2019

Evaluation of sUAS Education and Training Tools

Brent Terwilliger
Embry-Riddle Aeronautical University, brent.terwilliger@erau.edu

Scott Burgess
Embry-Riddle Aeronautical University, burgesco@erau.edu

James Solti
Embry-Riddle Aeronautical University, SOLTIJ@erau.edu

Kristine Kiernan
Embry-Riddle Aeronautical University, kiern4fd@erau.edu

Christian Janke
Embry-Riddle Aeronautical University, jankec@erau.edu

See next page for additional authors

Scholarly Commons Citation

Terwilliger, B, Burgess, S, Solti, James, Kiernan, Kristine, Janke, Christian, & Shepherd, Andrew. (2019). Evaluation of sUAS Education and Training Tools (paper no. 19136). In Volume 2019: Proceedings of the 2019 Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC). Arlington, VA: National Training and Simulation Association.

Authors

Brent Terwilliger, Scott Burgess, James Solti, Kristine Kiernan, Christian Janke, and Andrew Shepherd

EVALUATION OF sUAS EDUCATION AND TRAINING TOOLS

Brent Terwilliger, Scott Burgess, James Solti, Kristine Kiernan, and Christian Janke
Embry-Riddle Aeronautical University
Worldwide Campus, Daytona Beach, FL
terwillb@erau.edu, burgesco@erau.edu, soltij@erau.edu, kiern4fd@erau.edu, jankec@erau.edu

Andrew Shepherd
Sinclair College National UAS Training and Certification Center, Dayton, OH
Andrew.Shepherd@sinclair.edu

ABSTRACT

The wide distribution and demographic composition of students seeking small unmanned aircraft system (sUAS) education presents a need to fully understand the capabilities, limitations, and dependencies of effective training tools. Concepts, practices, and technologies associated with modeling and simulation, immersive gaming, augmented and mixed-reality, and remote operation have demonstrated efficacy to support engaged student learning and objective satisfaction. Identification and comparison of key attributes critical to an aviation educational framework, such as competency-based training, enables educational designers to identify those tools with the highest potential to support successful learning. A series of factors, such as system performance, regulatory compliance, environmental conditions, technological familiarity, and personal experience, require consideration in the selection, optimization, and application of such tools. Embry-Riddle and the Sinclair College National UAS Training and Certification Center have overseen the development, launch, and sustainment of respective sUAS education programs. Effectiveness of these programs is dependent on continuous evaluation of tools, specific to educational settings. A relevant example was the assessment of popular multirotor sUAS conducted by ERAU-W, which led to publication of the "*Small Unmanned Aircraft System Consumer Guide*" and selection of the Parrot BeBop 2 platform to support sUAS operations curricula. The intent of this work is to present critical considerations, including influencing factors and dependencies, associated with the selection and adoption of technological tools best supporting sUAS education. Background details; emerging approaches, models, and technologies; and examples of past tool evaluation, inclusive of assessment criteria and observations, are discussed. Finally, a series of reflective remarks, including recommendations, relating to evaluation, adaptation, and incorporation of future tools supporting sUAS education are presented.
Keywords: *Small Unmanned Aircraft Systems; sUAS; Training Tools; Competency-based Training; Aviation Education*

ABOUT THE AUTHORS

Dr. Brent Terwilliger is a tenured Associate Professor of Aeronautics and the Associate Dean of Research for Embry-Riddle Aeronautical University, Worldwide campus, College of Aeronautics. He holds a Ph.D. in Business Administration from Northcentral University, a Master's of Aeronautical Science and B.S. in Aerospace Studies from ERAU, and more than a decade of experience in defense contracting. Dr. Terwilliger is a publishing board member of the *Journal of Unmanned Aerial Systems,* lead author of "*Small Unmanned Aircraft Systems Guide: Exploring Designs, Operations, Regulations, and Economics*," and has contributed to twenty-five peer-reviewed published articles and papers.

Dr. Andrew Shepherd serves as the Executive Director and Chief Scientist for UAS at the Sinclair College National UAS Training and Certification Center. With experience in the defense industry and academia focused on modeling and simulation, research, course development, accreditation, instruction, and mentorship, Dr. Shepherd offers extensive knowledge in many areas of technology, higher education, and workforce training and development. He serves as the Managing Editor for the *Journal of Unmanned Aerial Systems*, an Editorial Advisory Board Member for the *Two Cultures Journal*, Vice Chairperson of the National Science Foundation Center for UAS Industry Advisory Board, and as a Board Member for the Aviation Trail.

EVALUATION OF sUAS EDUCATION AND TRAINING TOOLS

Brent Terwilliger, Scott Burgess, James Solti, Kristine Kiernan, and Christian Janke
Embry-Riddle Aeronautical University
Worldwide Campus, Daytona Beach, FL
terwillb@erau.edu, burgesco@erau.edu, soltij@erau.edu, kiern4fd@erau.edu, jankec@erau.edu

Andrew Shepherd
Sinclair College National UAS Training and Certification Center, Dayton, OH
Andrew.Shepherd@sinclair.edu

INTRODUCTION

Recent Federal Aviation Administration (FAA) projections indicate continued growth of commercial small unmanned aircraft systems (sUAS), evidenced through trending aircraft registrations and remote pilot certifications. In 2017, the FAA observed 110,604 sUAS registrations and certification of 73,673 remote pilots; these values are anticipated to increase by more than 300% to 451,800 registrations by 2022 and 301,100 remote pilot certifications for 2020 (FAA, 2018a). Sustainment of this growing field is dependent on the availability and effectiveness of specialized training and education. Such specialization will ensure sUAS use meets an equivalent or improved level of safety, enhances operational efficiency, and follows a consistent pathway for building, measuring, and certifying proficiency (Association for Unmanned Vehicle Systems International [AUVSI], 2019; Deloitte, 2018; FAA, 2018b; Kuzma, Robinson, Donson, & Law, 2018; Lercel & Steckel, 2018; Szabolcsi, 2016; U.S. Government Accountability Office, 2015). The combination of new technologies and processes have already enabled expanded sUAS operations within the U.S. through FAA approved regulatory exemptions (i.e., operational waivers) to 14 Code of Federal Regulations (CFR) Part 107 (Abaffy, 2019; FAA, 2019b). Expanded operations now include sUAS flights beyond visual line-of-sight (BVLOS), over people, and at night. Effective and safe use of sUAS requires comprehensive understanding, application experience, and practiced proficiency, which are gained through interoperable education and training (Baum, Kiernan, Steinman, & Wallace, 2018; Rostker et al., 2014).

Concepts, practices, and technologies associated with modeling and simulation, immersive gaming, augmented and mixed-reality, and remote operation have exhibited benefit to support engaged student learning and objective satisfaction (Ak, Topiz, Altikardes, & Oral, 2018; Hu-Au & Lee, 2017; Stevens & Kincaid, 2015; Wang, Wu, Wang, Chi, & Wang, 2018). Prior research evidences that student (i.e., human) performance can be optimized with higher visual immersion as an element of the training transfer process or within a structured and complimentary learning design (Stevens & Kincaid, 2015; Taher & Khan, 2014). This indicates presence, fidelity, and instructional design integration as key attributes for consideration in the evaluation of training and education tools. Identification and comparison of other key attributes, critical to an aviation educational framework, such as competency-based education (CBE) or training, further enables educational designers to identify those tools with the highest potential to support successful learning. Example of such attributes include system performance, regulatory compliance, environmental conditions, technological familiarity, and personal experience.

The intent of this paper is to present critical considerations, including influencing factors and dependencies, associated with the selection and adoption of technological tools best supporting sUAS education. Background details, including emerging approaches, models, and technologies, as well as examples of past tool evaluation are discussed. Finally, a series of reflective remarks, including recommendations, relating to evaluation, adaptation, and incorporation of future tools supporting sUAS education are presented. Examination of critical factors affecting successful tool adoption, among such a widely varied and distributed community, is envisioned to support improved development of future educational programming and tools.

EDUCATIONAL REQUIREMENTS

The definition, use, and confirmed satisfaction of educational requirements vary among institutions, based on the organization's mission, populations served, stakeholder needs, and available resources. However, there is commonality in meeting accreditation requirements, applying best practices, and ensuring compliance with FAA criteria for the operation and certification of sUAS (Arendale, 2018; FAA, 2019a; Office of Educational Technology, 2019). Aviation educational programs, including manned and unmanned curricula, utilize highly structured frameworks, such as competency-based training and assessment, to support the development, assessment, and improvement of pilot competencies (Suren, 2018). Enabling improved interactivity, within the educational setting and through use of real-world replicative exercises, scenarios, and topics has exhibited potential for improved performance (Competency-Based Training, 2017).

Educational Design and Assessment

Educational activities are best measured through direct *authentic* assessments, which require students "to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills" (Muller, 2012, para. 1). Unfortunately, within competency-based training programs, where students progress at their own pace, it can become difficult and time-consuming for instructors to monitor and evaluate progress of large student cohorts. Integrated toolkits therefore become a critical element in the evaluation process and while not a complete solution, adaptive learning models and artificial intelligence (AI) based capabilities hold added promise for online and distance-learning programs (Johnston et al., 2015). Whatever the assessment mechanisms, clear alignment between measures and the desired skills must be maintained. This can be difficult as often in broad areas of study, as is the case with sUAS, the number of knowledge, skills, and abilities (KSA) and associated assessment measures can quickly grow, becoming untenable unless the program is *a priori* intentionally focused on achieving a set of specific outcomes. Examples of common measures associated with remote operations include: oral and written comprehension and expression; aviation principals (fundamentals of flight); visualization; judgement and decision making; deductive and inductive reasoning; selective attention; spatial orientation; perceptual speed; control precision; multi-limb/end-effector/control surface coordination; rate control; and reaction time (Howse & Schartz, 2011).

A student's ability to successfully satisfy assessment criteria is dependent on individual ability, quality of instruction, the technology in use, as well as a myriad of external and environmental factors. Personal experience and technological familiarity often argument raw individual talent and can be initial discriminators of student performance. As such, early success within a competency-based training program is not always indicative on future achievement, where often higher-order physical and cognitive skills are required. Early success in one's program, however, may translate to objective satisfaction and can serve to motivate students through more challenging experiences. Values-based assessments may offer insight into intrinsic motivators. Such a framework has been developed by the Office of Educational Technology (2014) and offers several additional measures for consideration in training programs. Except in rare cases, quality of instruction, defined here as quality content, quality [course] design and quality delivery, is axiomatic to student achievement and it is important to evaluate each component in its own right. In academia, separate and deliberate processes exist to assess both course content/design and instruction. The former is typically led by an Instructional Development and Design (IDD) team; the latter by a Quality Management (QM) department. In both cases, final quality assessment is accomplished through an academic department chair and subject matter expert. For online and distributed modalities, assessment can be challenging. There is antidotal evidence that the quality and frequency of student-instructor interaction is a key indicator and motivator for student and instructor alike.

Online Education and Demographics

The proportion of students pursuing a form of online learning has been increasing steadily, from 24.8% in 2012 to 33.1% in 2017, with 15.4% of students enrolled exclusively in distance education courses (National Center for Education Statistics, 2017). Online learning in aerospace colleges and universities has also been observed to be growing rapidly (Tulis, 2017). Interest and enrollment in sUAS flight training at Embry-Riddle Aeronautical University-Worldwide (ERAU-W) has increased, particularly in the wake of adopting the AUVSI Trusted Operator Program. The increasing importance of online education in aviation, and in sUAS in particular, makes it critical to adopt learning strategies and technologies that promote engaged learning. Technology that facilitates student engagement can improve learning outcomes (Bryan et al, 2018; Revere & Kovach, 2011). Engagement as a construct is made up of a combination of academic challenge, active and collaborative learning, student-faculty interaction, enriching educational experiences, and a supportive campus environment (Kuh, 2009).

Creating opportunities for engaged learning in online education depends upon selecting technology appropriate for the curriculum, course content, and user. The online environment has particular requirements in terms of user parameters that an in-person environment might not. In online academic programming (e.g., Master of Science in Unmanned Systems), engagement is fostered through course design, instructor expectations, and through the use of technological tools. The selection of which tools to use for flight instruction is particularly critical, as the student must learn and master the use of the tools without an instructor physically present, and in a physical environment that may be quite different than a traditional classroom. The development, fielding, and success of sUAS training and educational programs is directly associated with the ability to exhibit, practice, and assess foundational to advanced operational KSAs.

Ascertaining the availability, cost, and potential effectiveness of tools becoming critical to determining such capabilities. Additionally, the wide distribution and demographic composition of students seeking sUAS education and training, presents a further need to fully understand the capabilities, limitations, and dependencies of effective training tools. For example, the composition of sUAS Operations students at ERAU-W (246 total) consists of 93.3% online, 6.1% hybrid, .6% classroom (F2F); 82.9% undergrad, 17.1% grad; 45.9% civilian, 54.1% military; 9.4% female, 87.8% male, 2.8% unreported (*data retrieved 4/4/2019 from Embry-Riddle Business Intelligence, Worldwide Dashboard Database*). Sinclair had 393 total program enrollments in UAS short-term technical certificates focused on first responders, geospatial information, precision agriculture, and data analytics, one-year UAS certificate, and two-year associate of applied science degree. Course modalities included standard in-person (F2F) and online formats, as well as CBE offerings that were developed through a National Science Foundation (NSF) Advanced Technological Education (ATE) grant, “Building an Academic Pathway for the Aerial Sensing Data Analyst” (NSF Proposal 1601038). In academic year 2017-18, approximately 17% of UAS related enrollments were in a CBE modality, and that value had increased to 22% for available reported values for academic year 2018-19. Demographic data are still being collected for academic year 2018-19. However, UAS CBE enrollment statistics from 2017-18, indicated that the percentage of female UAS students taking CBE (i.e., 25%) was double the percentage of female UAS students in classroom-based courses (i.e., 12.4%). Additionally, the representation of Black/African American students in CBE courses (i.e., 9%) is more than double their representation in classroom-based UAS courses (i.e., 3.9%). These data are supportive of CBE as a valuable instructional modality option for technical curricula (*retrieved data available as of June 4, 2019 and provided from Sinclair College Office of Registration and Student Records*). These factors, in addition to specified key attributes, require further examination in the selection, optimization, and application of sUAS training and education tools.

SUAS Curricula Development

Success of sUAS educational and training programs to confirm student acquisition of KSAs requires continual evaluation of tools, specific to educational settings (e.g., online, hybrid, and face-to-face [F2F]). A relevant example of such tool evaluation was conducted by ERAU (2016), with support from the Nevada Institute for Autonomous Systems, from 2015-2016. This project featured a sequential exploratory, mixed-methods examination with operational testing of 12 popular multirotor sUAS platforms to determine potential suitability as an initial system for novice users. The initial inquiry required the capture and analysis of published quantitative metrics, including maximum speed, endurance, payload capacity, camera quality, pricing, communication range, utility, and availability of critical metrics (ERAU, 2016). Subsequent operational testing was performed to determine applicable values for a series of qualitative metrics, in accordance with an associated evaluation rubric (ERAU, 2016). The results of this effort included calculation of scores for *novice suitability*, *total system performance*, and *cost-effectiveness*, and the eventual selection of the Parrot BeBop 2 platform for inclusion in sUAS operations curricula, as a required element of a sUAS toolkit (ERAU, 2016).

An sUAS and respective tools must meet basic performance criteria, including quantitative and qualitative metrics enabling confirmable evaluation of student performance (ERAU, 2016). In the ever-changing and varied regulatory landscape, the system must also be able to comply with applicable local, state, and federal regulations throughout the U.S. Operational education and training outside the U.S. are not currently accounted for because of the complexity and variation among the differing international regulatory bodies. System performance in diverse environments is an important factor, as students may be flying in weather very different from that experienced by their instructors. Graduate students in online programs are as diverse in age and experience as they are dispersed geographically. Consequently, the students’ levels of technological familiarity and personal experience with UAS vary widely. Some students are digital natives with large military UAS experience, others are traditional (i.e., manned) pilots with little previous experience using unmanned platforms, while still others are experienced with sensors and post-processing tools but are not versed with air vehicles. This wide variation in student experience requires consideration of both the curriculum design, as well as the selection of tools used to build upon existing experience.

In 2015 and 2016, Sinclair College worked with the Air Force Research Laboratory (AFRL), Warfighter Readiness Research Division (711 HPW/RHAS), to conduct and analysis and develop a report titled “*Small Unmanned Aerial Systems (sUAS) Initial Competency Set (ICS), Developmental Experiences, Knowledge and Skills, and Curriculum*

Review" (The Group for Organizational Effectiveness, Inc. & Aptima, Inc., 2016). The research featured identification of key attributes to enable successful employment of sUAS by entry-level operators of non-military government and commercial organizations. The study was focused on the training and educational requirements for students in a two or four-year academic degree program or those directly hired into a sUAS operator position. Subject-matter experts (SMEs) drawn from academia, government, and industry were engaged in in-person sessions and remote interviews, developing an initial list of four ICSs, including: planning and preparing for a mission; set-up and preflight; launch, execution, and recovery; and conducting post-flight procedures. Supporting these ICSs, 137 points of knowledge and skill, later refined to a set of 57 key points of experience needed for a sUAS operator were also defined, along with a measure of their importance. This study was critical to the formation and maturation of the Sinclair UAS certificate and degree programs. Additionally, as part of Sinclair's NSF ATE award (NSF Proposal 1601038), the college engaged The Ohio State University and industry SMES to conduct a Designing A CUrriculum (DACUM) analysis to identify key requirements for training an sUAS aerial sensing data analyst (results available upon request; Moser & Gillette, 2016).

In the development of sUAS flight operations competencies, a traditional approach to impart knowledge, introduce and expose students to requisite skill sets, and finally to practically assess abilities was adopted. Students within the traditional academic framework in a conventional learning environment are led through a continuous progression of academics and labs in an in-person (i.e., F2F) setting following time honored traditions of producing aviators (FAA, 2016a; FAA, 2016b). Flight simulation has afforded flight knowledge and training a more cost-effective method, while enabling more complex higher learning through scenario-based emergency situations that are difficult to mimic or could be unsafe in real flight. Again, these methods have been successful in F2F settings. However, higher education has evolved into more distributed platforms (Ak, Topiz, Altikardes, & Oral, 2018). Not only has educational delivery broadened, so has the audience. Through distributed learning, educational institutions are now accessible to a much wider audience and as such, have a responsibility to deliver the same quality as in a F2F setting (O'Bryan, 2018). One particular challenge is achieving equivalent or improved results in a distributed educational environment with students who, on average, are adult learners in full time employment. In many instances the learners work in a related field (aviation) but are also burdened with personal responsibilities, such as being the head of a household (Carrier, 2010; Franks, Hay, & Mavin, 2014). These factors should weigh appropriately into developing the curriculum and practical flight skills training assessments using tools that will work best for a distributed educational environment (i.e., platforms and learners). The formal assessments of core training and education requirements is of paramount importance. Placing an emphasis on assessment ensures programs meet the needs of the industry and that resources (e.g., training technology or instructional modality) align with the core program requirements. Basic parameters of hardware and software need to be considered, as they meet the educational requirements of the pertinent institution. There are a number of graduate and undergraduate degree programs in the field of unmanned systems featuring differing modalities, including distributed, asynchronous and self-paced courses. Hence the choice of an educational platform should align on the circumstances of the students and faculty, which are distributed globally.

TECHNOLOGICAL TOOLS

There are a series of challenges associated with selecting sUAS training and education tools. These challenges include ensuring appropriateness of equipment, confirming supportability, meeting availability requirements, and supporting team-based approaches (Saunders & Beard, 2010). Locating and identifying suitable simulation for an initial building of flight skills required consideration of how this capability would be deployed. Such consideration included: 1) determining if students need to purchase their own simulation; 2) how it would be mandated in course materials; 3) whether it would be hosted on a server with licensed seats or installed individual for student access; 4) the appropriate assignment deliverables and submission mechanisms; 5) availability, fidelity, assessment options, and cost; 6) and the result of integration with regard to student performance. Rapid advancement of technology prompts the need for flexibility in current and future decision-making. Consideration of frequent changes to a broadly distributed curriculum can present challenges in resourcing and accreditation. Additionally, the practical assessment aspect of online flight training among a geographically dispersed student and faculty population, requires attention.

Tool Selection and Use Considerations

Careful consideration is necessary in presenting such materials to the average student, interested in this specialized educational opportunity. In many cases, such students are adult learners in full time employment in a related field (i.e., aviation experience) and also burdened with personal responsibilities, such as head of household. Such students, many of which are military students, reflect observations from Johnson et al. (2015) their educational subjects (i.e., soldier learners) are expected to learn and apply knowledge in a "more complex, dynamic, and ill-defined domains" (p. 1). Such conditions necessitate tailoring of tools and methods to the student's unique topical and experiential coverage areas. Developing realistic outcomes is critical, as well as determining the viability of such efforts in the field and marketplace. Designing a program with an appropriate flow, technology, and consideration of potential customers required the creation an academic department dedicated to flight training, proficiency, and operational research. This new department was subsequently staffed with manned and unmanned aviation professionals with flight curricula development and operational experience, in varying environments and platforms. After the first several students proceeded through the program, it was clear that the result far exceeded expectations. In early participation, several students possessing aviation ratings or experience, presented known characteristics of hazardous attitude (e.g., macho attitude relating to overconfidence in knowledge and ability; Aircraft Owners and Pilots Association, 1999). This observance was made in relation to the level of documentation, planning, and coordination required to appropriately conduct sUAS operational training. However, after being presented with contextual detail supporting the need for increased diligence in execution of responsibilities, such students were able to suspend and overcome their behavior. This correction in perception was reinforced by their observed results and improved performance in the program design. The academic design logic worked, though not perfect, by allowing flexibility of approach to other remote learning and practice methodologies.

Another advancement in development of remote sUAS operational training is the use of Remote Split Operations (RSO), which will enable a student to remotely command a sUAS with an Instructor (faculty), while being physically separated (Gaydos & Curry, 2014). The faculty member is local to the operational aircraft and retains an immediate override of control capability for any safety of flight issue. In such a model, the student performs the role of pilot at the controls from their remote location, while functionally the Instructor provides a safeguard and serves as the Remote Pilot-in-Command of record. A current challenge in this mode is the need for a complex communication architecture. Use of current communication network technology is cumbersome due to signal interference, coverage area, and throughput. However, performance is anticipated to significantly advance with the integration of 5G communication infrastructure (Condoluci & Mahmoodi, 2018). This capability is an example of the next logical step in a distributed educational model. As a strategic concept, the integration of RSO was also considered essential to introduce students to the same technology deployed in larger and more complex UAS, while also supporting the instructional model. The integration of RSO lends itself well to the utilization of simulation systems in both KSA development and through student exposure to complex systems. Additionally, in this operation, students are forced to think critically, and problem solve as their preflight preparation may occur from a completely different geographical perspective as they are remotely located. This represents an example where the development of KSA's from previous simulation experience can be beneficial.

Simulation and Augmented/Virtual Reality

Simulation helps students learn to perform basic flight maneuvers, especially in relation to contextualizing scenario-based exercises (Macchiarella, Brady & Arban, 2005). Simulation technologies, including Augmented and Virtual Reality, aids student visualization of complex spatial relationships and abstract concepts in an environment replicating real world conditions (da Silva, Teixeira, Cavalcant, and Teichrieb, 2019). Simulation within an sUAS curriculum is best used within a "crawl, walk, run" philosophy, to incrementally advance the development of the pilot's flight skills. Once these skills develop further, students are exposed to more complex controllability maneuvers, eventually progressing to scenario-based training. Beginning with basic explanations of egocentric (i.e., first-person) and exocentric (exterior) visual perspectives for aircraft control, then progression to more complex demonstrations, and finally to student performance in these exercises. The results in a distributed virtual classroom have been promising, as each student who has followed this process through to completion has passed their practical flight evaluations.

As observed in traditional flight training, scenario-based training can enhance pilot perception, critical thinking skills, and problem-solving abilities, all of which are vital for safe operation of the aircraft in the National Airspace Systems. Emergency situations require specific procedures for resolutions, which could be developed and practiced a virtual environment (McMahon, 2018). In a higher level of KSA acquisition, virtual environments provide exceptional capability to involve scenario-based training to specific industry mission sets. As simulation capabilities evolve, so will the ability to reach a wider audience in the distributed modalities. Scenario-based training has been fully integrated in manned flight to such an extent that requisite flight time for skill building can be substituted through simulation (Harriman, 2011; McMahon, 2018). Simulation in the sUAS industry continues to evolve (DJI, 2019). Combining a logical progression of initial pilot skill building with low-level simulation, practice with real aircraft, application of scenario-based and basic emergency procedures, and more advanced progression of skill building, is anticipated to produce a safe and professional pilot. The adoption of industry based operational standards (e.g., AUVSI TOP) has the potential to bring a unique and distinguishable capability to education and training.

Sinclair College's National UAS Training and Certification Center also uses UAS simulation in traditional F2F classroom environments and deployed training situations but has taken another approach from that employed by ERAU-W for advanced integrated scenarios. Sinclair, collaborating with Simlat, has also leveraged the development of its Live, Virtual, Constructive (LVC) capabilities to showcase how Concepts of Operations (ConOps) can be developed, tested, and refined in a safe and methodical approach. This approach features the use of technology as an aid to applied research and development and training. Sinclair has accomplished four substantial LVC exercises since 2016, including two focused on UAS aided first responder missions at the National Center for Medical Readiness (NCMR) and two Beyond-Visual-Line-Of-Sight (BVLOS) operations from Springfield-Beckley Municipal Airport. Recent and ongoing work has demonstrated the utility of LVC for research, training, and real-world ConOps development for UAS operations in the National Airspace System.

TOOL EVALUATION FRAMEWORK

The successful implementation and sustainment of an sUAS educational or training program is dependent on the quality, function, and supportability of tools. The selection of these tools requires consideration of a number of critical elements associated with the instructional design and method, delivery mechanism, and educational assessment strategies (outcome confirmation). Prior research has indicated that traditional research-based approaches to the selection of educational tools provide insufficient capacity or efficiency to meet the demands of rapidly evolving fields (Anstey, L., & Watson, 2018; Office of Educational Technology, 2014; U.S. Department of Education, n.d.). An evaluation framework should feature the capture of relevant data in the form of evidence to support decision-making (U.S. Department of Education, n.d.). Such frameworks should also represent an approach that is rapid (timely), cost effective, in pace with technological development timelines, iterative and repeatable, and in direct alignment to the needs of the student (Johnson et al., 2015; U.S. Department of Education, n.d.). Ensuring the availability of a uniform process that retains sufficient flexibility to respond to changes (technology, regulations, and other key dependencies), yet is structured enough to provide consistent measurable evidence is essential.

Applicable evidence to fully assess and understand the potential utility of training and education tools can occur in numerous formats. The Office of Education Technology (2104) categorizes evaluation evidence into three types: 1) Indicators, to measure the generation and format of a value (benefit); 2) Stories, to measure participation change and suggested cause of the change; and 3) Artifacts, to measure materials produced through learning and collaboration efforts and contextual details of indicator changes. Another repeated observation from the literature is that both the tools and their associated evaluation process should be cost effective (affordable), effective, readily available, and easy to use (Anstey & Watson, 2018; Johnson et al., 2015; Office of Educational Technology, n.d.). Anstey and Watson (2018), as well as da Silva, Teixeira, Cavalcante, and Teichrieb (2019), noted the criticality of including both Instructional Development (design) personnel and Instructors (i.e., SMEs) in the review and implementation of education and training tools. Anstey and Watson (2018) developed a rubric, specifically for evaluation of e-learning tools (i.e., internet-connected technology to facilitate online education). Their intent was to mitigate instructor frustration from a lack of fluency in e-learning evaluation and the wide variety of tools available (Anstey & Watson, 2018). Their approach was built on the notion of presenting an evaluation option (i.e. rubric) that instructors would already be familiar with from their classroom experience (Anstey & Watson, 2018). This rubric features the definition of a series of categorical characteristics that the tool is evaluated against: Functionality; Accessibility; Technical; Mobile Design; Privacy, Data Protection, and Rights; and Social, Teaching, and Cognitive Presence (Anstey & Watson, 2018). The framework is to be adapted to the specific topic and applicable instructor needs; if a criterion is not applicable, it can be excluded (Anstey & Watson, 2018).

Past research, introduced and discussed under *Educational Requirements,* featured the identification, capture, and analysis of key criteria for the assessment and distinction of sUAS (ERAU, 2016). The assessed criteria included initially investigated quantitative values, followed by qualitative analysis using a customized rubric (ERAU, 2016). The development and use of this rubric were similar to Anstey and Watson's (2018) approach. The quantitative values included performance metrics indicating system capability and limitations, while the qualitative values included subjective characteristics indicative of critical system traits (ERAU, 2016). Each qualitative assessment was performed through inspection, investigation, and operational testing analysis and was scored using one of four possible categories: none (0), low (1-50), medium (51-75), and high (76-100; ERAU, 2016). These parameters have since been adapted to address other critical requirements (e.g., regulatory compliance, learning environment and technical infrastructure needs, technological familiarity, and personal experience) to assist faculty in identifying applicable tools for incorporation into educational programming. Table 1 represents a rubric of the adapted criteria to specify and define considerations associated with the evaluation of sUAS training and education tools.

Table 1. sUAS Technological Tool Evaluation Rubric

Measure	High (100-76)	Medium (51-75)	Low (1-50)	None (0)
Performance Capability	Functional ability to meet training/ educational requirements and use in known environments			
	Significant performance, wide functional variety across known conditions; Incremental advancement of capability; No safety issues anticipated	Sufficient performance and functionality; Utility limited within controlled environment; Some functional capability segmentation; Minor safety issues to be addressed in planning	Limited performance and functionality; Suitable function in tightly controlled environment; Little to no functional segmentation of capability; Notable safety issues to be addressed in planning.	Provides no discernible performance capability for needed use; Significant safety issues present
Construction Quality	Workmanship evident in construction and assembly			
	Construction materials highly durable/ able to withstand unexpected stresses; Designed for maintenance; Components fitted with no movement/ gaps, except where required	Construction materials somewhat durable/ able to withstand expected stresses; Designed for limited maintenance; Components fitted with slight movement/ gaps	Construction materials not durable/ may not withstand stresses; Designed to accommodate little to no maintenance; Components fitted with significant movement/ gaps	No quality of construction evident in design and manufacture
Operational Ease, Accuracy, and Suitability	Operational learning support for specified user			
	Significant thought towards specified user; Responsiveness matches user ability; Important information/ controls easy to locate/ use; Efficiency and safety controls provided; Simulation fidelity and presence high; Seamless learning management system (LMS) integration with clear assessment connection	Some thought towards specified user; Adjustable responsiveness; Important information/ controls accessible; Limited efficiency and safety controls provided; Simulation provides sufficient fidelity to convey spatial relationships and some level of presence; LMS integration possible	Single experience level; Little to no customization; Important information not present and/or controls not easy to locate or use; No efficiency and safety controls provided; Simulation is low fidelity with little to no presence; Low LMS integration potential	Provides no user control for operation, basic simulated visualization, and has no discernible suitability for use, as needed
User Support	Level of support available to tool user			
	Substantial level of support, with detailed operational and maintenance guidance provided; Dedicated website features documentation, user forums, and dedicated service personnel to address inquiries	Supports finding answers to inquiries through a FAQ, system specification, and limited operational and maintenance guidance; Dedicated website provides user access to some relevant information and/or guidance	Support facilitates limited answers to inquiries; Website provides access to basic system specifications	No support available; Only advertised through resellers with information subject to considerable change
Availability	Availability and accessibility of tool and associated resources			
	Widely available from online and national retail outlets; Stock high with no order backlog; Associated materials readily available	Available from online and local retail outlets; Stock sufficient to meet needs with little to no order backlog; Associated materials available online	Limited availability online; Stock low and may not be sufficient to meet needs (order backlog common); Associated	Tool and resources not available, in-person or online

Measure	High (100-76)	Medium (51-75)	Low (1-50)	None (0)
			materials only from paid sources	
Cost	Cost of tool, in relation to other equipment, materials, and resources used within program			
	Affordable, low-threshold cost; Comparable to similar student educational expenses (e.g., textbooks; under $500)	Significant cost, acceptable if used in multiple educational segments (courses); Comparable to similar student educational expenses (e.g., PC; $500-$1,000)	Substantial and potentially cost-prohibitive cost, only acceptable if used across duration of entire program; Represents significant cost burden to student ($1,000+)	Tool is cost-prohibitive and does provide sufficient benefit
Regulatory Compliance	Confirmed conformity of tool with domestic legal/regulatory requirements where tool is to be used, at federal, state, and local levels			
	Fully compliant with existing regulatory requirements; Fully conforms with standards; Credential to operate within scope of program requirements	Primarily compliant with existing regulatory requirements (may require waiver); May not fully conform with standards (may require waiver); Credential to operate may require minor modification of program scope/ requirements	Not compliant with existing regulatory requirements or standards (will require waiver[s]); Credential to operate requires significant modification of program scope/ requirements	Cannot be operated in-compliance with regulatory requirements or standards, even with waivers; Incompatible credential requirement

Each of the specified criteria has previously been utilized to evaluate sUAS tools through a variety of methods. *Performance capability* was assessed by examining and cross-comparing published performance metrics, program requirements, safety mandates or requirements, operational abilities or functions, and use in known environments. *Construction quality* featured the inspection and testing of construction material durability, ease of maintenance and calibration, and precision of assembly. *Operational ease, accuracy, and suitability* was determined by cross-comparing program requirements with the results of a qualitative human factors assessment (e.g., analyzing the intuitiveness and placement of controls, ability to vary response to suit proficiency, quality and accuracy of simulation, and interface features integration). The level of *user support* featured the review and scoring of the amount and quality of media, documents, specifications, training, and user communities (e.g., forums). Rating the *availability* of a tool involved investigating potential sourcing options, including original equipment manufacturers (OEMs), online resellers, and national and local retail options. Identification of *cost* required the sourcing of pricing options from the same sources used to rate availability. Finally, assessment of *regulatory compliance* necessitated cross-comparing associated documentation to the enacted regulatory requirements in known operational locations. Completion of these evaluations resulted in confirmation or rejection of tool suitability, including operational requirement satisfaction, conformity, and credential dependency to operate. Further adaptation and customization of this mechanism, especially in light of prior example criteria, could further enable alignment to meet the needs of online educational providers. This rubric could also be expanded to include unique educational modality requirements of various delivery mechanisms (i.e., online, hybrid, and F2F).

RECOMMENDATIONS

The intent of this work is to present critical considerations, including influencing factors and dependencies, associated with the selection and adoption of technological tools best supporting sUAS education. These training tools and their associated assessment mechanisms are fundamental to any competency-based program where student experience, availability and nature can widely influence personal achievement. This can be of particular challenge in underrepresented populations where opportunity is not always evenly distributed and students must quickly “level up” to a minimum training baseline. In such cases and to the furthest extent possible, education and training tools should seek to provide the student with the greatest opportunity to succeed; unencumbered by unnecessary technical jargon, complexity, or cultural/environmental bias. The seven, tool agnostic, criteria presented here intend to aid in that consideration and the successful adoption of sUAS technologies to serve a widely varied and distributed community. Further research is required to validate the efficacy of the proposed rubric and any future study should account for the business case and tradeoffs associated with program/curriculum changes. Additionally, mechanisms to capture increased demographic data fidelity, methods to better understand sUAS-specific experiential learning, and the unique dependencies of interactive and immersive technologies within this space warrant further study.

CONCLUSIONS

The rapid and global proliferation of sUAS, coupled with the dynamic nature of the current technology evolution, are pushing education and training programs to continuously evaluate curricula, training tools, and pedagogy to ensure students leave with the requisite physical and mental acumen to safely operate unmanned systems in compliance with regulatory guidelines. To this end a series of processes to evaluate individual programs, based upon student demographics and needs, have been identified. The success and efficacy of the assessment is dependent on frequent evaluation and timely adoption of relevant training tools. In support, a sUAS Technological Tool Evaluation Rubric has been developed with assessment metrics based on performance capability, construction quality, operational ease and sustainability, user support, availability, cost, and regulatory compliance. Such a rubric assists to mitigate individual bias and speculation, especially in online, asynchronous programs where student incoming proficiency and availability are widely varied.

ACKNOWLEDGEMENT

This work was made possible based on the prior work and support of our colleagues and research collaborators, including Dr. Ken Witcher (Dean of College of Aeronautics, ERAU-W), David Thirtyacre (Flight Department Chair, ERAU-W), and Dr. Ryan Wallace (ERAU-Daytona Beach). Additionally, recognition is due to Dr. Aaron Judy, I/ITSEC Education subcommittee representative, for providing guidance and support as the "birddog" for this paper.

REFERENCES

Abaffy, L. (2019, January 23). FAA's Previewed Drone Rule Could Vastly Expand Allowed Flights. *Engineering News-Record*. Retrieved from https://www.enr.com/articles/46250-faas-previewed-drone-rule-could-vastly-expand-allowed-flights

Ak, A., Topiz, V., Altikardes, A., & Oral, B. (2018). Development of a Remote Laboratory Infrastructure and LMS for Mechatronics Distance Education. *EURASIA Journal of Mathematics, Science and Technology Education, 14*(6), 2493-2508. doi:10.29333/ejmste/89947

Anstey, L., & Watson, G. (2018, September 10). A Rubric for Evaluating E-Learning Tools in Higher Education. *EDUCAUSE Review.* Retrieved from https://er.educause.edu/articles/2018/9/a-rubric-for-evaluating-e-learning-tools-in-higher-education

Arendale, D. (2018, August 6). *What is a best education practice?*. Fridley, MN: Educational Opportunity Association. Retrieved from http://www.besteducationpractices.org/what-is-a-best-practice

Association for Unmanned Vehicle Systems International. (2019).*Trusted Operator Program protocol certification manual* (1.3 ed.). Washington, DC: Author, Remote Pilots Council.

Banta, T.W. & Palomba, C.A. (2015). *Assessment essentials: planning, implementing, and improving assessment in higher education*. San Francisco, CA: Jossey-Bass.

Baum, M.S., Kiernan, K.K., Steinman, D.W., & Wallace, R.J. (2018). *UAS pilots code* (annotated version 1.0). Retrieved from http://www.secureav.com/UASPC-annotated-v1.0.pdf

Bryan, T. K., Lutte, R., Lee, J., O'Neil, P., Maher, C. S., & Hoflund, A. B. (2018). When do online education technologies enhance student engagement? A case of distance education at University of Nebraska at Omaha. *Journal of Public Affairs Education, 24*(2), 255-273. doi: 10.1080/15236803.2018.1429817

Carrier, K. K. (2010). Perspectives on the Realities of Virtual Learning: Examining Practice, Commitment, and Conduct. In T. T. Kidd & J. Keengwe (Eds.), *Adult Learning in the Digital Age: Perspectives on Online Technologies and Outcomes* (pp. 23-31). Hershey, PA: Information Science Reference.

Competency-Based Training: The future of the aviation industry?. (2017, June 23). *The Journal for Civil Aviation Training.* Retrieved from https://www.civilaviation.training/pilot/competency-based-training-future-aviation/

Condoluci, M., & Mahmoodi, T. (2018). Softwarization and virtualization in 5G mobile networks: Benefits, trends and challenges. *Computer Networks, 146*, 65-84.

Deloitte. (2018). *Managing the evolving skies: Unmanned aircraft system traffic management (UTM), the key enabler*. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/global/Images/infographics/gx-eri-managing-the-evolving-skies.pdf

DJI. (2018). DJI flight simulator. Retrieved from https://www.dji.com/simulator/info

Embry-Riddle Aeronautical University. (2016a). *Small unmanned aircraft systems consumer guide.* Daytona Beach, FL: Author, Worldwide campus. Retrieved from http://nias-uas.com/wp-content/uploads/2016/07/erau-suas-consumer-guide-june-2016-release.pdf

Federal Aviation Administration. (2019a, March 11). *Educational users.* Retrieved from https://www.faa.gov/uas/educational_users/

Federal Aviation Administration. (2019b, April 23). *Integration Pilot Program lead participants*. Retrieved from https://www.faa.gov/uas/programs_partnerships/integration_pilot_program/lead_participants/

Federal Aviation Administration. (2018a). *FAA aerospace forecast: Fiscal years 2018-2038.* Washington, DC: Author. Retrieved from https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2018-38_FAA_Aerospace_Forecast.pdf

Federal Aviation Administration. (2018b, July 23). *Fact Sheet – Small Unmanned Aircraft Regulations (Part 107).* Retrieved from https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22615

Federal Aviation Administration. (2016a). *Airplane flying handbook* (Faa-8083-3b). Retrieved from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/airplane_handbook/

Federal Aviation Administration. (2016b). *Pilot's handbook of aeronautical knowledge* (Faa-h-8083-25b). Retrieved from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/phak/

Franks, P., Hay, S., & Mavin, T. (2014) Can competency-based training fly?: An overview of key issues for ab initio pilot training. *International Journal of Training Research, 12*(2), 132-147. doi: 10.1080/14480220.2014.11082036

Gaydos, S. J., & Curry, I. P. (2014). Manned-Unmanned Teaming: Expanding the Envelope of UAS Operational Employment. *Aviation, Space, and Environmental Medicine, 85*(12), 1231-1232.

Harriman, S. L. (2011). *The impact of collegiate aviation student learning styles on flight performance: A scenario-based training approach* (Doctoral Dissertation). Retrieved from from ProQuest Dissertations & Theses Global. (904412037).

Howse, W.R. & Schwartz, K.L. (2011). *Knowledge, skills, abilities, and other characteristics for remotely piloted aircraft pilots and operators* (Technical report: AFCAPS-FR-2011-0006). Fort Belvoir, VA: Defense Technical Information Center.

Hu-Au, E., & Lee, J.Y. (2017). Virtual reality in education: a tool for learning in the experience age. *Int. J. Innovation in Education, 4*(4), 215-226. Retrieved from http://virtualrealityforeducation.com/wp-content/uploads/2018/06/HuAu_Lee_2017_VRinEd.pdf

Johnston, J.H., Goodwin, G., Moss, J., Sottilare, R., Ososky, S., Cruz, D., & Graesser, A. (2015). *Effectiveness evaluation tools and methods for adaptive training and education in support of the US Army learning model: Research outline*. Fort Belvoir, VA: Defense Technical Information Center.

Joint Committee on Standards for Educational Evaluation. (2011). *Program evaluation standards statement.* Retrieved from http://www.jcsee.org/program-evaluation-standards-statements

Kuh, G. D. (2009). The national survey of student engagement: Conceptual and empirical foundations. *New Directions for Institutional Research, 2009*(141), 5-20.

Kuzma, J., Robinson, A., Dobson, K., & Law, J. (2018, September). Practical Pedagogy for Embedding Drone Technology into a Business and Computing Curriculum. *Journal of Education and Human Development, 7*(3), 1-9. doi: 10.15640/jehd.v7n3a1

Lercel, D., & Steckel, R. (2018, June). *Unmanned aircraft systems: An overview of strategies and opportunities for Missouri* (Report no. cmr 18-009). St.Louis, MO: UAViation. Retrieved from https://library.modot.mo.gov/RDT/reports/TR201808/cmr18-009.pdf

Macchiarella, N. D., Brady, T., & Arban, P. K. (2005). *High fidelity flight training devices in the training of ab initio flight students*. Paper presented at the IEEE 24th Digital Avionics Systems Conference, Washington DC. doi:10.1109/DASC.2005.1563375

McMahon, A. (2018). *Train like you fly: A flight instructor's guide to scenario-based training* (2nd ed.). Newcastle, WA: Aviation Supplies & Academics.

Moser, J., & Gillette, A. (2016). *DACUM research chart for aerial sensing data analys*t. Columbus, OH: The Ohio State University, College of Education and Human Ecology.

Muller, J. (2012). *Authentic assessment toolbox. What is authentic assessment?* Retrieved from http://jfmueller.faculty.noctrl.edu/toolbox/whatisit.htm

National Center for Education Statistics. (2017). *Enrollment and Employees in Postsecondary Institutions, Fall 2017; and Financial Statistics and Academic Libraries, Fiscal Year 2017*. Retrieved from https://nces.ed.gov/pubs2019/2019021REV.pdf

Office of Educational Technology. (2019, March 18). *Accreditation in the United States.* Washington, DC: U.S. Department of Education.

Office of Educational Technology. (2014). *Evaluation tool: examining progress towards future ready professional learning.* Washington, DC: U.S. Department of Education.

Revere, L., & Kovach, J. V. (2011). Online technologies for engaged learning: A meaningful synthesis for educators. *Quarterly Review of Distance Education, 12*(2).

Rostker, B.D., Nemfakos, C., Leonard, H.A., Axelband, E., Doll, A., Hale, K.N., McInnis, B., Mesic, R., Tremblay, D., Yardley, R.J., & Young, S. (2014). *Building toward an unmanned aircraft system training strategy*. Santa Monica, CA: RAND Corporation.

Saunders, J., & Beard, R. (2010). UAS flight simulation with hardware-in-the-loop testing and vision generation. *Journal of Intelligent & Robotic Systems, 57*(1-4), 407-415. doi:10.1007/s10846-009-9354-6

Stevens, J.A., & Kincaid, J.P. (2015). The relationship between presence and performance in virtual simulation training. *Open Journal of Modelling and Simulation, 2015, 3,* 41-48. Retrieved from https://nil.cs.uno.edu/publications/papers/stevens2015relationship.pdf

Suren, J. (2018, September 25). *Competency Based Training and Assessment.* Retrieved from https://www.aerosociety.com/media/9779/02-jacqui-suren.pdf

Szabolcsi, R. (2016). UAV operator training: Beyond minimum standards. *Scientific Research & Education in the Air Force – AFASES, 1*, 193-198. Retrieved from http://www.afahc.ro/ro/afases/2016/RP/SZABOLCSI.pdf

Taher, M.T., & Khan, A.S. (2014). *Impact of Simulation-based and Hands-on Teaching Methodologies on Students' Learning in an Engineering Technology Program* (Paper no. 10786). Paper presented at the 121st American Society for Engineering Education Annual Conference and Exposition, Indianapolis, IN. Retrieved from https://www.asee.org/public/conferences/32/papers/10786/download

The Group for Organizational Effectiveness, Inc. & Aptima, Inc. (2016). *Small Unmanned Aerial Systems (sUAS) Initial Competency Set (ICS), Developmental Experiences, Knowledge and Skills, and Curriculum Review: Summary Report.* Prepared for Sinclair College and Air Force Research Laboratory.

Tulis, D. (December 11, 2017). Enrollment up at many aviation colleges. *AOPA News.* Retrieved from https://www.aopa.org/news-and-media/all-news/2017/december/11/enrollment-up-at-many-aviation-colleges

United States Government Accountability Office. (2015, May). *Unmanned aerial systems: Action needed to improve DOD pilot training* (Report no. GAO-15-461). Washington, DC: Author. Retrieved from https://www.gao.gov/assets/680/670225.pdf

United States Department of Education. (n.d.). *Educational Technology Rapid Cycle Evaluations*. Retrieved from https://tech.ed.gov/rce/

Wang, P., Wu P., Wang, J., Chi, H.L., & Wang, X. (2018). A critical review of the use of virtual reality construction engineering education and training. *Int. J. Environ. Res. Public Health 2018, 15*(6), 1204. doi:10.3390/ijerph15061204