Best Practices and Lessons Learned for Digital Training Asset Repositories

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ABSTRACT

Several recent meta-analyses suggest that Augmented Reality (AR) and Virtual Reality (VR) based training are effective at improving learning-related outcomes (cf. Clark et al., 2016; Garzon et al., 2019; Kaplan et al, 2021; Zendejas et al., 2013). However, the development of AR and VR training can be extremely resource intensive. For example, instructional designers must first obtain 3D models of the tools and technologies with which the learner must interact during the training event. VAMR trainers need behavior models to accurately mimic the behaviors of the weapons systems, including articulating components of graphic models and system software models that drive graphic displays. If these models do not already exist, they must develop them from scratch with aid of high-resolution source photos, scans, videos, and Computer Aided Design (CAD) files. As a result, it is common for the development of AR and VR training to require six to nine months of completion time. While the use of digital asset repositories is extremely common in the commercial sector, the DoD is only recently starting to embrace this approach. A review of publicly accessible content repositories reveals that they are often associated with an online community of practice (CoP), each with varying structures and levels of organization and user participation. In this paper, we systematically review and code 15 publicly accessible digital content repositories across multiple disciplines such as education, research, and gaming, and score them on dimensions of CoP processes, features, and effective practices. The paper provides empirical data related to the influence of a CoP on digital object repository utility, with the goal of better understanding emerging digital asset repository collaboration processes. The paper concludes with a prioritized list of best practices that can reduce the time needed to discover, share, and reuse relevant digital assets, thereby accelerating their availability for use in DoD training.

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Keywords Augmented Reality, Virtual Reality, Communities of Practice, Digital Objects, Repository, Military Training, 3D, Modeling, Simulation

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BACKGROUND

"Usually when we think of where people turn for information or knowledge we think of databases, the Web, intranets, and portals or other, more traditional, repositories such as file cabinets or policy and procedure manuals. However, a significant component of a person's information environment consists of the relationships he or she can tap for various informational needs."

Cross et al., 2001, p. 100.

U.S. military operations continue to increase in complexity as the Department of Defense (DoD) adapts to the future operating environment. As potential adversaries develop technologies that undermine our strengths, U.S. military organizations work to meet those challenges through several means, one is through creating highly realistic training environments to prepare Warfighters for the future environment. One of the most rapidly growing areas of military training is the development of high-fidelity visual environments that accurately depict a Warfighter's setting, whether it be an aircraft cockpit, a cyber operator's console, or an entire aircraft. Warfighters observe and interact within these environments using low-cost, Commercial-Off-The-Shelf (COTS) Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) (collectively referred to as VAMR) head mounted displays (HMDs). VAMR technologies enable Warfighters to train in detailed, realistic environments that are free of the hazards and resource requirements of training on live equipment.

Statement of the Problem

The increased adoption of COTS VAMR technologies for military training allows trainees to conduct more training trials than they can on simulators with limited numbers and availability, or on actual equipment with limited training space and portability. This increased training capacity provided by VAMR technologies will increase demand on military instructional developers who must design digital training environments and their associated digital objects. While many argue there is no substitute for training on live equipment, as weapon systems become significantly more expensive to maintain and operate, military training organizations typically find that traditional hands-on system training is financially unfeasible. As an example, the F-35 Joint Strike Fighter costs approximately $110 million per unit, and $50,000 per hour to operate. While the capabilities of this aircraft are the most advanced of any fighter in history, the substantial operating costs of this and other systems continue to drive the need for training alternatives to operating the actual weapons systems or other equipment, and high-fidelity VR simulation is emerging to be the predominant alternative modality.

Another area driving the increased use of VAMR training is for mission rehearsal. VAMR training is increasingly being used to prevent adversaries from observing our weapons systems capabilities. In some weapons systems such as advanced fighters the weapons and avionics detection ranges exceed the physical space currently available at facilities used for live training.

This paper provides relevance to the Modeling and Simulation literature as all the military services continue to increase their use of VR/AR technologies for training, creating a gap in how to best develop and share 3D objects.

Issue

As the military services continue to expand their use of VAMR technologies for training, it also expands the demand for digital objects, which are the artifacts that trainees see and interact with while in the digital environment. Using existing military VR training programs as an example, pilots and aviation maintainers will interact with virtual cockpits, checklists, aircraft components, tools, ground support equipment, virtual people, and numerous other objects which developers must create to visually mimic the actual object. Digital content such as this is resource intensive, both in terms of dollars and man hours (United States Air Force Scientific Advisory Board, 2019). Beaubien et al. (2022) described many of the challenges instructional designers face in obtaining the requisite digital objects necessary to facilitate experiential VR/AR training, such as obtaining digital models with the appropriate levels of visual and functional fidelity (reference here) for a given training scenario. When instructional designers and SMEs create lesson plans and scenarios that require the use of specific digital objects, they often learn that they may not already exist. If another military organization has created a digital object, such as UH-60 helicopter or U-2 airplane (Figure 1), there are no present methods to share these objects readily, where digital assets are easy to find, obtain, and have licensing or other appropriate permission to use.

Figure 1. U-2 Aircraft in Hangar

Note. The aircraft, numerous aircraft components, and the hangar are all distinct digital objects

Beaubien et al. (2022) addressed this problem through their evidence-based recommendations on searchable, web-based repositories for sharing VAMR training assets. This article extends that research by recommending that these repositories also incorporate the creation and use of a related CoP to enhance the utility of these increasingly necessary repositories. The themes on knowledge sharing are reflected in how CoPs have experienced increased growth and popularity among practitioners and has focused the important link between knowledge and activity, and the importance of relationships (Chindgren, 2005). As the military services begin to organically develop the talent pool which needs to possess the knowledge, skills, and abilities to create, develop, and utilize digital objects for training, the need to collaborate and share this knowledge will increase, to prevent the expenditure of scarce resources on digital objects that may already be available. The next section discusses asset repositories and the role of CoPs in learning.

Digital Asset Repositories

Large corporations and businesses began to utilize digital asset management systems in the early 1990s (American Library Association [ALA], 2009). The rapid growth and use of digital technologies in business led to the need for large-scale archiving of digital artifacts. A good explanation of the lifecycle of a digital asset is found in Styblińska's (2006) description where the author states, "digital objects are created, edited, described and indexed, disseminated, acquired, used, annotated, revised, re-created, modified and retained for future use or destroyed" (p. 318). Modern digital asset repositories ensure that digital objects, such as 3D renderings of military weapons systems and equipment, are preserved and available for access with standardized documentation and formats. As the services continue to increasingly adopt VR/AR systems for training, the need to have a searchable, web-based repository for military use will allow training developers to quickly share digital assets to avoid redundant and resource-intensive development costs for objects that may already exist (Beaubien et al., 2022). Digital object repositories are now ubiquitous and standardized in the commercial VR/AR and gaming industries, and this paper asserts that not only is there urgent need for digital object repositories in the military, but to enhance the development and use of the objects in different training programs, they should be associated with a requisite CoP.

Communities of Practice

Based in the theory of Situated Learning (Lave & Wenger, 1991), CoPs are an essential element of the instructional approach that states knowing and doing are inseparable, and learning occurs within authentic contexts. Situated Learning Theory (SLT) posits that learners are much more inclined to learn when actively participating in a learning experience (Lave & Wenger, 1991), and VR training is well suited to experiential learning (Kwon, 2019). A model of SLT (Figure 2) shows a CoP near the center of the circle, representing expertise. The novice is at the periphery, and as a member of the CoP, the novice moves toward the center through interaction and support with experts (Lave & Wenger, 1991).

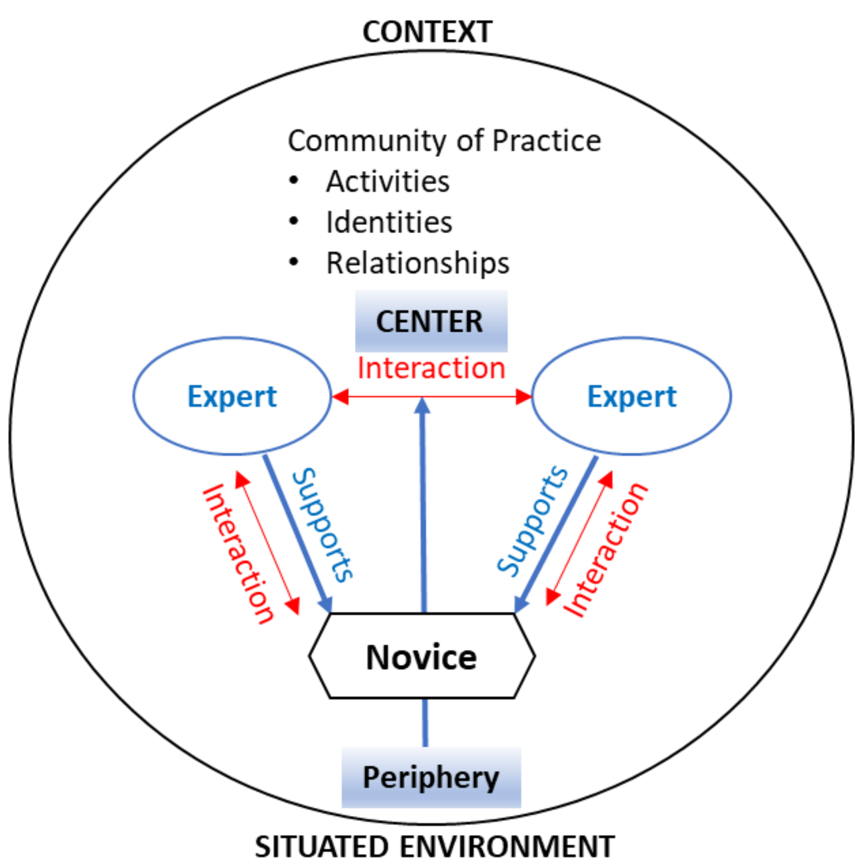

Figure 2. Model of Situated Learning Theory

There is extensive literature on CoPs and the application of a community-based approach to knowledge (Wenger, 1998; Wenger et al., 2002), as well as their potential within a military training context (Ayers, 2022). A review of publicly accessible content repositories reveals that they are often associated with an online CoP, each with varying structures and levels of organization and user participation. Discussion forums are a ubiquitous communication tool within an online learning environment and significantly shapes the types of communication that takes place. The various modes of internet discussion and knowledge management provide an effective opportunity for CoP members to engage (Tallent-Runnels et al., 2006; Levine, 2007) with the goal of the novice transitioning toward the center of the circle in Figure 2.

This paper systematically reviews and analyzes 15 publicly accessible digital content repositories across multiple disciplines such as education, research, and gaming. It measures their impact across the dimensions of CoP processes, features, and effective practices, with the intent of identifying best practices that can reduce the time needed to discover, share, and reuse relevant digital objects, thereby accelerating their availability for DoD training.

METHOD

Design

The nature of this inquiry is exploratory, seeking to identify key ideas and concepts around the impact of CoPs on digital asset repositories. The authors utilized a qualitative descriptive design (Sandelowski, 2000; Creswell & Clark, 2011) which is appropriate for exploratory research because little is known about the topic under investigation. The authors used inductive content analysis (Hsieh & Shannon, 2005) to code and categorize the various communicative engagements associated with repository CoPs. The sample included a mix of organizations across different disciplines that have publicly accessible user-generated content such as knowledge bases, discussion forums, message boards, and user-accessible knowledge resources

Data Collection

The authors conducted a qualitative analysis of the various social metadata content found in web-based communication exchanges that take place within CoP-associated digital asset repositories. The fifteen Communities of Practice represented organizations from private industry and academia: Industry - five that deal primarily with the web-based development, sharing, and sales of 3D models (3D Model Repositories A, B, C, D &, E); two commercial gaming engines (Gaming Engines A & B); a personal hobby repository (Hobby Repository A); a platform that deals primarily in teaching how to create and use 3D models (3D Model Learning Platform); and an organization that deals primarily with 3D models for the use of 3D printing (3D Printing Community A). For academia, the authors examined four public and private universities (Universities A, B, C, & D) and one nonprofit digital asset repository (Digital Asset Repository A). Each of the 15 organizations in this convenience sample had varying levels of publicly accessible communication exchanges between CoP members, and the uses of digital assets varied widely across organizations. The authors obtained access to each of these publicly accessible sites, and reviewed them for their features and functionality, as well as any publicly available metrics that they report (e.g., number of users, number of interactions, number of assets). The authors pieced together sets of discussions fitted to the specifics of the impact of CoPs on digital asset repositories. As needed, they created publicly available accounts to access CoP communication data.

Data Analysis

The analysis was guided by the original research question: “What is the impact of CoPs on the people who use digital asset repositories?” Data was categorized into similar themes analogous to the work of Hew and Cheung (2003) for evaluating the levels of participation and quality of online interaction. A combined framework of Kirkpatrick’s (1996) model of training evaluation, Wenger and McDermott’s (2011) three elements of a CoP, and Wenger, Trayner and DeLaat’s (2011) five levels of value creation of a CoP were used to evaluate the impact of CoPs on digital asset repositories.

Kirkpatrick’s Model

Kirkpatrick first developed this model in the 1950s to evaluate the effectiveness of training programs (Kirkpatrick 1996). The model is divided into four levels that describe the different elements of evaluating learning, described below in Table 1.

Table 1. Four Levels of Kirkpatrick's Evaluation Model

Level	Description
Reaction	How people felt and their personal reactions to the knowledge sharing experience
Learning	What people learned through their experience engaging with CoP members
Behavior	The extent to which CoP members applied their learning and changed their behavior
Results	The effect of the learning on CoP member due to the increased domain knowledge

Wenger's Elements of a Community of Practice

CoPs are formed by "people who engage in a process of collective learning in a shared domain of human endeavor" (Wenger-Trayner E, & Wenger-Trayner B., 2015, p. 1). Wenger and McDermott (1998) posit that a unique feature that distinguishes CoPs from other learning communities is that CoPs possess three distinct elements that uniquely describe them. These three elements, which are interrelated and therefore cannot be understood separately, are described below in Table 2.

Table 2 Three Elements of a Community of Practice

Elements	Description
The Domain	A CoP is not a club of friends or a network of connections between people. It has an identity defined by a shared domain of interest. Membership therefore implies a commitment to the domain, and therefore a shared competence that distinguishes members from other people. They value their collective competence and learn from each other.
The Community	In pursuing their interest in their domain, members engage in collaborative activities and discussions, help each other, and share information. They build relationships that enable them to learn from each other, and they care about their standing in the community.
The Practice	A CoP is not merely a community of interest. Members of a CoP are practitioners. They develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems; a shared practice. This takes time and sustained interaction.

Note: Element definitions from Wenger, McDermott, and Snyder (2002).

Levels of Value Creation in CoPs

To examine if CoPs appear to create value and have an impact on digital asset repositories, the authors looked for the qualitative indicators of value at each of the levels below (Table 3). Indicators in each cycle were evident in most of the CoP data collected. In the Wenger et al. (2011) value assessment framework they recognize that interactions and exchanges, such as the ones the authors observed, produce their own value, some of which is not immediately realized. The descriptions of the five levels of value creation in a CoP (Wenger et al., 2011) are listed below in (Table 3):

Table 3 Five Levels of Value Creation in a Community of Practice

Level	Description
1 – Immediate Value	The activities and interactions between members have value in and of themselves.
2 - Potential Value	The activities and interactions of level 1 may not be realized immediately but saved up as knowledge capital whose value is in its potential to be realized later.
3 – Applied Value	Knowledge capital may or may not be put into use. Leveraging capital requires adapting and applying it to a specific situation.
4 – Realized Value	A change in practice does not necessarily lead to improved performance, so it is important to find out what effects the application of knowledge capital is having on the achievement of what matters to stakeholders.
5 – Reframing Value	This occurs when learning causes a reconsideration of how success is defined. It includes reframing strategies, goals, and values.

For each of the 15 CoPs, the authors reviewed the publicly available user communications (e.g., threaded discussion groups and forum posts) to divide the online communications into small units, to assign labels to those units, and to then group the codes into themes as described in Nandi and Chang (2011). Through manual qualitative data analysis, the authors were able to measure CoP performance along the variables of community, domain, and practice, as well as the variables of the four levels of Kirkpatrick's model. Each variable was given a rating of Fair (red), Good (amber), or Excellent (green) relative to presence, as depicted in Figure 2.

For the Domain element, the authors looked to see if CoP members demonstrated commitment, if the domain had clear boundaries, and if CoP members demonstrated a shared competence. For Community, the authors looked to see if there was evidence of trust among members, whether there were other engagements beyond the discussion boards, the frequency of interaction, whether there was evidence of a sense of loyalty in the CoP, and evidence of any type of CoP structure. For the Practice element, were the CoP members receiving what they needed from the group? Next the authors looked at the activities in the CoPs, such as synchronous discussions, available trainings, methods of knowledge sharing, and levels of interaction.

Regarding the Kirkpatrick model evaluation criteria, for Reaction the authors looked for individual reaction to CoP membership, whether their needs were being met, if they indicated that they felt their needs were being supported, and for a sense of positivity around knowledge sharing. For Learning, the authors looked for elements of learning, where CoP members were sharing insights or demonstrating an understanding of a new concept or tool which resulted in an evident behavioral change. Behavior was the most challenging variable in the Kirkpatrick model to evaluate via online discussions, but evidence was present. The authors looked for evidence that CoP members were applying their learning in their respective environments, reading threaded discussions over time that showed increased levels of confidence and engagement as a result of gaining new knowledge and a willingness to share. For Results, the authors looked for tangible results of CoP interaction and engagement, such as if CoP members were offered a new position based on the new skill, whether a student achieved their academic goals with a given project, and a generalized sense of how the CoP was contributing to the success of the digital object repository. The data were most disparate at the Results level, where private sector organizational discussions had more feedback loops and evidence of value. Some of the academic institutions lacked the richness of the private sector organizations, although sufficient data was available. The generalized results are summarized below.

RESULTS

At the end of data collection and analysis, it was evident that the CoP impacts were positive, albeit to varying degrees. Generally, those CoPs associated with private sector digital asset repository associations met all of the evaluation criteria, were the most active, and provided the greatest number and diversity of resources to their members. Both initial evaluation criteria of Content and Interaction Quality were excellent, and the Levels of Impact across the three CoP Elements were easier to observe and interpret. The two gaming engine CoPs were identified as exemplar CoPs, providing their members the most impact at all of Kirkpatrick's four levels. In Figure 3 below, the authors refer to the COPs by pseudonym because the focus of this paper is on general trends across CoPs rather than making evaluative decisions about individual CoPs.

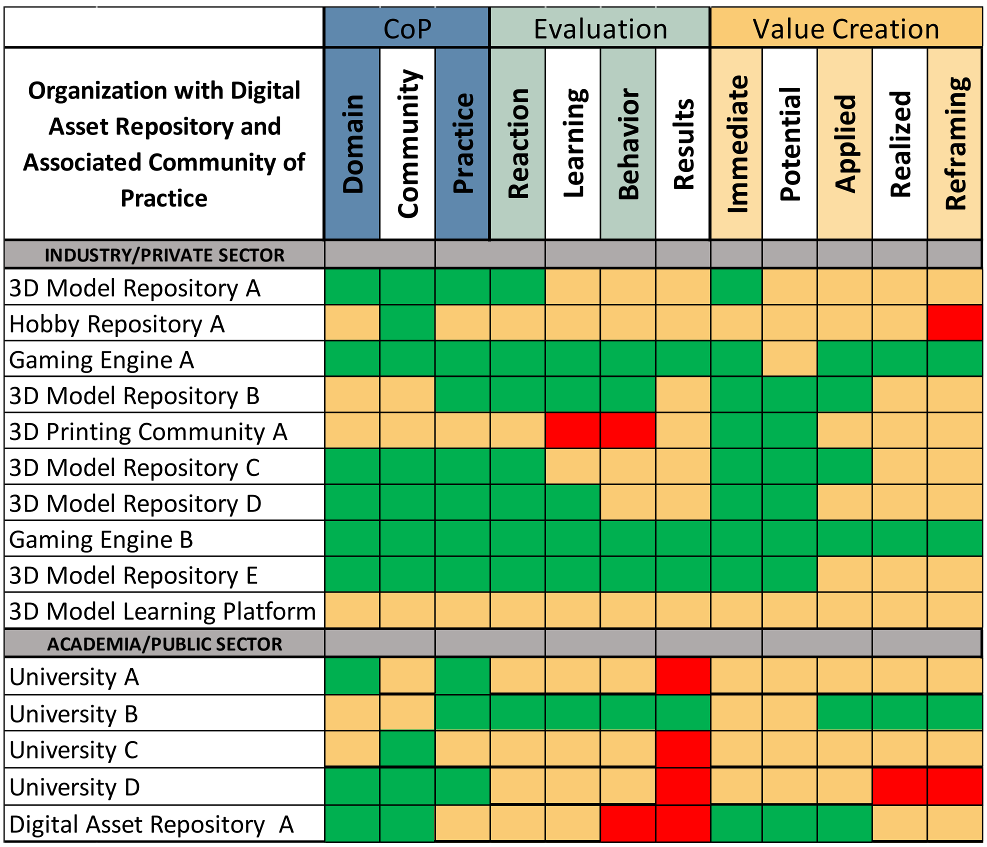

Figure 3 Evaluation Matrix - Impact of CoPs on Digital Asset Repositories

One theme that emerged quickly was the Industry CoPs appeared highly effective, and exemplars here were the gaming engine CoPs. The gaming engine CoPs were well organized with clear alignment to the three CoP elements (Domain, Community, Practice). The focus of CoP members appeared very narrow, with developing successful games, whether for entertainment, training, or education. The gaming CoPs have tens of thousands of members all looking to achieve the same goals within digital environment that use 3D objects, creating a greater homogeneity of goals. This also led to the observation that the greater homogeneity across such a large group made the gaming engine CoPs less niche, as all users are trying to use these objects to build some kind of game

The Academia-related CoPs appeared to differ, as these CoP members tended to have much more individualized goals. Most of the observed user interactions in these CoPs were students, with each appearing to have unique requirements in relation to the need to interact with the 3D objects. As such, it was more difficult to find the level of commonality as with the industry-related CoPs who had a much larger number of people and interactions.

Through evaluating the impact of CoPs through the criteria in Figure 3, the authors summarize the observations for each as they set to identify the impact of CoPs on digital asset repositories and to see if any best practices emerged from the data. Three evaluation criteria-related themes emerged and are discussed below.

The first centers around the motivation of organizations with digital asset repositories to support their associated CoPs. As exemplar examples, both gaming engine CoPs advance the interest of their organization by advocating for their respective digital asset's creation, development, and use. When developers use an organization's platform and tools to create interest and demand for their products and services, it provides benefit for the organization. Both gaming engine organizations had numerous different resources available for their respective CoPs through formal and informal training and education pathways such as tutorials, projects, courses, licensing, and certifications. It was evident that the impact of the CoPs on the gaming engine repositories was significant with how members articulated information, engaged in critical discussion, as well as the substantial number of CoP participants.

The second theme centered around the three elements of a CoP, and the authors looked for members demonstrating behaviors related to the three elements of Domain, Community, and Practice. The data showed that each CoP clearly shared a common domain of interest, where membership in the domain was focused on the requisite relationship with digital object repositories. Consistent with the previously discussed element definitions (Wenger McDermott, 1998), data showed that members of CoPs existed in a community with a central purpose, which can be described each element in their postings. It was evident that each of these CoPs indeed were in pursuit of a focused area of interest, and that through the engagement of online activities and discussions were able to assist each other through information sharing. Moreover, the members developed and shared ways, to varying degrees across CoPs, to address familiar challenges and increase their shared knowledge.

The third theme relates to the performance of the CoPs as it relates to the Kirkpatrick's four levels of evaluation. Kirkpatrick's model distinguishes the uniqueness and logical flow across the four levels of impact, and successful knowledge creation through these communities was evident at each level. The analysis of the impact of the CoPs was informed by the framework of Laursen and Webne-Behrman (2015) in their evaluation of the impact of CoPs on a university campus. Examples of Reaction data include CoP members sharing their reactions to the knowledge sharing community and their ability to find what they were looking for, or the ability to answer another member's question or direct them to another CoP resource.

Again, the gaming engine CoPs had the richest reaction expressions, where it was clear that beginners and experts had positive reactions to the availability of information and ease of use of the available resources, which were thorough, well-organized, and easy to read. Some of the academic CoPs showed less enthusiasm but were able to express positive reactions to support that allowed them to meet the needs of their assignments. The Learning level was easier to code, and the results reveal that not only did CoP members discuss the acquisition of new knowledge but shared this knowledge in other forums where new discussions emerged. The data also showed some extent of an advancement or change in the trainee's discussion inputs after obtaining some new knowledge about digital objects. The Behavior level also showed rich data from which to code that revealed CoP members putting their new knowledge into effect, whether in a workplace, school project, or personal hobby.

Following specific usernames across discussion threads, the effects of CoPs seemed evident after members would return to the online discussions to share how that knowledge was used. Finally, the Results level showed positive effects of CoPs on digital asset repository utility, as members described the results of CoP membership solving their challenge or creating a new opportunity. The authors could see the relative contribution of CoP membership as a success factor in working with digital asset repositories.

OBSERVED BEST PRACTICES AND LESSONS LEARNED

Based on our review of the data, we propose the following best practices and lessons learned for military organizations that are beginning to establish digital asset repositories for the purpose of making digital objects available for use in support of military training.

Recommendation #1: Establish rules and practices that promote learning, the sharing of ideas, and keeping members focused on the topic at hand. The most significant impact of CoPs on digital asset repositories was found within the gaming engine communities. With the rapid expansion of game engine use beyond entertainment into training and education, there has been a corresponding demand for game engine developer talent. The gaming engine discussion forums, blogs, and other knowledge sharing platforms were supported by a common code of conduct agreed to by all users, and this is a best practice. As a CoP, members should know that they are in a safe place to ask questions, share knowledge, engage in discussions, and help others across the community. Moderators were actively present to ensure only digital asset discussions took place, and no abuse, spamming, or non-value-added discussions were allowed, and any that were posted were promptly removed, thereby allowing users to stay focused on relevant content.

Recommendation #2: Tailor reward structures appropriately to balance both individual and organizational goals. In many of the commercial COPs, the users are often focused on pursuing individual goals. For example, users often receive financial compensation by licensing their models for others to use. By comparison, in the military, individuals frequently PCS (Permanent Change of Station) from one organization to another. Therefore, the unit of analysis should be on the organization that the user represents, rather than the individual per se. Individual users seek to improve the performance of their own organizations, as well as peer and superordinate organizations, rather than their own enrichment. Because of the DoD’s inherent bureaucracy, organizational performance is often enhanced by cutting across boundaries. If the military services want the widest use of the assets within their repositories, the ability to transmit knowledge and models across official channels for widespread viewing will help direct potential future members to the CoP. If military leaders can support CoP engagement, this would lead to increased participation and active CoP knowledge sharing and utility.

Recommendation #3: Include a healthy mix of both bottom-up and top-down knowledge and resources. The users generate bottom-up knowledge and resources themselves, such as sharing models with one another, participating in threaded discussion groups, and working on collaboratively developed documents. By comparison, top-down knowledge and resources are provided by the CoP administrators, such as conducting user polls to assess the users’ needs, inviting guest speakers to deliver targeted demonstrations on specific topics of interest, developing new features and functionality that support the users’ needs. Most of the 15 organizations either had internal trainings or links to external resources that provided different training opportunities for tasks such as navigating the repository, and how to create, share, sell, view, and reuse digital objects. The ability for CoP members to quickly locate and use self-development resources was shown to be positively received and able to increase the level of human capital in the CoP. A one-stop shop type of community where members could be directed by other CoP members to find resources that addressed their questions and improved their domain related skills was deemed valuable by members across organizations.

CONCLUSION

The impact of CoPs on digital object repository utility was shown to be positive across disciplines. Future research needs to ascertain the use of digital objects in a military context to inform current military repository creation and growth. Additional research should also be generalizable to other objects beyond 3D objects used for VAMR applications including sharing of behavior models driving the 3D components. Achieving these results would enhance the knowledge creation and sharing provided by digital asset repositories when accompanied by an associated CoP**.** Including CoP features in the VAMR repositories encourages continued use by participants of repository contents and refreshing of content as users share enhancements to objects downloaded, modified, and then shared on the repository.

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