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Developing a Competency Learning Model for Students of Unmanned Aerial Systems

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Over the past decade, Unmanned Aerial Systems (UAS), along with commercial UAS pilots, have become an established and increasingly regulated industry. Unfortunately, in the U.S. the number of near misses and incidents involving unsafe UAS operations is increasing dramatically. Additionally, industries looking to adopt UAS technologies not only require trained professionals to ensure safe and legal operations but may look for competencies that go well beyond the minimum regulatory requirements. To date, research regarding the higher order learning outcomes and competencies that are expected of UAS university graduates is lacking. Therefore, this research attempts to provide perspective of the core competencies that industry organizations may desire in a UAS graduate and, by extension, in a UAS professional. This paper describes the methods used to identify core UAS competencies, and presents a UAS Competency Learning Model that may help educators better prepare graduates for successful industry careers. Researchers utilized a multi-phase process over an 18-month period using both quantitative and qualitative methods, which included literature reviews, surveys, interviews, focus groups, and attendance at UAS industry events. Ultimately, from this research emerged the following six UAS competencies: Leadership, Technical Excellence, Safety and Ethics, Analytical Thinking, Teamwork, and Entrepreneurship.

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Over the past decade, Unmanned Aerial Systems (UAS) have grown from a hobbyist curiosity, to a disruptive technology, to what is now becoming an established and increasingly regulated industry. This rapid growth would be significant in any industry and remains unprecedented within aviation. For example, the United States (U.S.) issued its first manned pilot certificate in 1927. Almost 100 years later, the Federal Aviation Administration (FAA) has certified over 672,000 manned pilots in the U.S. In contrast, since the FAA enacted Part 107 regulation for small UAS in August of 2016, they have issued over 170,000 remote pilot certificates, which already comprises over 20% of the total pilot population (FAA, 2016, 2020e). The new Part 107 regulation was a first step in enabling broader commercial UAS operations in the U.S., but as the number of UAS pilots continues to grow and the industry evolves, there also comes a growing need to train and educate this emerging skills-based workforce.

With the explosion of UAS platforms and pilots, in addition to the already numerous Radio Control (RC) model aircraft, the FAA's approach to ensuring the safety of the National Airspace System (NAS) for all users has evolved over time as the technology has developed and the number of UAS has increased. Today there are over 1.5 million unmanned aircraft registered in the United States, with 420,000 registered for commercial use. The number of unmanned aircraft far exceeds the approximate 250,000 registered manned aircraft (FAA, 2020a). The FAA (2020b) continues to work towards developing policies and technologies that will expand future UAS operations beyond the current Part 107 limitations and increase integration into the NAS. These future operations include services such as package delivery and urban air mobility.

The FAA foresees UAS operations seamlessly integrating with manned aircraft in the NAS (FAA, 2020b, 2020d). Throughout this integration process, there will be more opportunities for public and private sector research to enable UAS to fly in the NAS with manned aircraft. Pilot and aircraft certification and training, airspace, safe separation of aircraft, air traffic procedures, and regulations will need to be developed as UAS operations and technologies evolve.

Unfortunately, in the U.S. the number of near misses and incidents involving unsafe UAS operations is accelerating. According to the FAA, reports of unmanned aircraft (UAS) sightings from pilots, citizens and law enforcement have increased dramatically over the past two years. The FAA now receives more than 100 such reports each month (FAA, 2020c). These unsafe operations challenge the economic opportunities and public benefit that UAS stands to provide (GAO, 2018). A properly trained and certificated workforce is a precursor to safe UAS operations and advancement of any socio-economic benefits. Additionally, industries looking to adopt UAS technologies not only require trained professionals to ensure safe and legal operations *but may require competencies that go well beyond the minimum regulatory requirements*.

There seems to be little agreement in the literature on the definition of a competency. Jubb and Robotham (1997) write that: "It still remains the case that a precise and widely accepted definition of competences continues to elude both those researching the field and trainers themselves" (p. 171). However, from an educational and training perspective it is generally accepted that competency refers to the underlying attributes of a person such as their knowledge, skills or abilities (Hoffmann, 1999). While discussing competency-based education in aviation, Kearns, Mavin, and Hodge (2016) suggest competency "means having a specific ability to do something that can be defined in advance" (p. 10), adding a competency may include knowledge, skills, attitudes, values and understanding that enable competent performance. Bernstein (2000) relates competency with one's performance – simply assessing a person's behavior for a given situation. The International Civil Aviation Organization (ICAO) defines competency as a combination of skills, knowledge and attitudes required to perform a task to the prescribed standard (2013). Defining competencies within these contexts places a focus on the required inputs of individuals to achieve competent performance. By describing the knowledge, skills or abilities required of competent performers, the inputs needed for the development of a learning program may be better defined.

The FAA regulation prescribes knowledge of the limitations and requirements to operate a small UAS in the National Airspace (NAS). For example, the operator must maintain visual sight of the UAS, operate no higher than 400 feet above ground level, and maintain minimum clearances from clouds (FAA, 2016). ASTM International (ASTM, 2020), formerly known as the American Society for Testing and Materials, developed a defined set of UAS pilot training standards. Similar to FAA regulation, a review of these standards also found an overwhelming focus on operational limitations, safety, and compliance. Likewise, the ICAO's focus is on ensuring a safe, efficient, secure, and sustainable civil aviation sector. In its Manual on Remotely Piloted Aircraft Systems (RPAS), the ICAO writes that their purpose is to provide "an international regulatory framework…and guidance material, to underpin routine operation of RPAS throughout the world in a safe, harmonized and seamless manner comparable to that of manned operations" (ICAO, 2015, p. 5).

Based on the literature's definition of competency in the context of education, these polices fall short of prescribing UAS competencies. Furthermore, although these organizations prescribe policy surrounding safe and legal UAS operations, they do not describe the competencies, or additional knowledge, skills, and abilities that employers may require of UAS professionals.

To date, research regarding the higher order learning outcomes and competencies that are expected of UAS university graduates is lacking. This is likely due to the infancy of the UAS ecosystem. Such a dearth of information presents significant barriers toward development of a UAS program that can properly address industry demands while keeping pace with technological developments. Despite these challenges, a detailed review of emerging patterns and trends within the UAS industry provides a plethora of information for creation of a UAS program that addresses both safety and technological concerns.

This research provides perspective into the core competencies that industry organization may desire in a UAS graduate and, by extension, in a UAS professional. The objective of this paper is to describe the methods used to identify these core competencies, with the goal of developing a UAS Competency Learning Model that may help educators better prepare graduates for successful industry careers. Ultimately, this Model may be used as a foundation for future research.

Methodology

A preliminary review of UAS programs at other universities and job postings for UAS pilots/operators, and mission specialists (in a wide variety of domains such as agriculture, law enforcement, geospatial intelligence, etc.) revealed that UAS graduates ideally will have a holistic understanding of the UAS ecosystem and technology. Key to this worldly approach is for the UAS graduate to grasp proper UAS application, how to safely and effectively operate a UAS in the NAS, and how to manage UAS operations at the enterprise business level.

The cross-disciplinary nature of UAS has both technical and personal benefits to diverse student populations across a diverse and increasing number of applications. Ideally, a UAS educational program should accommodate and adapt to future changes in UAS technology, market trends, and FAA policy. Such an approach produces well-rounded students with diverse marketable skills sets that appeal to a wide range of job markets and research fields, now and into the future.

Market and technological trends demonstrate that the UAS graduate need not be an expert in a single discipline, such as engineering, aviation policy, or data science; ideally, they have a well-rounded knowledge of UAS related realms (Bennett, Nex, Gerke, Zevenbergen, & Stöcker, 2017; Colomina & Molina, 2014; Watts, Ambrosia, & Hinkley, 2012). Table 1 provides a non-comprehensive summary of the typical skills often employed in the UAS industry. To teach each of these skills in a detailed manner within the resource limitations of a degree program would be unfeasible, so there is a need to provide an overall UAS education, yet focus on key areas based upon key emergent trends in the UAS industry.

Table 1.
Example of UAS Industry Skills

Technology	Operations	Data	Policy
• Maintenance/Repair • System Evaluation • Integration • Sensors	• Safety Management • Mission Planning • Crew Resource Management • Software Apps	• Management • Processing • Analyses • Remote Sensing • GIS	• Regulations • Safety • Ethics • Training • Security

This study involved a multi-phase process over an 18-month period using both quantitative and qualitative methods, which included literature reviews, surveys, interviews, focus groups, and attendance at UAS industry events. Study participants included FAA and industry representatives; events included the Association of Unmanned Vehicle Systems International (AUVSI) annual Xponential show, the annual FAA UAS Symposium, Environmental Systems Research Institute's (ESRI) User Conference, and Aviation Accreditation Board International (AABI) meetings.

The qualitative data was primarily collected from a diverse group of subject matter experts across the UAS industry. Researchers utilized this data to gain perspective on the current and future competencies needed by the industry and to understand their competency priorities. From the qualitative data, researchers developed a survey instrument to collect quantitative data from across the broader population. To achieve the objective toward development of a theoretical competency model, these researchers developed a phased approach outlined below.

Phase 1

Phase 1 focused on gaining perspective of the UAS ecosystem and, more specifically, the aspects related to workforce development and demand, employer requirements, and economic trends. The authors conducted an extensive literature review, which included reviewing regulatory documents, demographic data, industry publications, economic and market forecasts, UAS related job postings, university's UAS curriculum, and related workforce studies.

Phase 2

In Phase 2 qualitative data was gathered across several activities. First, researchers established a UAS Industry Advisory Board (IAB) comprised of a diverse network of eight UAS industry leaders. Researchers engaged the IAB to discuss and affirm the findings from Phase 1, gain perspective and a deeper understanding of industry workforce priorities, and support development of a UAS workforce survey instrument. Next, researchers attended key UAS industry events, which included discussion sessions related to UAS workforce competencies, applications, and the UAS ecosystem. Further building upon Phase 1, the focus of Phase 2 was to gather a broader perspective of attitudes and opinions regarding the current and future workforce needs. At these events the authors attended day long workshops concerning development of a Safety Management System (SMS) and Crew Resource Management (CRM) (Ginnett, 2019). They also conferred with various attendees and conducted informal interviews regarding sought after competencies in the UAS industry. Researchers recorded notes of these discussions and collected marketing and technical literature, interviewees included representatives from the FAA, UAS hardware and software companies, manufacturers and service providers. Additional informal interviews were conducted with UAS faculty from various universities, students, and recent graduates. No identifying information was collected nor was audio or video recording utilized.

Phase 3

Phase 3 combined input gathered in Phase 1 and 2 to generate and distribute a survey that allowed for a broader collection of quantitative data to aid in generating a theoretical competency model. This survey instrument attempted to identify and prioritize the top UAS competencies required of current and future UAS professionals.

Survey taxonomies were developed from Phase 1 and 2 research and in consultation with the IAB. With the list of competencies and their respective knowledge, skills and abilities developed, a survey was created that assessed the broader industry population. Survey participants ranked the importance of competencies, and then second, ranked the importance of knowledge, skill and ability items corresponding to each competency. Before distribution across the survey population, researchers tested the survey across a beta group of 20 individuals, which was comprised of industry representatives (including IAB members), other faculty members, and graduate students. Only minor edits and adjustments to technical settings were required. Researchers recruited survey participants by utilizing publicly available information obtained from FAA and other industry databases. Researchers emailed a web-based online survey instrument to 2,856 UAS professionals. Survey responses were completely anonymous and collected using the Qualtrics online survey software platform. Survey participants were asked to select their top three competencies and rank these three competencies in order of importance. Competencies were ranked by mean (M) score.

Phase 4

Phase 4 was conducted in parallel with Phase 3 efforts and involved a basic text-mining exercise of online UAS job postings. Sources included popular aviation related online job boards, such as Indeed, JS Firm, AVJobs, and several others. Researchers collected text from 72 UAS job postings. Microsoft EXCEL software with the Analytic Solver Data Mining add-in was used for the text analyses. An initial word frequency indexing was conducted to identify common non-value or stop words, which were then removed (Manning, 2008). From this index, researchers identified key words and performed a stemming exercise. Stemming removed derivational and inflectional affixes and reduced the word down to its root or stem, which improved the data retrieval process (Jabbar, Iqbal, Akhunzada, & Abbas, 2018). Trigrams were then created for stem words with counts greater than 40 to help improve context and perspective of the job requirements. These data were then reviewed by researchers to develop categories ranked by frequency of stem word count and trigrams. The results of this text mining exercise were then compared with the workforce survey results.

Results and Discussion

The Competency Gap

As part of this study, researchers evaluated industry's perspective of the requirements of the FAA Part 107 airman certificate and industry's requirements of UAS professionals. The results indicate a competency gap may exist between the regulatory requirements and what industry requires of UAS professionals. This finding suggests a need for additional education and training for current and future UAS professionals and is consistent with findings from previous research regarding FAA certification of Aviation Maintenance Technicians (Lercel et al, 2015; Gray, 2009). Survey participants were asked three questions regarding newly certificated FAA Part 107 Remote Pilots. The questions and the associated results are shown here in Table 2.

Table 2.
Survey results regarding competency of newly certificated FAA Part 107 Remote Pilots

Survey Question	Agree	Neither Agree or Disagree	Disagree
Do newly certificated FAA Part 107 remote pilots have the proper level of training that is required to be productive?	20%	25%	55%
Do the FAA Part 107 certificate requirements adequately prepare a new remote pilot to enter the workforce?	28%	23%	49%

Do newly certificated FAA Part 107 Remote Pilots have the proper level of training to operate safely?	28%	29%	43%

Comments from survey respondents and interviewees affirm these findings that meeting the minimum regulatory requirements do not adequately prepare a person for the UAS industry and do not ensure the level of safety required by industry.

Competency Model Trends

Preliminary results gathered in phases one and two demonstrated that UAS is driven predominantly by trends in the Aerospace and Geospatial industries, coupled with FAA regulatory policy and legislative mandates. Along with competency in the realm of aerospace (Figure 1), the UAS graduate must maintain certain core skills associated with the Geospatial Competency model (Figure 2). Both the Aerospace and Geospatial competency models are grounded in three foundational learning theories: (1) Bloom's (1956) theory of integration of the problem-based inquiry and the learning experience itself; (2) Litzinger, Wise, & Lee (2005) theory of relationship between level of individual maturity and level of learning; and (3) Cervero (1986) theory of learning as a by-product of inquiry rather than an outcome of a teaching process.

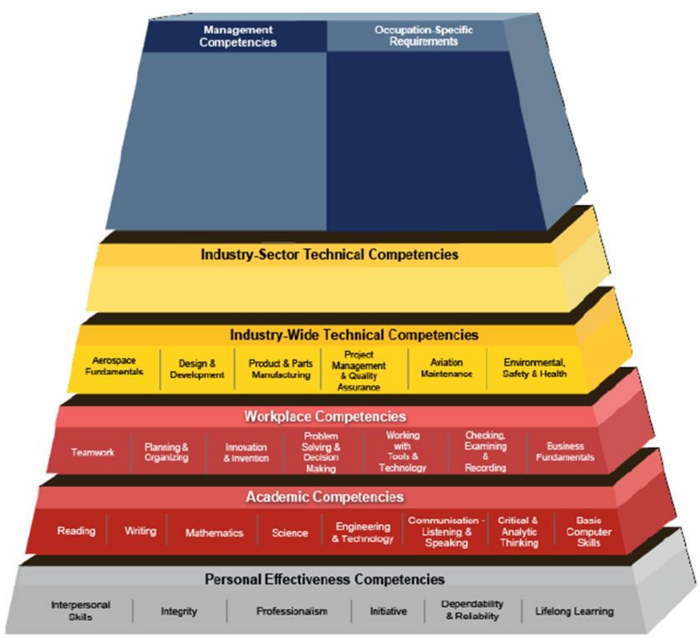

Figure 1. U.S. Dept. of Labor aerospace competency model (Note: This figure illustrates the aerospace industry's desired workplace and workforce interpersonal and technical competencies. Source: U.S. Dept. of Labor, Employment and Training Administration (2018). Aerospace industry competency model. Tier 3 Workplace competencies)

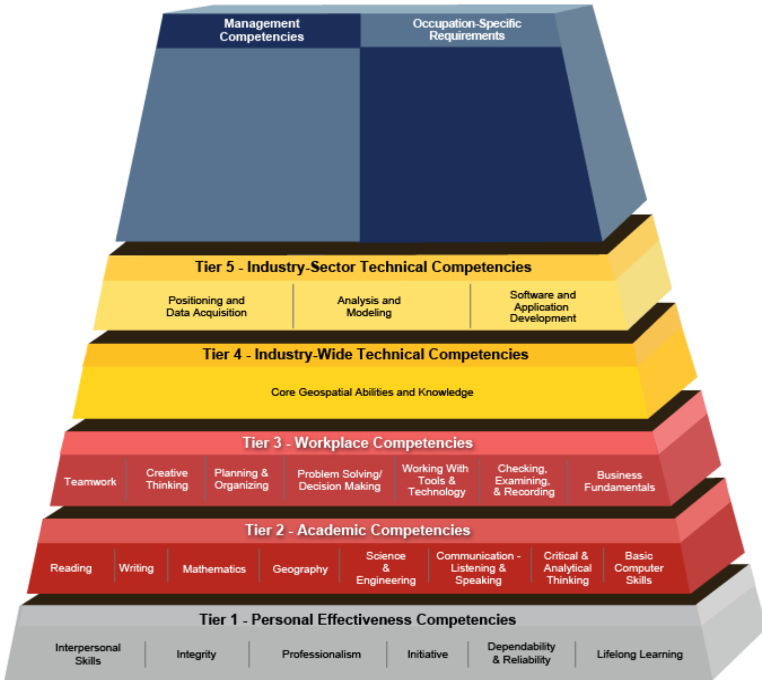

Figure 2. U.S. Department of Labor geospatial competency model. (Note: This figure illustrates the geospatial industry's desired workplace and workforce interpersonal and technical competencies. Source: U.S. Dept. of Labor, Employment and Training Administration (2018). geospatial industry competency model. Tier 4 Workplace competencies)

The workforce survey results from phase 3 found the four most selected competencies to be Safety and Quality Focus (81%), Technically and Mechanically Proficiency (64%), and Operations Acumen (54%), and Data Collection/Processing Acumen (43%). Participant's survey comments further suggest a significant importance for responsible and ethical behavior, leadership abilities, and an entrepreneurial mindset by UAS professionals These findings are supported by Figure 3, which illustrates the number of times a competency was selected by survey respondents, while Table 3 illustrates the mean ranking of each competency. For example, from Figure 3 we find that 98 survey participants selected Operations Acumen as a top three competency, making it the third most selected competency. However, from Table 3 we see that the mean rank of Operations Acumen was fifth - meaning those that selected Operations Acumen generally ranked it lower in importance than the other selected competencies.

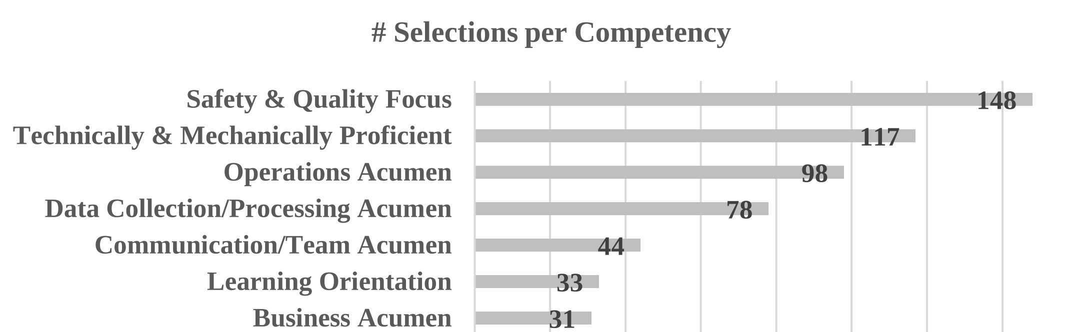

Figure 3. Number of Selections per Competency from UAS Workforce Survey

Table 3.
Mean Ranking of Selected Competencies from UAS Workforce Survey

Selected Competency	**Mean Rank**
Safety & Quality Focus	1.56
Technically & Mechanically Proficient	2.11
Data Collection/Processing Acumen	2.12
Learning Orientation	2.15
Operations Acumen	2.16
Communication/Team Acumen	2.27
Business Acumen	2.32

One of the distinguishing attributes developed at the foundational level in the academic context but is refined and sharpened throughout one's own professional service is the ability to make sound ethical decisions while delivering operational excellence in a high-risk environment. Oliver, Collin, Burns, & Nicholas (2006) noted the importance of teaching/learning leadership and ethical decision-making skills in the context of real-life scenarios and impact. The UAS students learn about work in a profession that constantly manages risk—even in the academic setting. From the time they begin their course of study, the students own experience should demonstrate that their actions have consequences and are meaningful. This provides immediate relevance to the competencies developed by the students. In general, competencies have been defined as combined and integrated components of knowledge, skills, and attitudes. As such competencies are changeable, learnable and attainable through experience, training or coaching (Man, Lau, & Chan, 2002; Volery, Mueller, & Von Siemens, 2015). In this context, various competencies arise when subject matter excellence needs of the UAS program are overlaid with the literature regarding the knowledge, skills, and abilities needed for the success of the aviation industry.

The job description text mining results found 28 stem words with counts greater than 40 (Figure 4). From these 28 stem words emerged 21 trigrams with counts greater than four. Researchers reviewed these results and performed a content analyses to categorize the content and develop themes. The text mining results generally align with the findings from the workforce survey and the previous quantitative research. The following eight themes emerged from this text mining exercise.

1. Safety Risk Management
2. Operational Skills
3. Technical Expertise
4. Certification/Training
5. Problem Solving
6. Data Gathering/Analytics
7. Communication Skills
8. Experience

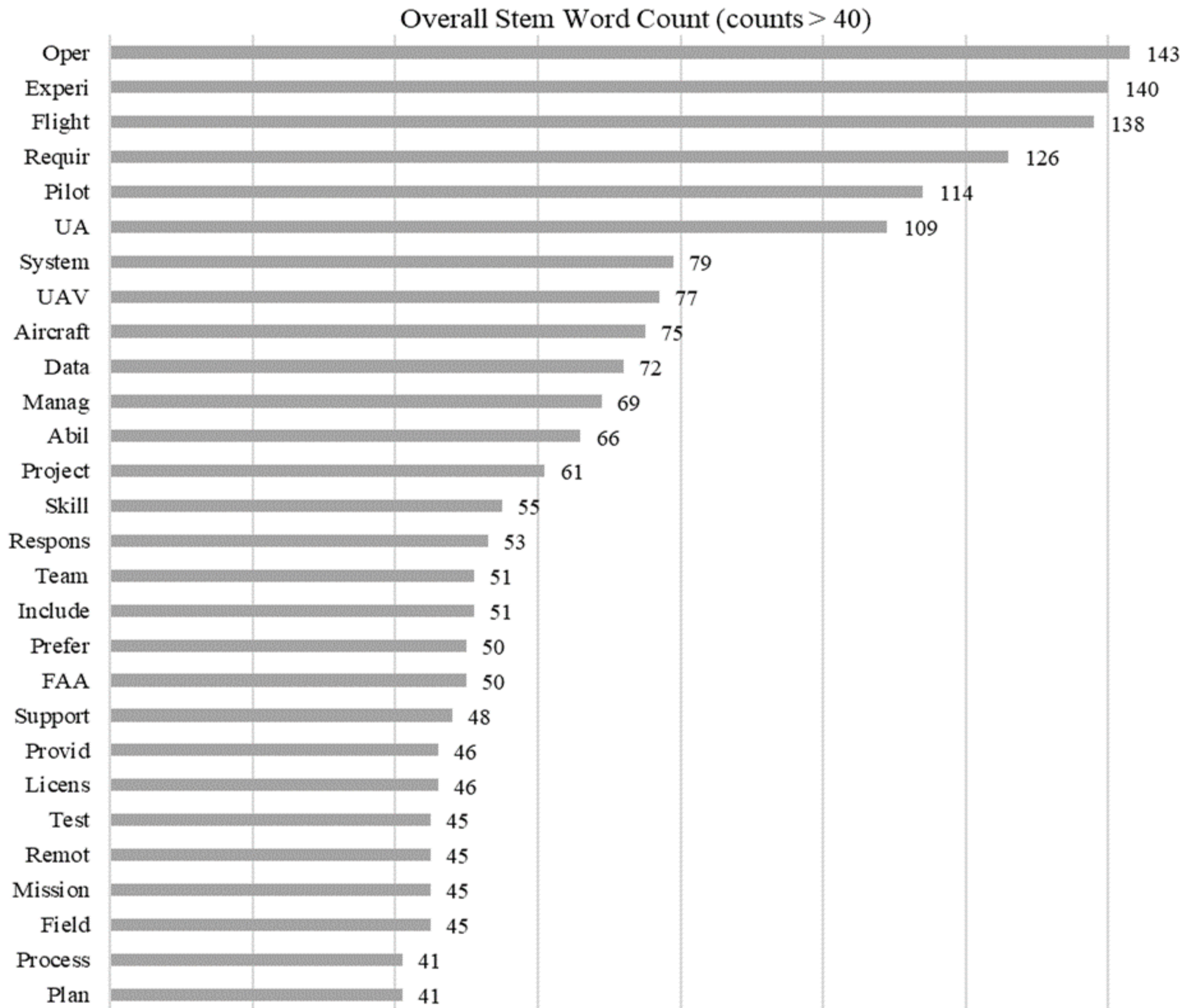

Figure 4. Text Mining Stem Word Counts from UAS Job Postings

The UAS Competency Learning Model

This study of the UAS ecosystem and a review of the other aviation related disciplines such as flight, technology, and management, found the emergence of the following six UAS competencies: Leadership, Technical Excellence, Safety and Ethics, Analytical Thinking, Teamwork, and Entrepreneurship. Figure 5 illustrates the contributory nature of UAS competencies toward the development of a theoretical UAS Competency Learning Model. Ideally, a UAS graduate will exemplify each of these six competencies at a minimum.

Figure 5. Theoretical UAS Competency Learning Model

Leadership

A review of the literature and these research results confirmed that the aviation community continues to highly desire graduates who possess the maturity and ability to lead others. More specifically, interviews and discussions with IAB members and other UAS industry leaders found leadership is a key competency sought after in a UAS graduate. Leadership is a multidimensional competency. As a person's leadership matures, they gain more holistic views and become more adept at cross-functional interactions. This competency houses the skills to adapt to different levels of an organization: the operational/functional level, the business level, the corporate level, or the industry/sector level. Singer (2014) identifies critical performance capabilities for an innovative leader to master different stages of innovation. These include (1) Ideation or gathering promising ideas, (2) Building a team, (3) Refining ideas with the teams, (4) Estimating the cost and values of the proposed idea, (5) Reviewing the ideas against predefined criteria and objectives, (6) Identifying the best ideas for likely funding and seeking budgets for implementation, and (7) Delivering a finished product on the ideas put forth while developing the ability to see larger pictures, and understand how one set of problems and solutions fit into larger problems and solutions. Intrinsically, leadership can also be about leading one's self even when performing an individual task, where sound planning, communication, task execution and integrity remain paramount in the context of the hazardous aviation environment.

As the leadership elements identified in this review began to saturate and repeat, researchers returned to the U.S. Department of Labor aerospace model (Figure 1). This review identified key elements of leadership competency outcomes targeted by the UAS curriculum. The Leadership learning outcomes selected were distilled into the following five categories:

1. Fostering actions towards achieving vision, mission, and goals of a project or activity.
2. Facilitating group processes.
3. Utilizing situation, context, and cultural aspects of organizations effectively.
4. Demonstrates the knowledge, skills and abilities to manage, lead and empower others to efficiently address group needs and objectives.
5. Manages and resolves conflicts and disagreements in a constructive manner.

When these leadership elements are examined across the other five UAS program competencies (Technical Excellence, Safety and Ethics, Analytical Thinking, Teamwork, Entrepreneurship), the Leadership competency emerges as an important component of each competency. A goal of a UAS degree program is to produce graduates that are at least equal in caliber of the graduates from other traditional aviation programs – graduates who are highly valued as leaders across the aviation and aerospace industry.

Technical Excellence

Technical excellence was the second most selected competency by survey participants and #2 in mean rank. This finding was further supported associated words in the text mining results and interviews with industry representatives. An Unmanned Aerial System is an extremely complex machine comprised of integrated hardware and software that must work together as a system. The UAS student must demonstrate competency in understanding how UAS platforms operate and combine this with a knowledge of accepted industry standards, safety management, regulatory policy, and customer requirements. Furthermore, understanding the significance of the sensor payload on a UAS platform in terms of what it can and cannot do, make Technical Excellence a crucial competency for the UAS graduate. What sets the UAS graduate apart from other aviation programs is that not only must they have a solid aviation knowledge but they must also demonstrate an understanding in one or several areas of what constitutes the Digital Transformation in our current economy; i.e. Edge Based Computing, Cloud Computing, Artificial Intelligence, and Data Science (Siebel, 2019). For the UAS student, strong background knowledge is needed in the geospatial and data realm, as the majority of UAS market growth is related to the sensor payload that gathers some form of data. While a UAS program will not develop an expert in data science, graduates should be familiar with the fundamentals of the emerging technology, which includes not only its capabilities but also its limitations.

Subtitle D in the 2018 FAA Reauthorization Bill called for development of UAS Centers of Excellence, thus establishing the need to produce UAS operators that are trained to operate UAS platforms safely and efficiently (FAA, 2018). Although the UAS industry is new, it is growing at a rapid rate and often demonstrates itself as a disruptive technology. This technological growth often outpaces the evolution of public policies and challenges socio-economic norms. These factors suggest that a UAS program must be structured to not only meet the current needs of the UAS ecosystem, but also remain flexible and agile to adjust for future changes in the UAS industry.

The pyramid-based skill set development put forth by the U.S. Department of Labor Aerospace and Geospatial Competency Models (U.S. DOL, 2018a, U.S. DOL, 2018b) were utilized as a basis for performance rubric development. Other related rubrics for assessing technical performance also correspond to related learning objective development for subject matter excellence (AACU, 2009; Lercel, et. al, 2015; Roffeypark, 2018; State of Washington, 2018). These sources provide cross-validation of common performance themes most salient to the outcome targets for the UAS program. Thus, the outcomes for Technical Excellence follow:

1. Implements and manages UAS technology in accordance with applicable laws, regulations, standards, and accepted means and successfully completes appropriate UAS certifications.
2. Makes sound decisions and solves problems.
3. Demonstrates appropriate business acumen that achieves joint optimization of business benefits and technical excellence.
4. UAS airmanship and airworthiness.
5. Operates and applies technology in a manner that meets certification and industry standards, ensures safety, and meets customer expectations.

Safety and Ethics

Safety/Quality was the most selected competency by survey participants with a #1 mean ranking. Text mining results further supported the importance of safety. A review of the literature along with interview data found that ethical behavior is strongly associated with safety and remains a steadfast requirement among aviation professionals. In the context of a UAS professional, ethical behavior goes beyond the traditional pillars of aviation safety because of the discreet operational capabilities of UAS along with the collection of often sensitive data.

In a sense, ethical behavior and integrity competencies relate most immediately to airworthiness in the most profound way. Airworthiness, operational safety, quality and reliability ultimately come down to choices by the individuals (Patankar et al, 2005; Oderman, 2002). Ethical behavior should be instilled in a UAS operator in the same way it would for an individual working within a manned aviation organization, such as an airline or airframe manufacturer. Society continues to cast a wary eye on UAS, and it remains a disruptive technology often viewed with great trepidation by those in manned aviation and the general public. Being grounded in the concepts of ethics is a competency in the UAS program that should not be glazed over, nor ignored. In a broader sense this competency area is intertwined with several other aviation competencies. UAS graduates must incorporate ethics and integrity into every decision, identifying right from wrong and choosing to follow the right path. If one part of ethics and integrity is doing something the right way even when nobody is around, similarly the aviation professional must be willing to take a professional stand if something is not safe (Patankar et al, 2005; Oderman, 2002).

The authors reviewed associated ethics and integrity performance rubrics from prevailing academic literature (AACU, 2009; Texas A&M, 2018) to identify observable metrics at the individual learner level that best map to the UAS program curriculum. A guiding definition was distilled from this review regarding ethics and integrity as it relates to UAS programmatic and industry expectations: a reasoning about right and wrong human conduct. It requires a student be able to assess their own ethical values and the social context of problems, recognize ethical issues in a variety of settings, think about how different ethical perspectives might be applied to ethical dilemmas and consider the ramifications of alternative actions. The guiding definition of integrity was similarly derived: adherence to moral principles, honesty, truthfulness, uprightness, sincerity and making choices based on your belief of what is right. Thus, the outcomes for Safety and Ethics are as follows:

1. Recognize ethical issues.
2. Personal Responsibility.
3. Demonstrate knowledge and understanding of UAS human factors.
4. Understanding current and proposed UAS regulatory framework and its intent.
5. Knowledge and understanding of Safety and Risk Management principles and the ability to develop appropriate policies and processes that support these principles.

Analytical Thinking

Data analytics/processing acumen was the fourth most selected competency but #3 in mean rank. Similarly, data acquisition, processing, and analysis remained a dominant theme in the text mining results. Analytical competency is tightly coupled to making sense of the data, making effective decisions, and solving problems; therefore, analytical thinking is a crucial skill across the realm of aviation and key to the success of a UAS graduate. Analytical thinking is demonstrated by the ability to effectively communicate in written, graphics-based and verbal forms. The ability to critically analyze and interpret data gathered by UAS sensors also presents itself as a needed skill for the UAS graduate. The need to effectively convey critical and analytical information in such forms is well documented (ICAO, 2016). Below we discuss the two components of analytical thinking important for UAS professionals: (1) Decision Making and Problem Solving and (2) Data Analysis.

Decision Making and Problem Solving

Effective analytical thinking also lends itself to proper decision-making skills. Scholars indicate there are two broad categories of decision-making theory: normative and descriptive (Peterson, 2009). Normative decision-making theory is one that describes how decisions ought to be accomplished. In contrast, descriptive decision-making theory pertains to how the decision was accomplished, in a post-hoc fashion. Theories have led to the development of a range of training and practices to improve the decision-making process. Many of these use the ‘classical decision method’ within the normative category which involves the rational analysis of options in order to make the best choice. In simple terms, this method of decision-making can be described as a step by step process which comes in different variations. One example is identifying the problem, gathering information, identifying alternatives, weighing the evidence, choosing, acting, and reviewing the results (Royal Institute of Technology, 1994). Proactive and effective decision-making can provide a competitive edge to organizations, reduce risks and liability, and improve critical thinking and situational awareness (Concordia, 2017). Variations of step-by-step decision-making processes can be taught, evaluated, and utilized in discipline-specific contexts.

The FAA (2020f) defines Aeronautical Decision Making (ADM) as:

> A systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. It is what a pilot intends to do based on the latest available information (p. 2-2).

The foundation of the assessment for the decision-making competence is Bloom's Taxonomy to include psychomotor, cognitive, affective, and interpersonal levels (Bloom, 1956; Callister, 2017). Ideally, Bloom's taxonomy may be used to describe instructional objectives and conduct objectives-based assessments on the UAS students' achievement for aligning curriculum and assessment. Bloom's taxonomy and the decision-making literature suggest the following sub-level competencies for a UAS program:

- Applies appropriate decision-making processes.
- Demonstrates the ability to address complex issues.

Graduates of a UAS ideally will demonstrate proficiency in analytical thinking and decision-making which will allow them to understand and solve complex problems, including those related to aviation safety, advanced technology, and a wide range of technical matters, as well as abstract concepts.

Data Analysis

Critical, logical, and analytical thought are necessary data science for the UAS graduate. Data, especially geospatial data, is in almost every part of UAS operations ranging from mission planning, execution, and post-flight record keeping. The UAS graduate must also be able to logically and effectively gather, process, and analyze data gathered by UAS sensors. The UAS graduate is a significant participant in the information age economy, and therefore must be able to demonstrate all the needed skills associated with Data Science (Rasheva-Yordanova and Nikolova, 2018).

By definition, a student versed in analytical thinking within Data Science must be able to identify and define problems, extract key information, develop workable solutions, and test and verify workable solutions to problems. The Analytical Thinking learning outcomes selected were distilled into four categories:

1. Demonstrates the ability to access, interpret, and appropriately apply technology, data and technical information.
2. Demonstrates the knowledge, skills, and abilities to focus and think clearly while under pressure.
3. Uses an action-oriented and objective approach to problem solving.
4. Demonstrates knowledge, skills, and abilities that are required across the entire UAS workflow, which includes data collection, data analyses, and interpreting data.

Teamwork

When preparing the next generation of aviation professionals, it is important to consider that teamwork provides a redundant system that could have a positive impact on individual and team performance as well as aviation safety and efficiency, critical factors to the aviation industry. This research suggests UAS professionals should have the competence to work as members of a team to effectively convert team inputs into targeted outcomes. Effective teamwork requires one to possess key disciplinary skills, among them are the ability to effectively communicate, and participate in key decision making and problem-solving activities.

Teamwork is a competence that should be taught and practiced (Brannick, Prince, & Salas, 2005). To be successful in today's professional flight environment, students need to develop knowledge, skills, and abilities to work interdependently, adaptively, cooperatively, and dynamically toward shared and valued goals. In addition, they should develop the knowledge, skills, and abilities to guide, coordinate, and facilitate teamwork activities across cultural boundaries and as the team leader. With regards to Teamwork, suggested student learning outcomes for graduates of a UAS Program are as follows:

1. Facilitates the Contributions of Team Members, Responds to Conflict (Conflict management).
2. Individual Contributions Inside and Outside of Team Meetings (Task development and completion).
3. Develop skills to immerse with others from different cultures.
4. Understand and apply crew resource management (CRM) concepts to UAS operations.

Entrepreneurship

This research found the UAS ecosystem is comprised of mainly small start-up companies, which includes anything from software, to sensors, to airframes; or larger companies looking to integrate UAS technologies into their existing business operations – seeking the potential value that UAS may add to their work product. A little over 57% of survey respondents work in organizations with 10 or fewer employees and 49% have been in business less than six years. Group discussions and interviews confirmed that a majority of UAS companies describe themselves as a "start-up," engaged in some aspect of "technology or market development," and have "evolved or pivoted" business strategies multiple times. This innovative and evolving environment requires graduates who have an entrepreneurial skill set with the ability to "think outside the box" and develop innovative solutions, stay motived and resilient. Multiple authors have stated that the entrepreneur is central to the success of small and medium sized business (Man et al., 2002; Man, Lau, & Snape, 2008). These claims offer a positive perspective for supporting (aspiring) entrepreneurs as most authors agree that competencies are not fixed traits but can be developed and learned through experience and training (Wagener, Gorgievski, & Rijsdijk, 2010).

Successful entrepreneurs possess an orientation towards learning, searching for new knowledge and developing skills that help improve themselves. It refers to participating in training and development activities, seeking and following up on new opportunities, knowing where to find relevant information and being interested in new methods and techniques that are relevant for their profession (Lans, Hulsink, Baert, & Mulder, 2008).

Economic forecasts estimate that over the next decade the UAS market will total $88.3 billion. UAS technologies and markets will continue to evolve at an ever-increasing pace (Goldman, 2017; Teal, 2019). Venture capitalists and companies like Intel, Qualcomm, Microsoft, and Apple invested over $455 million into drone startups in 2018. U.S. start-ups received 67% of this total, enabling them to take the lead in drone analytics (Teal, 2019).

These optimistic market forecasts along the findings from this research suggest that graduates with an entrepreneurial skill set may be best prepared for long term success; therefore, the authors propose the following Entrepreneurship learning outcomes:

1. Adaptability/Innovation: demonstrate an ability to engage in critical thinking by analyzing situations and constructing and selecting viable solutions to solve problems.
2. Self-efficacy: identify and assess individual and group strengths and weaknesses and believe in one's ability to influence the course of events, despite uncertainty, setbacks and temporary failures.
3. Learning through experience and coping with ambiguity and risk.
4. Creativity and Vision: develop ideas and opportunities that may create value, solutions, or improvements and develop a vision that turns these ideas into action.
5. Initiative and Action: initiate processes that create value or address challenges. Act and work independently to achieve goals, stick to intentions and carry out planned tasks.

Conclusions

A review of the literature found little data regarding the specific competencies employers seek in UAS professionals. This research found a preponderance of the UAS literature focuses on the knowledge that may be required of a remote pilot to operate a UAS legally and safely, namely basing training and curriculum toward the ultimate goal of the student pilot earning their FAA Part 107 remote pilot certificate. A preliminary review of UAS student internships and post-graduation plans demonstrate active growth in the UAS industry.

Although this research attempted to include many stakeholders in the UAS industry, the 220 research participants in this study are but a small percentage of an industry that continues to evolve at a break neck pace with thousands of participants in myriad roles. The UAS Competency Learning Model presented here provides a solid background on which to create a UAS program capable of developing a high level of practitioner skills. Despite this foundation of competencies to build upon, it should be noted that technology and regulations continue to develop and it is anticipated that future competencies of UAS graduates will continue to morph; therefore, it is vital that research continues in this area. UAS programs, curriculum, and training models built around these competencies should be designed to be adaptable in changes within the industry as technology and regulations continue to evolve.

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