Development of a Searchable, Web-Based Repository for Sharing ARVR Training Assets

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ABSTRACT

Over the past decade, there has been an explosion of interest in the use of COTS Augmented (AR) and Virtual Reality (VR) technologies in training (Bacca, Baldiris, Fabregat, & Graf, 2014; Clark, Tanner-Smith, & Killingsworth, 2016; Zendejas, Brydges, Hamstra, & Cook, 2013). These technologies allow instructional designers to embed critical resources, such as checklists and animations, within the training environment to enhance the learning experience. They also allow learners to interact with the environment using naturalistic gestures, thereby allowing them to focus on the training content rather than on the user interface. However, the development of ARVR training involves a significant resource investment. For example, training developers first need access to realistic 3D models of the technology with which the learners must interact. If these models do not already exist, they must generate them with the aid of reference photos, videos, or Computer-Aided Design (CAD) files (United States Air Force Scientific Advisory Board, 2019). Asset repositories are standard practice in both video game development and 3D printing. Bringing this capability to the Air Force will align it with industry and minimize the need to reinvent the wheel on every new training application. In this paper, we describe the Air Force Research Laboratory's multi-year effort to design and develop a secure, web-based Community of Practice (COP) that will allow instructional designers to quickly and easily share 2D/3D models, reference photos and videos, and CAD models, among others. In addition to the asset repository, the system will help users to learn from one another via threaded discussion groups, monthly webinars, and community-developed knowledge products. This paper describes the results of our needs assessment process, our high-level system design principles, screen captures of the actual software, user feedback data from our evolving system designs, and lessons learned regarding the development of online COPs.

ABOUT THE AUTHORS

Dr. Jeffrey M. Beaubien is the Chief Behavioral Scientist at Aptima, Inc. For the past 20 years, his work has focused on training and assessing leadership, teamwork, and decision-making skills. His research has been sponsored by the U.S. Navy, the U.S. Army, the U.S. Air Force, and the Telemedicine and Advanced Technologies Research Center, among others. Dr. Beaubien holds a Ph.D. in Industrial and Organizational Psychology from George Mason University, a M.A. in Industrial and Organizational Psychology from the University of New Haven, and a B.A. in Psychology from the University of Rhode Island.

Dr. Winston "Wink" Bennett Jr. received his Ph.D. in Industrial and Organizational Psychology from Texas A&M University. He is the Readiness Product Line Lead for the Airman Systems Directorate at Wright Patterson AFB. He is a Fellow of the Society for Industrial and Organizational Psychology, the American Psychological Association, and the Association for Psychological Science, as well as a Research Fellow at the Air Force Research Laboratory. He is the USAF representative to the NATO Modeling and Simulation Group (NMSG). He is spearheading the Combat Air Forces migration to proficiency-based training and is conducting research related to the integration of live and virtual training and performance environments to improve mission readiness and job proficiency. He served as the Technical Advisor for the Joint Secure LVC Advanced Training Environment Technology Demonstration (SLATE). This was

the first fully integrated LVC capability demonstration with live combat-coded aircraft and combat-coded aircraft operational flight program software. He leads research that has developed methods to monitor and routinely assess individual and team performance across live and virtual environments and evaluating game-based approaches for training, work design, and job restructuring. He maintains an active presence in the international research and practice community through his work on various professional committees and his contributions in professional journals and forums including I/ITSEC.

Dr. Richard B. Ayers is a Senior Lead Human Performance Engineer with Booz Allen Hamilton, where he uses principles, theories, and methods of organizational development to design and evaluate the impact of integrating complex digital solutions into military training. As a retired military instructor pilot with 1,800 combat hours, he is particularly interested in understanding shared patterns and potential causal factors in poor quality aeronautical decision making that lead to degraded human performance in high threat environments. Dr. Ayers is currently studying cognitive loading effects of Joint All Domain Operations systems. He holds a Ph.D. in Organizational Development from the University of Southern Mississippi, and B.S. and M.S. degrees from Embry-Riddle Aeronautical University.

Mr. Rick Keithley is the Director of Strategic Engineering Planning for CymSTAR. He has long-term experience integrating emerging technologies with legacy DoD training platforms. His hands on engineering started as an Electrical Engineer, then Software Engineer as well as various other roles including Program Manager, Engineering Manager, and Director of Engineering. He stood up the engineering department at CymSTAR starting in 2004 as well as the engineering department at a prior company. Roles in prior companies included standing up of Flight Training Device (FTD) design and production capability in the U.S.A. utilizing technology transfer in a multi-national training and simulation company. Throughout his career he also concurrently led Information Technology (IT) deployment moving companies through emerging technologies including Operating Systems (OS) upgrades starting with DOS / Unix through new versions of Windows, Unix, and Linux as well as deployment of web-based applications. He was also a key motivator for CymSTAR connecting training platforms to Distributed Mission Operations (DMO) networks starting with KC-135 training platforms. He holds a B.S. degree in Computer and Electrical Engineering Technology from Kansas State University and is a registered Professional Engineer (P.E.) in Oklahoma since 1997.

Mr. Kevin Audrain is the Innovation Software Developer at USAF Air Combat Command (ACC) Training Support Squadron (TRSS) in the newly created Innovation Flight. He has spent the last 5 years developing interactive games commercially and immersive training for the U.S. Navy. Prior to that, Mr. Audrain spent 20 years in the U.S. Navy as an enlisted submarine sailor in the Navy Nuclear Propulsion Program. Mr. Audrain holds an MBA with a focus on Applied Computer Science from Northcentral University and a B.S. in Nuclear Engineering Technology from Thomas Edison State College.

Dr. James Belanich has been a research psychologist conducting applied research projects for the Department of Defense for the past 20 years. Since 2012, at the Institute for Defense Analysis (IDA), he has conducted research analyzing human behavior, investigating workforce issues, evaluating STEM (science, technology, engineering, and math) education program, assessing training technology, and modeling intermediate force capabilities. He was also a member of the U.S. Army's Education Advisory Committee (2015-2021). From 2001 to 2012 he was a Research Psychologist at the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), managing ARI's research program, coordinating institute-wide activities, and conducting research on advanced training methods. He received his Ph.D. in Psychology – Learning Processes from the City University of New York in 2001.

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BACKGROUND

"Creating content for ALT [Advanced Learning Technology] systems is a labor-intensive activity that dominates the cost for implementation. Content developers create scenarios, import two-dimensional and three-dimensional objects to build scenes and apply textures, animation, lighting, audio, and interactivity in representing detailed, complex, and expert knowledge to ALT systems. This can be very time consuming, particularly if digital models are not readily available and must be created."

USAF Scientific Advisory Board, 2019, p. 55.

Several factors have contributed to the adoption of low-cost, Commercial-Off-The-Shelf (COTS) Augmented Reality (AR) and Virtual Reality (VR) technologies in training. First, there has been a precipitous drop in hardware costs, with per unit costs averaging less than $1000. This cost reduction allows DoD organizations to purchase more units, thereby increasing the number of simultaneous learners. Moreover, to the extent that learners can perform a greater number of "reps and sets" using these COTS devices, they will arrive better prepared for subsequent training events that can only be conducted using high-end, limited-availability simulators or actual vehicle systems. Second, COTS ARVR technologies are extremely flexible, thereby allowing them to be used in many different ways. Ideally, instructional designers can develop a single model (or set of models) and then reuse them several times. This reusability is where savings are realized over the long-term. The upfront costs to develop ARVR training are high, however the costs decrease with each reuse. For example, instructional designers can reuse a single F-16 outer skin model for training maintenance technicians' pre-flight inspections, as well as for training new pilots' ability to visually discriminate friendly vs. enemy aircraft. Similarly, that same model could be used in a high-end simulator to train perceptual-motor skills; on a COTS ARVR device to train decision skills, and; on a tablet device to reinforce factual knowledge. Third and finally, no fewer than 10 empirical meta-analyses have demonstrated the relative effectiveness of ARVR training versus active control conditions (Clark et al., 2016; Cook, Erwin, & Triola, 2010; Garzón, Pavón, & Baldiris, 2019; Howard, Gutworth, & Jacobs, 2021; Kaplan et al., 2021; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014; Nagendran, Gurusamy, Aggarwal, Loizidou, & Davidson, 2013; Tekedere & Göke, 2016; Uttal et al., 2013; Zendejas et al., 2013). The mean meta-analytic derived effect size across these studies is approximately 0.69 standard deviations (SD), which represents a "large" improvement in learning (Cohen, 1998).

Unfortunately, ARVR content development is both costly and labor-intensive (United States Air Force Scientific Advisory Board, 2019). For example, an instructional designer must first obtain 2D and 3D digital models that have sufficient fidelity characteristics for the planned training application. These models include both the physical hardware (e.g., the radio) with which the learner must interact, as well as the larger environment (e.g., the cockpit) within which the learner must perform the task. To the extent that these models do not exist or cannot readily be located, the instructional designer must develop them from scratch with the aid of other assets such as reference photos, videos, and Computer Aided Design (CAD) files. In some cases, the instructional designer may be able to record these reference photos and videos firsthand. Even when this is possible, however, doing so can present a challenge because

the instructional designer will need to deconflict aircraft schedules with operational and maintenance organizations that also require access to the aircraft. Compounding this problem is the fact that the actual airframe may not be organic to the instructional designer's location. In such cases, the instructional designer will need to coordinate with another Air Force organization to obtain the reference materials. Finally, after developing the necessary 2D and 3D models, the instructional designer must also develop or obtain additional training-related assets – such as photos, schematics, animations, checklists, instructional videos, performance measures, and the like – that they want to embed within the ARVR training environment. In summary, whenever digital training models and related assets have to be developed from scratch, the inevitable results are cost increases and schedule delays.

There is a critical need for the Air Force to develop and maintain a searchable, web-based repository that will allow instructional designers to quickly and easily share digital training models and other assets so as to avoid "reinventing the wheel" on each new training application. The use of digital asset repositories – such as *cgtrader*, *Sketchfab*, *Substance3D*, and *TurboSquid* – is a standard practice in the field of video game development and adopting this approach will align the Air Force with the rest of the ARVR industry. However, there are notable differences between the military and civilian sectors that must be considered when designing a DoD-specific asset repository. For example, many commercial asset developers are freelance graphic artists who receive payment for licensing their artwork to game development companies. Moreover, the asset repositories are built, maintained, and hosted by commercial companies that receive a commission for every asset that is sold. By comparison, military asset developers are organizations, such as Training Support Squadrons (TRSS), that do not receive financial compensation for sharing their artwork. Instead, they are rewarded for supporting their immediate customer's training needs as well as the superordinate Air Force mission requirements. In addition, the funding for platforms such as asset repositories are typically centralized within the DoD, while the cost savings are dispersed across organizations, such as the TRSS. With this in mind, we conducted a user needs assessment to identify the critical challenges that USAF training organizations have been experiencing with regard to ARVR content development, the extent to which an asset repository might help them to overcome those challenges, and the candidate system features and functionality that are in greatest demand.

METHOD

We conducted a series of semi-structured interviews with 40 Air Force ARVR training stakeholders. The sample included a mix of active-duty personnel (n = 15), DoD civilians (n = 2), and contractors (n = 23). The participants' work-related roles included a mix of domain Subject Matter Experts (n = 15), instructors (n = 8), instructional designers/developers (n = 3), training managers (n = 12), software engineers (n = 11), and other training professionals (n = 8). Several of the interviewees performed multiple concurrent roles, which explains why the number of roles exceeds the number of interviewees. The interview format included a mix of individual (n = 10) and focused group interviews (n = 5) that were conducted either in-person (n = 6) or via video-teleconference (n = 10). The median interview length was 75 minutes, with a range of 45 to 120 minutes. In many cases, after the initial interviews were completed, the interviewees responded to multiple email-based requests for clarification and elaboration.

In addition, we reviewed 15 commercial and educational asset repositories to identify recurring themes, best practices, and lessons learned. As a general rule, these repositories were designed for very different purposes. While some were designed to share 3D models for use in commercial game development (*TurboSquid, GrabCraft*), others were designed to support 3D printing (*Thingiverse*), knitting (*Ravelry*), and military training (*Army MilGaming Portal*, *MOTAR*). Despite these surface differences, many of the systems had very similar features and functionality. These include threaded discussion groups for debating ideas and concepts; community-generated knowledge products for archiving critical lessons learned; invited instructional demonstrations/webinars to share cutting-edge techniques, and; full-time system administrators for managing the system's day-to-day operations. Finally, we reviewed published best practices regarding the development of online communities of practice (Wenger, McDermott, & Snyder, 2002) and e-commerce system design (Isherwood, 2019).

RESULTS

Six recurring themes emerged from the user needs analysis. For each theme, we summarize the major challenges that were identified, as well as candidate system features and functionality that will help to address those challenges.

The first theme centers around the related issues of asset availability and currency. The primary challenge is that if users cannot quickly find what they are looking for, they will likely not return to the site. With this in mind, we designed the user interface to mimic that of standard e-commerce sites (Isherwood, 2019) such as Amazon, which allow users to interactively search for (top of screen), sort (top of screen), and filter (left side of screen) information. Basing the UI design on standard e-commerce practices minimizes the users' workload while they navigate through the system, thereby increasing the chances that they will find what they are looking for. Commonly-requested search/filter/sort fields include: the date when the model was created; the name of the specific Air Force organization that created the model; the specific airframe (and block number) that is depicted in the model; the date and version number of any training-related publications upon which the model was based, and; technical details about the model itself (such as the file type, file size, and polygon count). As part of the needs analyses, we also learned that while necessary, an asset repository is not sufficient to support most users' needs. Many interviewees expressed the need for a thriving community of practice to engage with and to learn from via threaded discussion groups (such as posting requests for specific assets that may not already be hosted on the repository), collaboratively-developed knowledge products (for example to summarize the tradeoffs among competing development platforms), and invited webinars (to learn specific techniques that can help the users to work more efficiently or cost-effectively) (Wenger et al., 2002).

The second theme centers on the related issues of version control and each model's useful half-life. The primary challenge is that the value of any particular model decreases over time because the physical asset represented by it (such as a particular airframe model and block) is constantly being updated. Therefore, there is a critical need to include standardized metadata (described above) to support the user's process of searching, sorting, and filtering relevant models that will support their unique training needs. Additionally, several interviewees also expressed an interest in "social media" style functionality, such as subscribing to automated e-mail alerts when either a bookmarked or previously downloaded model has been uploaded to the portal. Finally, interviewees expressed an interest in tracing the provenance a given model, for example by linking multiple evolutions or variations of the same model together. As is done with multiple commercial repositories, the interviewees requested that when viewing the details of a given model, that they also be presented with "related models" which are based on it. An example might include multiple versions of the same aircraft "outer skin" model, each of which includes the insignia of a different Coalition partner.

The third theme centered around understanding "the art of the possible." While many of the interviewees are technical experts in their particular domain, they often found themselves re-using the same instructional strategies over and over again. For example, many users will develop a simulation that veridically represents a specific task, and then immediately follow it with a post-training debriefing. Several interviewees expressed little knowledge of or experience with novel instructional methods such as gamification (Belanich, Orvis, & Mullin, 2004), stress exposure training (Driskell & Johnston, 1998), dual task training (Jahn, Oehme, Krems, & Gelau, 2005), or visual orientation (Ward et al., 2008), all of which could easily be performed using COTS ARVR technologies (Beaubien, Oster, & Spruill, 2018). Simply put, they were not capitalizing on the unique affordances that are provided by these new technologies. Several participants also indicated that they would likely benefit from reading the scientific literature, however few reported having either the time to do so or the ability to understand the scientific jargon. When queried about the potential value of a "Cliffs Notes" style article database, many interviewees wholeheartedly embraced the idea as a way to quickly explore new possibilities. The article database also provides confidence in the application of ARVR technologies based on demonstrated evidence of effectiveness.

The fourth theme centered around the different cost/reward structures for military vs. civilian end users. In the commercial space, many model developers are freelance graphics artists who are paid for licensing their models to commercial game developers. In essence, their livelihood depends on their ability to develop models that other people want to buy. By comparison, many DoD models are developed by organizations (such as TRSS) that have revolving rosters of technical staff. Moreover, their key reward system is not financial. Instead, DoD users are motivated by addressing their immediate customers' training needs and by supporting the superordinate Air Force mission. A very powerful motivator to a TRSS or DoD contractor would be to receive a formal letter of commendation from another Air Force organization for having saved them several weeks of development time. To this end, the interviewees again expressed an interest in "social media" style functionality, such as being able to provide "star ratings" for each model, and a comments feature that will allow them to publicly thank the model developers or to suggest ideas for incorporation in future model builds.

The fifth theme centered around the need for operational security. It is a truism that operational security is everyone's responsibility. In addition to the system receiving a formal Authorization to Operate (ATO) on a DoD network, other critical features and functionality include the need for two-factor (Common Access Card) authentication; placing all uploads in a temporary "holding area" so that they can be reviewed and approved by the system administrator before being made available to the user community, and; the ability for every user to "flag" potentially inappropriate content so that it can be reviewed by the system administrator and removed from the portal if necessary.

The sixth and final theme centered around the related issues of centralization and standardization. Like many other DoD organizations, the Air Force is standing up several cross-functional working groups, systems, and policies/procedures to support the adoption of ARVR-based training. Recently, the Air Education and Training Command (AETC) has adopted the Member Operations Training Analytics and Reports (MOTAR) platform as a standard for delivering ARVR training-related content (Thurber, 2021). During the course of our needs analysis, many interviewees inquired as to how our repository is similar to or different from it. Because MOTAR has an open architecture, we are designing our portal to be fully compatible with it.

SYSTEM DESIGN

In this section, we provide a high-level overview of selected system features and functionality. Figure 1 shows the main asset repository search page. This page was intentionally designed to mimic standard e-commerce platforms with search and sort bars that are located along the top of the screen, and a filter bar that is located along the left side of the screen. The bulk of the screen's real estate is reserved for displaying the search results. Each asset – whether it be a model, a photo, video, an animation, a CAD file, or otherwise – is represented via a "card." The card depicts a thumbnail image of the asset, along with selected information about it, such as the name of the organization that developed it, as well as the number of times it has been downloaded and bookmarked, respectively. In addition, this screen also provides users with the option to upload an asset to the repository.
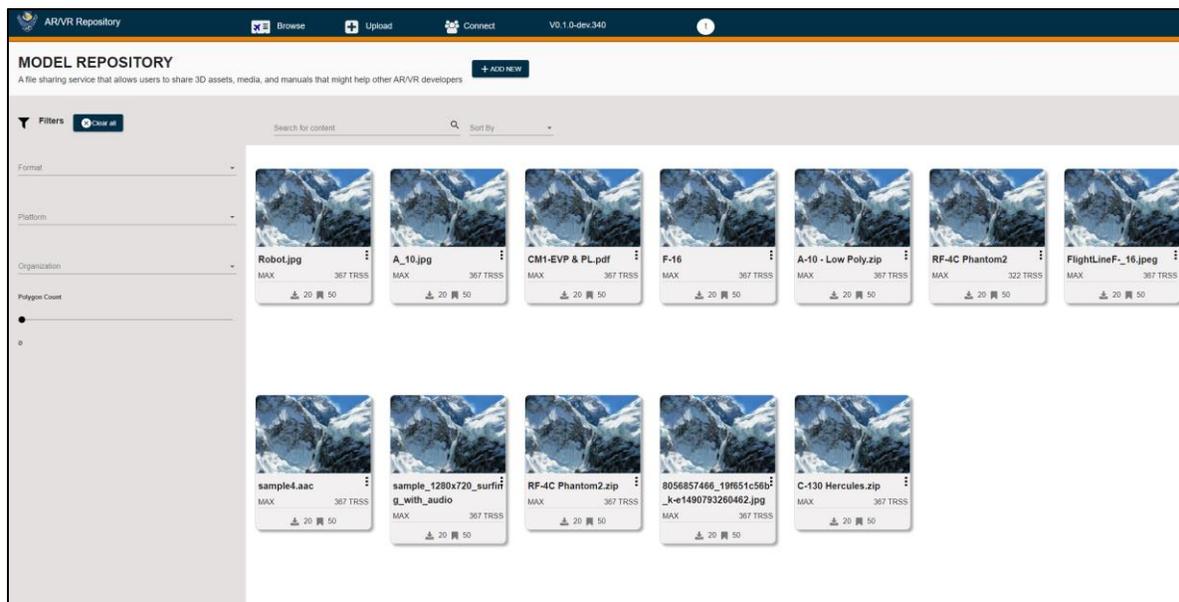
Figure 1. Model Repository Main Search Page (Note: Dummy Content is Intentionally Displayed)

Double-clicking on a card brings the user to the asset "details" page, which provides additional information that is not included on the card. As shown in Figure 2, the details page contains information such as the model creation date and version number, along with relevant object metadata that describe its intended purpose. User ratings and feedback are depicted along the right side of the screen, and related content appears along the left side of the screen.
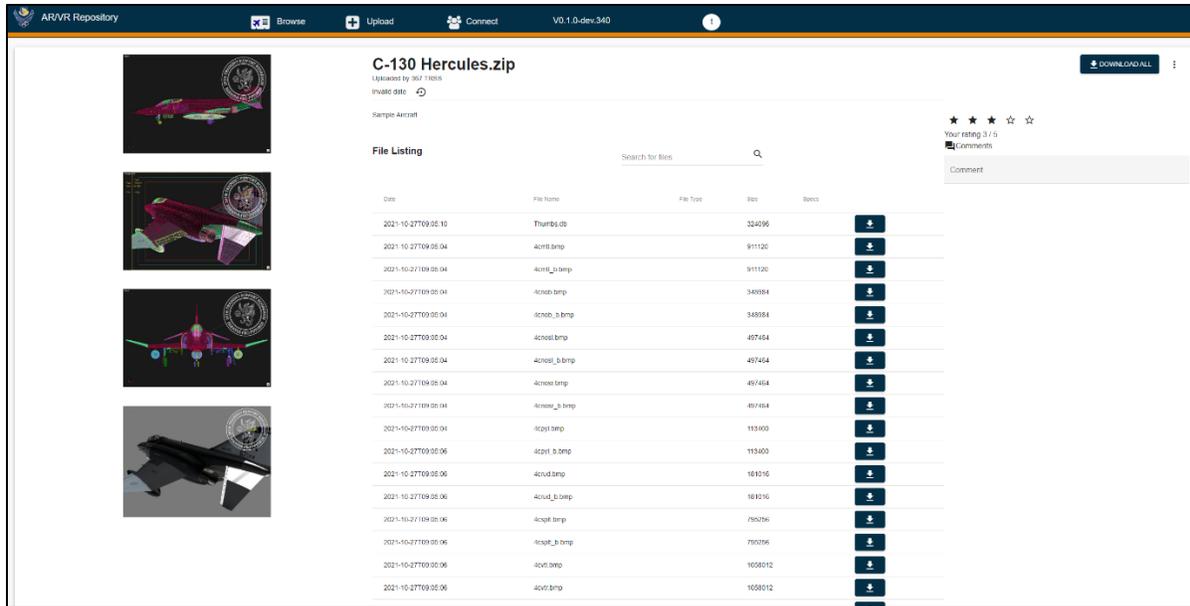
Figure 2. Model Details Page (Note: Dummy Content is Intentionally Displayed)

Figure 3 shows the main article database search page. As with the asset repository, the article database includes the same search, sort, and filtering capabilities. Additionally, each card is dynamic. For example, left clicking on the "Abstract" tab will provide a high-level summary of the article. Similarly, the "Technology" tab displays the specific technology platform that was used, while the "Performance" tab displays the specific types of tasks/skills that were performed by the participants. The actual article database was developed under a separate effort (Belanich et al., 2022). As with the asset repository, there is an option for users to create a new entry in the article database.
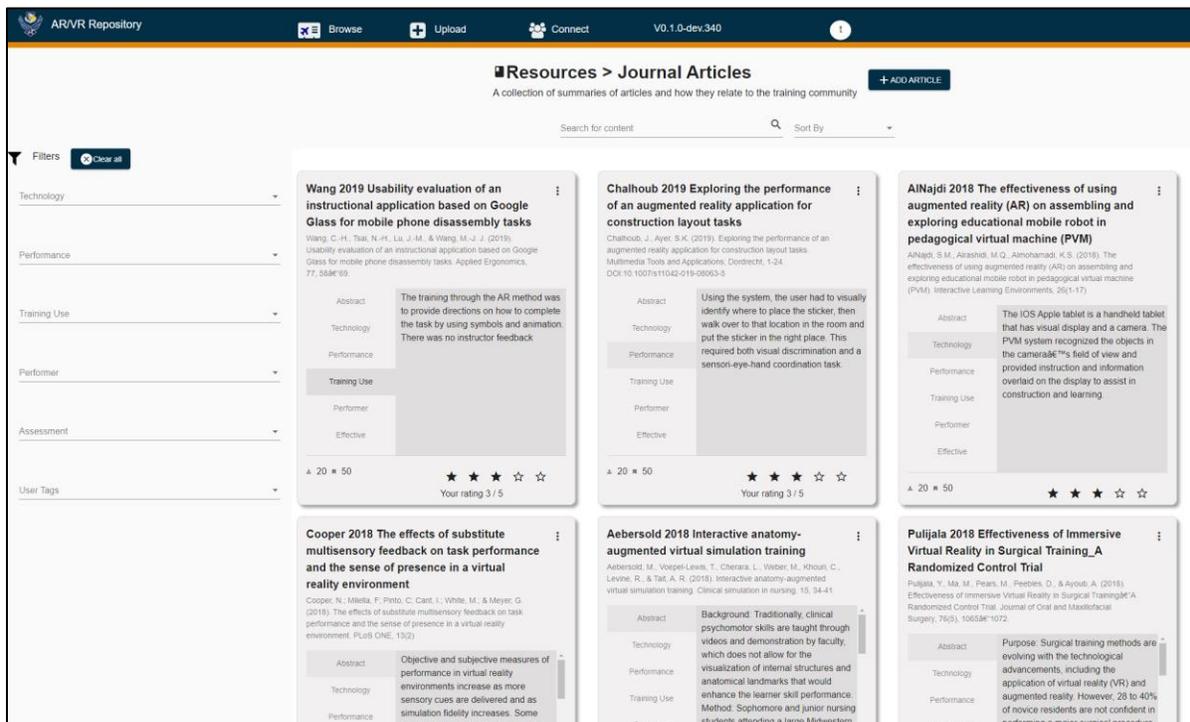
Figure 3. Article Database Search Page

Similar to the model details page, clicking on an individual card brings up detailed information about that article, as shown in Figure 4. All of the information is stored in self-contained sections, thereby allowing the user to quickly locate the specific information they are searching for. At the top of the page is a search bar. Any information typed in this search bar is "filtered in" thereby allowing the user to quickly locate the specific search term in the body text. For example, typing the words "Google Glass" would hide all sections that do not contain the term "Google Glass." Finally, the screen includes multiple different "views" of the data. For example, selecting the "System Developer" view prioritizes technology-centric information at the top of the screen, while selecting the "Instructional Designer" view prioritizes training effectiveness information, and the "Domain Specialist" view prioritizes task performance-related information. All of the same information appears on the screen; it is just prioritized in different orders.

Figure 4. Article Details Page

CONCLUSIONS

As part of our iterative process of knowledge elicitation, design, development, and user testing, we conducted a system usability test with five candidate end users. Previous research suggests that a sample size of five is sufficient to identify 85% of usability problems (Faulkner, 2003), which will then be addressed during the next cycle of iterative design, development, and user testing. The sample included a mix of active-duty personnel (n = 1), DoD civilians (n = 1), and contractors (n = 3). The participants' work-related roles included a mix of instructional designers/developers (n = 2), graphics designers (n = 2), game designers (n = 1), research scientists (n = 1), software engineers (n = 1), and domain Subject Matter Experts (n = 1). Several of the participants performed multiple, simultaneous roles. All of the usability tests were conducted remotely. The median interview length was 60 minutes, with a range of 50 to 75 minutes.

The primary criterion measure was the Post-Study System Usability Questionnaire (PSSUQ). The PSSUQ is a 16-item usability scale that measures perceived satisfaction with a system. The PSSUQ has question anchors that range from "Strongly Agree" (1) to "Strongly Disagree" (7), and has demonstrated high levels of internal consistency reliability (.97) (Lewis, 1995). The scale is frequently used in Human-Computer Interaction (HCI) research and has been translated into numerous languages including European Portuguese, Arabic, and Greek. The PSSUQ questions are organized into three categories. Questions 1-6 focus on the system/process quality. Example questions include "It was simple to use this system" and "I was able to complete the tasks and scenarios quickly using this system." Questions 7-12 focus on the quality of information provided by the system. Example questions include "Whenever I made a mistake using the system, I could recover easily and quickly" and "It was easy to find the information I needed." Finally, questions 13-16 focus on the interface quality. Example questions include "I liked using the interface of this system" and "This system has all the functions and capabilities I expect it to have."

After providing informed consent to participate and be recorded, naïve participants were tasked with performing four tasks: 1) searching for and downloading a model from the repository; 2) uploading a model to the repository and annotating it with relevant metadata; 3) searching for and downloading an article from the article database, and; 4) uploading an article to the database and annotating it with relevant metadata. As they performed the tasks, the participants were instructed to talk out loud. After performing all 4 tasks, the participants completed the PSSUQ questionnaire separately for the asset repository and article database. All of the sessions were digitally recorded. The development team is currently content coding the videos, the results of which will be used to iteratively revise the system prototype moving forward.

Mean PSSUQ scores are summarized in Tables 1-2 below. Table 1 contains item-level responses for the asset repository, while Table 2 contains item-level responses for the article database. The item means were compared to the scale midpoint (a value of 4.0), using a one-tailed, single sample t-test. To be considered statistically significant, the mean score had to be smaller than the critical t value of -2.02.

Table 1. Usability Questionnaire Results (Asset Repository)

Question	Question Text	MEAN	SD	Observed t	Significant
1	Overall, I am satisfied with how easy it is to use this system.	2.20	1.10	-2.85	*
2	It was simple to use this system.	1.80	0.84	-4.55	*
3	I was able to complete the tasks and scenarios quickly using this system.	2.00	0.71	-4.90	*
4	I felt comfortable using this system.	2.00	1.00	-3.46	*
5	It was easy to learn to use this system.	1.80	0.84	-4.55	*
6	I believe I could become productive quickly using this system.	1.60	1.34	-4.00	*
7	The system gave error messages that clearly told me how to fix problems.	4.80	1.30	1.37	
8	Whenever I made a mistake using the system, I could recover easily and quickly.	3.20	1.10	-1.63	
9	The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.	3.40	0.55	-2.45	*
10	It was easy to find the information I needed.	2.60	1.34	-2.33	*
11	The information was effective in helping me complete the tasks and scenarios.	2.40	0.89	-4.00	*
12	The organization of information on the system screens was clear.	2.40	1.14	-3.14	*
13	The interface of this system was pleasant.	2.60	1.52	-2.06	*
14	I liked using the interface of this system.	2.40	1.14	-3.14	*
15	This system has all the functions and capabilities I expect it to have.	3.40	1.52	-0.88	
16	Overall, I am satisfied with this system.	2.80	0.84	-3.21	*

Table 2. Usability Questionnaire Results (Article Database)

Question	Question Text	MEAN	SD	Observed t	Significant
1	Overall, I am satisfied with how easy it is to use this system.	2.60	1.14	-2.75	*
2	It was simple to use this system.	3.00	1.22	-1.83	
3	I was able to complete the tasks and scenarios quickly using this system.	3.00	1.41	-1.58	
4	I felt comfortable using this system.	2.40	0.89	-4.00	*
5	It was easy to learn to use this system.	2.20	1.10	-3.67	*
6	I believe I could become productive quickly using this system.	1.80	0.84	-5.88	*
7	The system gave error messages that clearly told me how to fix problems.	5.00	1.41	1.58	
8	Whenever I made a mistake using the system, I could recover easily and quickly.	3.00	1.00	-2.24	*
9	The information (such as online help, on-screen messages, and other documentation) provided with this system was clear.	3.20	0.84	-2.14	*
10	It was easy to find the information I needed.	2.40	1.52	-2.36	*
11	The information was effective in helping me complete the tasks and scenarios.	2.40	1.52	-2.36	*
12	The organization of information on the system screens was clear.	2.80	1.48	-1.81	
13	The interface of this system was pleasant.	3.20	1.79	-1.00	
14	I liked using the interface of this system.	3.40	1.52	-0.88	
15	This system has all the functions and capabilities I expect it to have.	3.40	1.52	-0.88	
16	Overall, I am satisfied with this system.	3.00	1.22	-1.83	

An analysis of the two sets of results reveals some consistent patterns. First, with the exception of a single item ("The system gave me error messages that clearly told me how to fix the problems."), all of the item means were below the scale midpoint value of 4.0 for both the asset repository and the article database. Second, the users exhibited strongly favorable attitudes towards the portal. Specifically, 13 of the 16 asset repository items reached statistical significance, while 8 of the 16 article database items also reached statistical significance.

An analysis of the users' verbal comments included the desire for greater consistency across the portal. For example, in the asset repository there is a large and prominent download button in the upper right corner, while in the article database there is a smaller .PDF icon located next to the article name. In addition, the users expressed an interest in greater clarity of terminology. For example, when uploading a model to the asset repository, several participants admitted not understanding the different types of intellectual property rights. Similarly, on the article database, several participants admitted having a difficult time understanding the different task types (e.g., cognitive, motor,

psychomotor) that were addressed in the database. Finally, many participants expressed an interest in tracking the system behaviors. For example, some participants requested an upload progress bar to track large file uploads, as well as a scanning/unpacking progress bar for when a .zip archive is uploaded to the system but the file details are not immediately available for preview. The development team is using both the quantitative and qualitative feedback to revise the portal prior to our next round of user testing, which will occur during Fall 2022.

BEST PRACTICES AND LESSONS LEARNED

In the following sections, we offer some practical guidance and lessons learned to other organizations that are considering whether or not to build their own asset repositories.

- *Lesson Learned #1: Stand-alone asset repositories are not sustainable over the long term.* When the project was first conceptualized, the intent was to develop an asset repository that would support training for Air Force operational and maintenance communities. During the course of our needs assessment process, however, we were unable to find a single example of a stand-alone asset repository that has been sustained over the long term. As a general rule, stand-alone asset repositories tend to suffer from the "tragedy of the commons," where users download more assets than they upload. Once users realize that the content is not being refreshed, they no longer return to the site. By comparison, COPs – which include threaded discussion groups, community-developed knowledge products, technical demonstrations and webinars – tend to have substantially longer lifespans because they promote sustained user engagement.

- *Lesson Learned #2: Communities of Practice can be scored on their ability to support organizational goals.* In the social nature of learning, COPs represent groups of people who share a common interest or passion for what they do, learning how to do it based on their mutual interactions (Wenger et al., 2002). Three characteristics distinguish communities of practice from other groups: the domain, which is a shared competence across the members who share a common interest; the community, which requires engagement that facilitates networking and the ability to share information; and the practice, where members are practitioners that develop and share resources and ways to solve problems (Wenger et al., 2002). By creating a COP to support the practitioners who will use the repository, the Air Force may be able to improve organizational goals – such as developing better, more cost-effective, and quicker training-related solutions, as well as a more qualified workforce of ARVR training developers. There are validated metrics for scoring the long-term effectiveness of COPs (Wenger et al., 2002), which can be used to help determine the extent to which COPs are achieving both their stated and implied goals.

- *Lesson Learned #3: Communities of practice reduce barriers to entry, thereby giving innovation a chance to succeed.* Passion is necessary but not sufficient for success. Without external support, passion often fails to reach its potential. Many of the interviewees that we spoke with were not trained software engineers, game designers, or graphics artists. Many were domain SMEs who learned these additional skills as part of their ongoing job duties and responsibilities. Their progress was often slow and incremental, but they achieved success through skill, luck, resourcefulness, and ingenuity. All of the interviewees expressed an interest in leveraging – and contributing to – the COP. However, none expressed that their organizations had the means with which to design, build, or maintain a COP. The key lesson learned here is that a centralized investment is often needed to achieve distributed effectiveness and cost reduction.

- *Lesson Learned #4: Hierarchical file systems simply do not scale.* Historically, many of our interviewees have used hierarchically nested file folders to organize their digital training assets. So, for example, they would have a folder labeled "Fighters" and within that folder, they would have sub-folders for the various airframes. Then within each of these folders, they would have various other subfolders for the different aircraft blocks, and so forth. One of the biggest problems with this approach is that certain hardware – such as safety and communications gear – are often reused across airframes and blocks. As a result, there would need to be multiple copies of the same model saved in different physical locations. This is particularly challenging with regard to version control. The alternative is to use semantic (subject-predicate-object) triples, which is the standard for the semantic web. While demonstrating our system prototypes to end users,

many of them quickly saw the similarities between our search approach and that of industry e-commerce sites such as Amazon, thereby helping them to more effectively navigate the system.

- *Lesson Learned #5: Whenever possible, pool and reuse existing assets.* The government is large, and many DoD organizations are simultaneously pursuing similar work under different contracts with partially overlapping timelines. Whenever possible, try to build coalitions and partnerships that mutually reinforce one another. For example, as part of this effort, we are intentionally pooling assets across multiple projects to provide the best value to the Warfighter. Specifically, the model repository is being built under one contract; the article database is being developed under a separate contract; the MOTAR system is being developed under a third contract, and; we are attempting to populate the repository with government-owned digital assets that have been developed by our partners under other contracts.

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