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Implementing Artificial Intelligence and Machine Learning into Advanced Qualification Programs

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Introduction

The current Advanced Qualification Program (AQP) was introduced in 1991 through a Federal Aviation Administration (FAA) Advisory Circular (AC) 120-54. AQP was the culmination of several recommendations from the FAA administrator and the National Transportation Safety Board (NTSB) (Federal Aviation Administration [FAA], 2017). Both were focused on making airline training safer by encouraging the development of innovative training, ensuring the tracking of training, approving new training practices, and focusing on Crew Resource Management (CRM) and situational based training. AQP was developed as a way to include new advancements in technologies and training methods to produce the safest most effective training possible (FAA, 2017). Artificial intelligence (AI) and machine learning are technologies that can analyze large data sets and make decisions (Buzko et al., 2016). While AI can be programmed to understand and analyze vast data sources, machine learning can develop on its own to make decisions and suggestions (Allen, 2020). In this way, implementing AI and machine learning strategies into AQP could be the next innovation for training.

Statement of the Problem

Since its development in 1991, many airlines have implemented AQP training programs. New technologies, like AI and machine learning, could be infused into this process to replace some of the manual data analysis and help to make decisions in the curriculum development process. It is important to understand if these technologies fit the tenants of AQP by making training safer and more effective. Similarly, it should be explored if there is a need for this advancement and what the cost is of implementing these technologies.

Research Questions

The research questions in this study focus on what technologies can be used to enhance airline AQP and what this process would look like.

1. How can AI and machine learning be used in curriculum building and decision making?
2. How can AI and machine learning be used in the analysis of AQP data?
3. What benefits are there for using advanced technologies in the AQP process?

Literature Review

Overview of AQP

AQP was introduced as a voluntary replacement to the more traditional method of training found in CFR 14, Part 121 and Part 135. It was designed to increase safety through improved training and to allow for changes due to advancements in training technologies and methodologies (FAA, 2017). Unlike the traditional training methods, AQP allows the airline to tailor their training to their specific operation by focusing the training on their operational priorities and targeting areas where their pilots are weaker. This allows a short haul domestic carrier to focus their training on that operation while a long-haul international carrier would be able to train their unique operations (Esser, 2006). Similarly, each airline's AQP is also tailored to each aircraft type. This allows training to be tailored to the pilot's actual operation (Longridge, 1997).

An AQP is developed by first outlining all the requirements of a specific duty position. For the pilots, this includes all job function inside and outside the aircraft in normal and non-normal situations, including emergencies. The skills, knowledge, and abilities (SKAs) that are required to perform each of these functions are then assessed. The curriculum is then built and designed to incorporate the identified SKAs into specific tasks. As pilots complete their training, data is collected on their performance. This information is then used to refine and validate the curriculum, to justify changes and frequency of training, and to show the FAA that the curriculum promotes safety (Longridge, 1997).

Artificial Intelligence and Machine Learning

Artificial intelligence (AI) is simply defined as the ability for machines to show intelligence (Allen, 2020). These machines are programmed to make decisions, perform tasks, and process information on their own. Machine learning is a subset of AI in which the machine can learn from the data that is input, and form predictions and make decisions without being programmed to do so. In effect, artificial intelligence requires humans to program the machine to make specific decisions. Whereas in machine learning, the machines are programed how to learn and then will make the decisions on their own (Allen, 2020).

As AI and machine learning have started to be used and researched, there have been many applications, some involving improvements in training methods and for analyzing large data sets. AI has been shown to be beneficial in analyzing large spacecraft performance data sets. In this application, AI has been able to model performance and perform root cause analysis (Tipaldi, Feruglio, Denis, & D'Angelo, 2020). AI can also be used as a tool to analyze large data sets without someone that has specialized skills in data analysis (Buzko et al., 2016). This might allow airlines to reduce staffing in this area, reducing the cost of the training program. These concepts are very similar to those used when analyzing the crew performance and flight data through AQP.

Methodology

An integrative review approach will be used for this research. An integrative review is used to combine perspectives from various literature sources and develop new ideas and theoretical models (Snyder, 2019). Implementing AI and machine learning into AQP is a very specific and new concept, with little to no literature. As such, an integrative review methodology will allow a detailed review of current AQP practices along with the use of AI and machine learning in other fields. From this, new concepts and perspectives on the use of AI and machine learning in AQP can emerge.

AQP Process

The AQP was created to allow airlines to use the most innovative training devices and techniques in their training programs. AQP in effect replaces the strict guide of required training and enables the airline to determine the most important aspects that need to be trained. The real goal of AQP is to allow airlines to respond to changes in training technologies and equipment. In the previous training method, airlines were restricted to a set curriculum of tasks that had to be accomplished, and they were required to be done on certain devices. With AQP airlines have flexibility to train specific operational priorities and can use the newest training devices (FAA, 2017).

According to AC 120-54A, an airline that chooses to train under AQP must meet certain criteria and have specific functions within their program. While the airline does not have to follow the previous set curriculum, under AQP the FAA monitors both the process and the product that is developed for training. Two of the main sections of an AQP are the Program Audit Database (PADB) and Performance/Proficiency Database (PPDB). The PADB contains an explanation of how syllabi were developed, the plan for implementing and operating training,

training objectives, and proficiency standards. The PPDB contains all the collected and recorded data from the training events. Both require a significant amount of analysis and review (FAA, 2017).

First, the PADB focuses on the curriculum building aspects of an AQP. Instructional Systems Development (ISD) is used to generate the preliminary training tasks and requirements. This process starts with developing a job task listing, followed by identifying the requirements for each individual seat, pilot and copilot. For each of these tasks, any skill and knowledge requirements are also recorded. From this list, items that require training or should be tested are selected and proficiency objectives are developed to capture these requirements. From here, qualification standards are created, and acceptable performance levels are defined.

The next process is developing tests for the above defined proficiency objectives, knowledge, and skills. Once these are created, they are taught to pilot evaluators. There should be a traceable link between task requirements, training requirements, training and evaluation activities, and evaluation results. This allows for audits of the training program to be conducted and constantly evaluated. As pilots progress through the training tasks, performance data (typically in the form of a 1-5 scale) is collected on each defined proficiency objective, knowledge, and skill tested. The data collected through this process then creates the PPDB. This data is also continuously analyzed, evaluated, and then used to revise the training program (FAA, 2017).

Training tasks are assigned values for criticality, currency, need for training, applicable conditions, and applicable standards. These factors determine the frequency of which each task, proficiency objective, or skill is to be trained, validated, and evaluated. A “train” task is one in which pilots can repeat the event as necessary to learn the skill or knowledge. A “validation” task allows for a specified number of repeated attempts. An "evaluation" task allows for no training and if performance is not acceptable, retraining and reevaluation will occur. Each task, proficiency objective, and skill are then tabulated to show how frequently it must be performed, at what level of evaluation, and in what type of training device. This list forms the basis of the training curriculum. Pilot performance, collected in the PPDB, can then be used to alter the frequency of these tasks (FAA, 2017). If performance is weak, training frequency might increase. If performance is stronger than expected, the frequency of which the task is trained might decrease.

Based on this AQP process there are several areas that AI and machine learning could be utilized. One such area is the curriculum development stages of AQP. Similar to the training aspects, AI and machine learning could be implemented in this stage to make the process more efficient by helping to make decisions and predicting areas of concern (Casey, 2019). AQP is an education process, the goal is to teach and train (FAA, 2017). With this in mind, AI and machine learning could be valuable in making the training more effective for the pilots and provide new technological resources to educate (Luckin, Holmes, Griffiths, & Forcier, 2016). Additionally, AQP entails a significant data analysis process, reviewing all collected training data (FAA, 2017). It is possible that this process could be done through the use of AI or machine learning to limit the time and personnel used for this analysis. This could also allow a more direct link between the outcome of the data analysis process and the curriculum development, one of the tenets of the AQP process (Kaput, 2019).

AI and Machine Learning in Training

The use of AI and machine learning in teaching is still a relatively new concept. Various studies discuss the advantages and disadvantages of using these technologies. However, few of the studies look at scenarios where AI and machine learning are already being used in practice. A study by Luckin and Cukurova (2019) points out that implementing AI into education and training falls behind using AI in other fields. This confirms the idea that this technology is not widely implemented in training and education yet. However, there are some areas where AI is used to collect large data sets that can be used in training and education. These include eye tracking, facial expressions, and movement. The study by Luckin and Cukurova (2019) also considers the various way more data can be collected through the use of AI and how these large data set can be used in training. Some of the discussed options for using AI in training include looking at nonverbal interactions between learners and instructors, creating personalized learning, and reduced workload for instructors.

Luckin et al. (2016) echo these thoughts and the suggestions of how AI can and is used in training and education. Luckin et al. (2016) consider how AI is being used to track student behavior. By looking at class attendance, submission of assignments, and grades, AI can detect if a student is falling behind. While training programs in airlines are not measured to these same standards, as attendance and assignments are not optional, similar progress markers could be used to detect students that are falling behind. Similarly, Luckin et al. (2016) make the case that by using eye-tracking, gesture recognition, and facial expressions, AI can detect a student’s engagement in the classes and their studies. While this is not currently being implemented in classrooms, research is beginning to show positive results that AI may be useful in measuring engagement (Sharma et al., 2020; Molina, Navarro, Ortega, & Lacruz, 2018; Kok & Jarodzka, 2017; Thomas & Jayagopi, 2017).

Several studies and articles argue that while new technologies like AI and machine learning are beneficial in classroom settings, there is no replacement for the interactions between students and teachers (Guilherme, 2019; Selwyn, 2019; Henry, 2014). Laura and Chapman (2008) show that there is an importance in using new technologies in education as it allows learning to be more effective. However, they also note that the virtual relationship of a student and teacher moderated through technology is not the same as the one cultivated in a classroom.

AI and Machine Learning in Curriculum Development

While there is very little information on how AI or machine learning could be used in the curriculum development process, there are several tenets of this process that can be explored. First, an understanding of the ISD process used in AQP is paramount to understanding if or how AI and machine learning could be included in this process.

AC 120-54A lays out the basics of the ISD process the FAA requires for AQP but clarifies that the airline can use any process that meets those requirements. These requirements are aforementioned. In the most basic form, this process involves developing a job task listing, determining the required skills and knowledge, teaching to these, and evaluating performance against these required skills and knowledge (FAA, 2017). The ISD process is not new to aviation. The U.S. Air Force has been using this process in flight training since the 1970s (Miller & Swink, 1978).

The U.S. Air Force uses a five-step process similar to the one outlined in AC 120-54A. They start with an analysis phase, then move to design, development, and implement phases, finishing with evaluation (Department of the Air Force, 2002). This cyclical process can be seen in Figure 1. It is this same cycle that is used in AQP, the evaluation of the students feeds the analysis of items that need to be trained (FAA, 2017).

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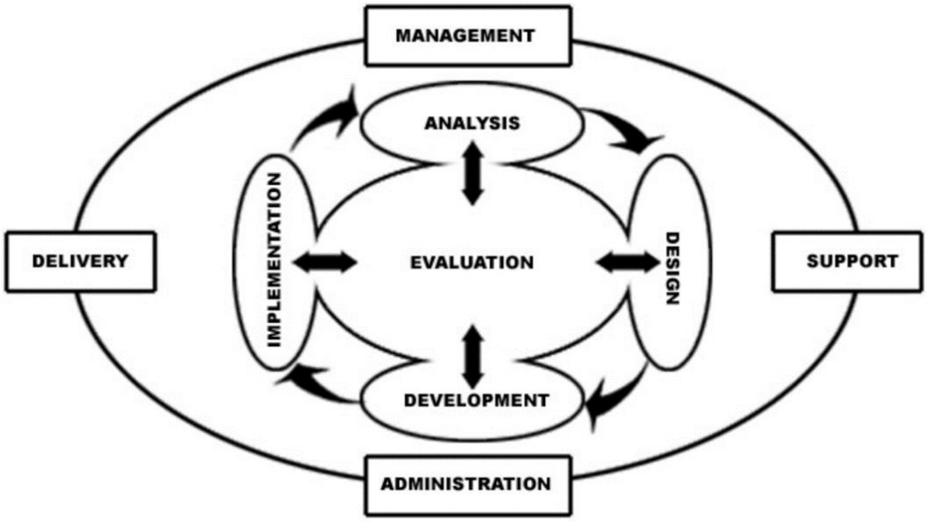

Figure 1. U.S. Air Force ISD process.

Note. From Information For Designers Of Instructional Systems Application To Technical Training, 2002 (https://static.e-publishing.af.mil/production/1/af_a1/publication/afh36-2235v9/afh36-2235v9.pdf). In the public domain.

Other ISD processes suggest similar strategies of cyclical patterns of analyzing job tasks, developing instruction, evaluating and re-analyzing (Hodell, 2007; Uzunboylu & Kosucu, 2020). AI and machine learning could fit into this process through the analysis of the results and in the decision-making process of what training needs to be modified.

Several studies show how AI can be used in data-driven decision-making (Buzko et al., 2016; Colson, 2019; Jarrahi, 2018). This would be a similar process to that of the decisions being made in curriculum development. In the ISD process, the evaluation of performance informs the decision maker of what might need to be changed in the curriculum (Department of the Air Force, 2002). The benefits of AI making these decisions is that it provides an objective look without any influence of cognitive biases. AI-driven decisions are made using all available data, whereas humans will tend to focus on specific items when making decisions. While also reducing costs by removing personnel, AI decision making is more complete and faster (Colson, 2019).

AI and Machine Learning in Data Analysis

It is well researched how AI and machine learning can be used in data analysis. Machine learning allows for exploratory research, learning algorithms, and the ability to generalize the computational complexity of learning (Wu, 2004). In essence, AI and machine learning are extremely adept at taking very large data sources and analyzing them effectively (Casey, 2019; Kaput, 2019).

Within the data analysis process, AI and machine learning remove some of the human interaction and allow for new methods of analyzing the data. New statistical methods for analysis and prediction allow for more detailed and complete analysis. While some of the process can be replaced with machines, reducing personnel requirements, humans are still critical in helping the machines learn and interpret results (Casey, 2019).

AI and machine learning can also be used to predict outcomes. These technologies can be used to take vast data sources and analyze and predict what methods work and which do not (Kaput, 2019). Machine learning is also constantly evolving, creating the ability for it to continuously reevaluate decisions and offer new solutions. As the machine learning programs get new data, they develop deeper understanding and make more complex decisions (AI gears up for data analysis: Making the most of machine learning, 2019).

AI and Machine Learning Concerns

Through AI and machine learning research, there is a common thread of concern with using these technologies: ethics and security. There are various examples of these concerns within research. Furey and Martin (2018) discuss the critical importance of ethics in education and the focus of AI and machine learning on them. Furey and Martin (2018) argue that some of these technologies are racially biased. As these machines are only focused on the data fed to them, they are unable to distinguish which data points contain protected characteristics and might make decisions based on these (Furey & Martin, 2018).

Similarly, Ryan et al. (2019) looks at smart information systems (SIS) including AI and Big Data. They focus on how SIS can be used to address the United Nations (UN) Sustainable Development Goals (SDG). While they note that SIS can be a benefit to some SDGs, they also note that SIS can cause ethical concerns such as algorithmic bias, job loss, power asymmetries, privacy infringements, and surveillance. The authors also note that if not used reasonably and responsibly, SIS can do more harm than good. Ryan et al. (2019) also look at the security concerns of using AI and machine learning. Having centralized data sources that are able to pull demographic information and detailed personal data are primed for data hackers (Ryan et al., 2019).

While the process of AI and machine learning seem to fit well, it is important to note the potential security concerns with using these large data sources. As Ryan et al. (2019) discuss the use of SIS, including AI and machine learning, can leave a vulnerability in cybersecurity. This is especially important in airline training departments using AQP where large amounts of FAA confidential information and information regarding pilot performance records are stored (FAA, 2017). In this situation, having a cybersecurity threat could be a very large concern.

Results and Discussion

Considering that AQP is centrally focused on using new and innovative technologies, it is primed for the implementation of technologies like AI and machine learning (FAA, 2017). Additionally, some of the terminology that is used within AC 120-54A is congruent with language used in AI and machine learning. Some of these terms include systemic analysis, progressive evaluation, and data-driven quality assurance. All of these indicate a continual and evolving data analysis process (Allen, 2020; FAA, 2017). These items are used not only in the analysis of the resulting training data, but also in the Task Analysis, Qualification Standards (TAQS) and curriculum development (FAA, 2017).

As AQPs are "systematically developed, continuously maintained, and empirically validated, proficiency-based training systems" (FAA, 2017, p. 2), AI and machine learning are well paired to this process. Research indicates that AI and machine learning are very good at taking large data sources and using them to draw conclusions and make decisions based on these (Casey, 2019; Kok & Jarodzka, 2017). Specifically, the PPDB, which is a vast source of training data, including pilot proficiency and performance, could be analyzed using AI and machine learning technologies. This would allow for more complete analysis of the data with the added benefit of reduced bias and prejudices (Colson, 2019).

AI could also simplify continual calculations of training task frequencies. As AI and machine learning allow for quick calculations of data and deeper analysis for predictive results, these technologies could provide a detailed list of training items that are required to be retrained based on their criticality and performance (Wu, 2004). These technologies could also use complete overviews of prior training data to predict where training might be lacking or needs improvement (Kaput, 2019). This would allow for changes to training before performance drops significantly or an incident occurs.

AI and machine learning are still new concepts within training and education, which form the basis of AQP. As such, the technologies and AQP could evolve together. The current uses of eye-tracking and gesture and movement tracking could create vast data sources that could be fed into the AQP system (Luckin & Cukurova, 2019). Having this information would allow for the study of student and pilot engagement and also consider the effectiveness of the instructor at drawing attention to critical points (Luckin et al., 2016).

There is also the ethical concern of using these technologies. While Colson (2019) points out that technologies, like AI and machine learning, can remove the cognitive biases that humans might have when analyzing an interpreting data, Ryan et al. (2019) suggests that they might develop their own biases and prejudices. Ryan et al. (2019) also discusses how to ethically design an employee monitoring system, which is the basis of an AQP system looking at performance training data (FAA, 2017). Similarly, Ryan et al. (2019) also notes that SIS can compartmentalize and reduce complexity of a system which could result in harmful or bias recommendations or policies. This would also be a concern of a complex training program such as AQP.

Conclusions and Recommendations

Overall, AI and machine learning seem to be well suited to the tenets of innovation and improvements of AQP. These technologies offer improvements in data analysis and decision making, which are the foundation of AQP (FAA, 2017). By allowing the data analysis process to be more encompassing and taking in new data sources, like eye and movement tracking, deeper understanding of engagement and performance can be determined. This would allow for a more complete understanding of performance with respect to the proficiency objectives and qualification standards outlined through the ISD process. Similarly, allowing technologies like AI and machine learning to perform some of this analysis would allow for links to be created between task and training requirements, training and evaluation activities, and evaluation results, which is another key aspect of the ISD process (FAA, 2017).

However, as the AI and machine learning technologies are still new and not fully explored in the training and curriculum fields, it may be prudent to investigate these applications more fully before choosing to implement them. Additionally, there are still significant concerns of the ethics of using AI and machine learning in areas where personal and demographic data is also used. The storing of this data in a centralized area also presents cybersecurity threats, where large amounts of personal data is stored in one common area. More research would have to be done in this area before the FAA and airlines felt comfortable taking these risks.

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