.

Storytelling Within and Across Communities

Many contemporary scholars and practitioners appear to agree with social constructivist theorists that problem solving and learning from experience are parts of everyday life (Argyris, 1991; Hoffman, 2003). Many now also believe that organizations benefit most when individuals share the knowledge they have obtained from their experience by working with others on organizational tasks as opposed to their sharing theoretically based information (Matthews and Candy 1999; Nonaka and Takeuchi 1995). Stories shared in group activities and during collaboration are essential to exploring, testing, and experimenting in the workplace (Byham, 2000; Caudron, 2000; Marsick & Volpe, 1999; Marsick & Watkins, 1996; Pace, 2000). Storytelling, especially within and across communities of practice, is an effective way to support and encourage the sharing of knowledge.

This is because a community of practice enables a process of creating, sharing, and applying new knowledge that is social and dynamic. Nonaka and Takeuchi (1995) described how, in a knowledge-creating organization, this process moves from the personal to the social, and in so doing builds on tacit as well as explicit knowledge in what they described as a *knowledge-creating spiral.* And because NASA's workplace is increasingly viewed as an essentially boundless environment, with knowledge passing across disciplinary, organizational, and even international boundaries, APPEL is exploring technology to amplify the contribution of the knowledge-creating spiral.

The community of practice model is based on the idea that one cannot separate knowledge from practice (Nonaka & Takeuchi 1995). As a result, a community of practice shares knowledge in *living* ways as opposed to the traditional approach of recording knowledge in databases or documents. Even when organizations publish such knowledge in a manual, the knowledge is frequently highly contextual. Such a documentary approach cannot fully collect the knowledge of project teams. In a community of practice, members come together to learn from each other, often though group activities. Wilson, Desmond, and Roberts (1994) have contended that the community of practice model of knowledge sharing is especially helpful when members have tacit knowledge and when, by working together, they recreate and reinterpret knowledge for other activities.

Face-to-face storytelling. At NASA, fostering co-participation entails gathering together individuals who perform similar tasks and engaging them to share best practices in the form of storytelling. Storytelling is increasingly used throughout the organization to ground the complex ideas related to project leadership in experience as well as to inspire change. The focus of the APPEL Masters Forum is to provide a forum for program and project managers and engineers to share their stories, face-to-face, about their work experiences. Since this initiative's inception, forum participants have crafted stories from their work experiences and then discussed concrete examples of best practices

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and lessons learned. Participants may or may not realize that a story shared during a group discussion results in knowledge sharing, but they leave the forum able to share what they have learned with others, perhaps in other communities of practice or their project teams.

The Masters Forum is customized to the needs and interests of NASA's program and project management and systems engineering community. As members of the community share information, knowledge, and activities; they also share values. Storytelling "establishes common meanings and transmits the values characteristic of…communities. It enables the members of…communities to see the world differently, to experience that internal 'ah-ha' that revitalizes them and reframes how they connect with each other and the world" (Denning, 2005, p. 5). Indeed, stories passed down through one generation of community members to another provide continuity in the practice or domain, containing the history of the community, and may result in strengthening the culture.

Storytelling also supports members actively obtaining new knowledge and meaning through experience and interaction from others within their community, as well as individuals in other communities or project teams. Since community of practice members generally belong to – and identify with – a project team and other related communities within and beyond their organization, there are countless opportunities to create new knowledge and exchange and interpret stories (Chindgren & Hoffman, 2006). Cohen and Prusak (2001) observed, "Stories have particular power to build and support social capital" (p 112). They add that telling and listening to stories, chatting, and sharing a little gossip, are the main ways that people in communities come to trust and understand one another. During the course of these conversations, technical expertise is also shared because when community members get together, they invariably "talk shop" and frequently enrich their knowledge doing so.

During the Masters Forum in September 2006, seasoned program managers and systems engineers gathered together to share stories and exchange lessons learned. More than 50 practitioners listened to and discussed a milestone event in NASA's history — the Viking science mission designed to determine if there was evidence of life on Mars. One instrument that was critical to achieving the mission's scientific objectives was a gas chromatograph-mass spectrometer (GCMS). During the forum, the participants were able to meet the business manager for the Viking mission and listen to his nuanced insight into the decisions made years earlier.

For example, the business manager shared that the head of the elite team of researchers responsible for developing, fabricating, and testing a lightweight, portable "breadboard" (experimental model) of the GCMS believed that the instrument was perceived as a "stepchild" and was not getting proper supervision at one of the NASA centers. In response, the Viking program manager placed the instrument on his "top ten problems" list and commented, "Specifically the problem is the systems design and program redefinition of a simplified GCMS." This "problem" altered his management style to more proactively and aggressively facilitate communication and coordination between and among the NASA Centers and contractors. Thirty years later, similar challenges confront current NASA managers as they design instruments for the next-generation of space vehicle which will replace the space shuttle, the Orion, that will transport astronauts back to the moon and to Mars. With stories, NASA practitioners are able to apply lessons learned by former generations of program managers and engineers. In this case, they reflected on crucial strategies for balancing technical priorities, scheduling pressures and cost implications.

In addition to sharing NASA stories, lessons from industry are also told at the Forum. Helen Greiner, the co-founder and chairman of iRobot, a leading company in the robot industry, discussed iRobot's early experience of "innovating for innovation's sake." For instance, an early version of an amphibious mine-clearing robot called Ariel walked in the surf and moved like a crab with twelve motors to drive twelve joints. At the time, it was the most advanced walking robot in the world. The company realized, however, that their technologies needed to respond to the customers' specific needs. For the military, the robot had to carry a payload, have the ability to travel long distances, and be simple enough for soldiers to use during combat. After the realization, iRobot altered the robot's design to satisfy the military's requirements. Today, their robot is used extensively throughout Afghanistan to search in caves for terrorists and explosives, saving countless lives of American soldiers. Although NASA has a tradition of technology transfer back to civilian use with "spin offs," listening to iRobot's experience reinforced the message for NASA practitioners that innovation must be practical, affordable and respond to the customers' science and engineering requirements.

At the Masters Forums, APPEL encourages relationship building among participants. APPEL leadership believes that the programs offer participants an opportunity to learn from—and network across—the Agency and with guests from industry and academia. APPEL views face-to-face contact as an important and tremendously valuable opportunity to initiate interpersonal relationships. In addition to APPEL leadership, forum participants also recognize the value: A content analysis of the September 2006 Masters Forum evaluation data revealed that the ideas for building social capital, collaboration strategies, and even the opportunities to network during meals, were the "most valuable to success" when participants returned to their jobs.

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Written stories. Written stories shared by program managers and engineers are also shared throughout NASA through *ASK Magazine.* The ASK Magazine (Academy Sharing Knowledge), launched in December 2000, is now available as both an online and print publication and features stories and best practices on project management and engineering challenges as well as subject-related interviews and book reviews. Many of the stories gathered from the semiannual Masters Forums are published in ASK Magazine. The print-version of *ASK Magazine* currently reaches 7,000 readers representing all of the ten NASA centers. The print version is also mailed to members of the U.S. Congress, industry partners like Lockheed Martin, and universities around the world including ESL Lille in Paris, France, University of Technology in Sydney, Australia, and Massachusetts Institute of Technology in Boston, MA. Thousands of additional readers access the stories through the *ASK Magazine* on-line version each month.

In a recent issue of the magazine, team members on the Hypersonic Technology Experiment (HyTEX) project shared their experience about developing a flying technology test bed for thermal protection systems, flight controls, sensors, communications, and other vehicle systems that need to withstand the rigors of high-speed re-entry to Earth's orbit. Five NASA centers, two Air Force groups, and Sandia National Laboratories collaborated on the effort. After a successful preliminary design review, the project was cancelled as a result of changing NASA priorities and budget pressures. Despite the disappointment, project participants remained extremely positive about the experience, citing outstanding cooperation among the multiple centers and organizations involved and the speed and quality of the work accomplished. The project manager commented that the relationships of trust and mutual understanding established during the work would persist and have lasting value for NASA and the participants. He commented, "The success of the project is relationships. The sense of trust sets you up for future engagements. You're not making a cold call; you've got an existing relationship and people will go out of their way to help you" (ASK Editorial Staff, 2006 p. 33).

Members of the cancelled project team commented that the successful collaboration was in part due to the project manager's clarity about the work to be done, including system boundaries, and fostering a "sense of safety" (p. 33). This encouraged colleagues to be open to offer and ask for help, and this behavior reinforced itself. The project manager also organized face-to-face meetings with team members at different locations which helped to create a sense of equality and partnership that would have been lacking if all meetings had been held at only one NASA center. Social times incorporated into the agenda helped team members get to know each other and catalyzed feelings of rapport and community.

Recounting the contributing factors through a written narrative, allows the magazine's readers to benefit from the experience of the project team. Readers have commented that a cancelled project is an unfortunate experience but valuing the relationships and leveraging them for future project work are important reminders. Stories are valuable because they connect information with values and relevance, giving us a sense of the context in which experience has been developed and helping practitioners grasp the tacit nature of the knowledge being shared (Newell et al. 2000).

Results

Social constructivism theory had implications for human resource development at NASA. Today at NASA, the community of practice model of knowledge sharing refers to any joint enterprise that brings individuals with shared interests together; communities of practice are relationships of mutual engagement that bind members together into a social entity of communal resources (Brown & Duguid, 1991; Chindgren & Wiswell, 2006; Lave & Wenger, 1991). Membership is based on voluntary participation of individuals who share values and work to resolve problems together. Members value all kinds of knowledge (including, for instance, hunches as well as demonstrable scientific knowledge) that transpires within a community. NASA is increasingly promoting learning based on collective performance and encouraging relationships within and across communities. Storytelling facilitates this vision. The Viking mission experience, the iRobot lesson learned, and the HyTEX project cancellation are interesting ways to present information. Practitioners resonate with the situation, empathize with the project team members and frequently personalize the information to themselves or people they know. As practitioners collectively listen to the stories at the Masters Forum, and read and reflect upon the articles in *ASK Magazine*, core values and beliefs are reinforced within the program management and systems engineering communities.

Knowledge sharing conferences, publications, and multimedia provide NASA managers, scientists, and engineers with examples and lessons learned from overcoming project challenges. The conferences include the semi-annual Masters Forum and the annual prgram management conference, PM Challenge Conference. Publications include the award-winning *ASK Magazine*, a recently launched biweekly electronic newsletter, and a library of robust case studies used throughout NASA to facilitate discussion and learning. In addition, Knowledge Sharing broadcasts video clips through the APPEL website featuring leading thinkers and practitioners in the fields of knowledge management, program leadership, and systems engineering.

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Next Steps

Solidifying and sustaining the relationships built at the Masters Forums and supporting the development of new communities are key reasons for APPEL to explore avenues to leverage computer-mediated technologies. The academy is in the process of planning an enterprise-level collaboration and document management platform—a Knowledge Center—that will serve as a tool for virtual storytelling within and across communities of practice. This multiphased approach will enable all APPEL business lines, including knowledge sharing, to improve current and future learning and development services, products, and processes.

During Phase 1, the Knowledge Center will be developed for use by the APPEL team to communicate and coordinate internally throughout the four business lines —Career Development, Performance Enhancement, Research and Advanced Concepts, and Knowledge Sharing. Emphasis will be placed on organizing, storing, and accessing core documents, team and customer data, and evaluation information. At this initial phase, for instance, the members of career development business line can post the training evaluations of vendors in order to review and monitor their performance. Currently at NASA, there are dozens of databases that provide this basic service to other groups, such as the NASA Engineering Network (NEN) which was developed for engineers to contribute "lessons learned" documentation.

The capabilities will improve with Phase 2, as the users will expand beyond the internal APPEL team to include the customers, NASA program and project managers and engineers. It is anticipated that this phase will support continuous learning and provide communities with a virtual learning environment with pre-and post-Masters Forum venues, workshop communication, and exchange of resources. The social constructivism approach to information and communication technologies (ICT) is influenced by organizational context and incorporates the assumption that communities use stories to communicate important information. For NASA, the community framework provides the designers of ICT a touchstone to ensure that the Knowledge Center supports interactive networking processes and fosters dialogue occurring through dynamic networks. Furthermore, NASA's organizational structure, cultural values, and group norms must be considered in the development of the Knowledge Center.

Rather than merely codifying information or warehousing data, the Knowledge Center will be designed to provide the contextual features that as much as possible facilitates tacit knowledge sharing by Phase 2. This means that the Knowledge Center will be effective if it is designed to connect communities rather than simply transfer information. At NASA, knowledge is often embedded in a discipline-specific community (e.g., software engineering) or context (i.e., mission-specific, such as completing the International Space Station or servicingvg the Hubble Telescope); therefore, developing a shared understanding and degree of trust will be the most critical step towards knowledge sharing (Newell et al., 2000).

ICT systems may complement but not replace the importance of authentic relationships and communities. This is because computer-mediated technologies, on their own, cannot encourage knowledge sharing across organizational, disciplinary, or geographical boundaries (Vandenbosch & Ginsberg, 1996). However, community practices that encourage the development of trust, commitment, and shared understandings can foster community development. It is recognized that in the early stages of community development, personal contacts and face-to-face conversation, like that which occurs at the APPEL Masters Forums, will likely be necessary before the successful launch of online communities of practice. Then, using ICT, practitioners can communicate different perspectives, solve problems together, and exchange stories—all of which may help reinforce the meaning and purpose of a particular community.

During Phase 3, APPEL intends to pilot innovative, blended learning methods and determine which strategies and tools are of most value to NASA practitioners. It is anticipated that participation in the Knowledge Center will be extended to NASA partners since more than 80 percent of the NASA workforce is situated in industry and universities across the United States and overseas. Offering customized support to informal communities and institutionally-coordinated strategic communities will be considered. For example, members who share a common history may need a space to simply post challenges, raise questions, and solicit suggestions. Yet, strategic communities may require more organizational learning support, such as a facilitator to capture and share key ideas, mediate disagreements, and network with other communities or project teams.

The developers of the Knowledge Center recognize that knowledge sharing is embedded in social relations and context and as a result, frequently occurs through conversations and storytelling. Furthermore, given the highly complex tasks required to accomplish the NASA mission, APPEL leadership believes that strong relationships within and across communities of practices are important contributing factors required for innovation and NASA mission success. For organizations that do not have such challenging goals as space exploration, scientific discovery, and aeronautics research requiring multifaceted and highly coordinated efforts involving human life and millions of dollars, approaching knowledge sharing as routinized and technology-driven, with little emphasis on personal ties, may be more efficient (Hansen, 1999).

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Summary

This applied theory paper used social constructivism as a framework for exploring communities of practice and storytelling at NASA. Social constructivism explains the process of practitioners learning from others through stories and "hands-on" activities. Although social constructivism theory describes learning, elements such as active inquiry, relationships, and environment are shared with our understanding of communities of practice and storytelling within organizations.

Also included in this paper was a brief overview of traditional learning and development efforts at NASA which illustrate the evolution of the current knowledge sharing initiative. With an understanding that learning is social and comes largely from the shared experience of participating in activities with fellow practitioners, APPEL has been able to encourage knowledge sharing and facilitate learning throughout NASA and with its industry and university partners. Storytelling has been a powerful tool to showcase problems and challenges and present detailed first-hand accounts of how they were confronted and, in many circumstances, how certain challenges were overcome successfully.

Finally, the conceptual plan for incorporating ICT to sustain communities and foster storytelling was introduced. Currently, the literature about applying the community model to develop ICT is substantially less developed than the research and experience on the technology-driven development of communities of practice. As a result, NASA is preparing to develop a fairly unique platform, the Knowledge Center, where learning will be approached as intentional and contextual, and the systems and structures will not only allow but encourage NASA practitioners to learn together.

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