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An Integrated Curriculum Design for Teaching Flying Qualities Flight Testing

Dr. M. Christopher Cotting, United States Air Force Test Pilot School

Dr. Chris Cotting is the Master Instructor of Flying Qualities at the United States Air Force Test Pilot School. During his professional career he has also worked for the NASA Dryden Flight Research Center and the Lockheed Martin Skunkworks. He has worked on numerous experimental aircraft projects including the X-43A and X-43C, X-35, and X-33. He has a BS and MS in Aerospace Engineering from Mississippi State University, and a PhD in Aerospace Engineering from Virginia Tech. He is an Associate Fellow of the AIAA where he serves on the Atmospheric Flight Mechanics Technical Committee as the Chair of the Flying Qualities Subcommittee.

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Abstract

An integrated design strategy for developing a new curriculum for the education of flight test professionals is presented. Tradeoffs between different methodologies are discussed and reasons are given for the choices made for this particular curriculum. Learning objectives development, issues associated with training versus education, student engagement, and creation of the desired learning environment are all discussed. Examples of current implementation issues are given.

Introduction

The United State Air Force (USAF) Test Pilot School (TPS) has undergone a transition of the methods used to educate future experimental test pilots and flight test engineers. Specifically the flying qualities phase of the school, which teaches typical aerospace engineering topics, has undergone a significant redesign to facilitate modern education on a graduate level. Originally designed to be a curriculum based on memorization of mnemonics followed by flight training skills, the new curriculum teaches basic as well as advanced aerospace engineering topics coupled with a focus on metacognitive skills. While the old curriculum was designed to be a series of short courses that maximized efficiency in curriculum execution, the new curriculum is designed to be tightly integrated to increase student learning at the sacrifice of execution efficiency.

The mission of USAF TPS is to "Produce highly-adaptive, critical-thinking flight test professionals and future senior leaders to lead and conduct full-spectrum test and evaluation of aerospace weapon systems." To fulfill this mission USAF TPS graduates must to be able to do much more than consult a catalogue of tests and then prescribe a series of tests to a new test program. Instead, graduates must be able to reference previous test programs as well as their own knowledge of aerospace engineering to create new test programs that will properly evaluate modern aerospace vehicles.

While a typical Master's level graduate degree often takes 18 months to 2 years to complete, the graduate program at USAF TPS is accomplished in just 11 months. This compressed schedule requires a very rigorous and disciplined approach to creating the new curriculum. Due to the nature of the school requiring both educational as well as training outcomes, and the need to maximize efficiency of learning, the new curriculum was designed with learning objectives that aimed to create an environment that mixes learner centered, knowledge centered, and assessment centered environments. These objectives were written with a focus on learning levels that are mapped to Bloom's Taxonomy so that students and staff can read the objectives and then be prepared for any assessment exercise. Implementation of these learning objectives primarily focused on problem based learning with a mixture of cooperative, role-based learning, and individual learning. Learning objectives are tracked down to each hour of student contact time to ensure the proper content is delivered as well as to ensure student time is being efficiently used.

This paper traces the development of the new flying qualities phase curriculum and the design decisions that were made during that process. A discussion on whether to design the curriculum as an integrated program versus a series of independent short courses is followed by the competing requirements for both training and education in the curriculum. Next the process used to create new learning objectives is discussed followed by a discussion on the proper level of student engagement. The learning environment at USAF TPS is unique, and a discussion of how to incorporate learner centered, knowledge centered, and assessment centered learning environments with a sense of community is addressed. The pedagogies used for the new curriculum are then explained followed by the execution challenges that USAF TPS faces. Finally initial results from student performance found from the new curriculum are provided, giving an example showing that students are performing at a higher level of learning with the new curriculum than with the old curriculum. Finally future work for the curriculum is presented.

Integrated versus Federated Curriculum

The old flying qualities phase curriculum was a collection of federated short courses that could be shuffled and presented in a way that matched aircraft and instructor availability. The sacrifice to this system is a synergistic effect that occurs when material is integrated tightly such that topics are reinforced, keeping threads of learning intact throughout a curriculum. The learning that occurred when the curriculum was federated was often described as a "mile wide and an inch deep." Students gained superficial procedural knowledge without understanding the "why's" behind that knowledge. According to *How People Learn* "Superficial coverage of all topics in a subject area must be replaced with in-depth coverage of fewer topics that allows key concepts in that discipline to be understood."[1] At USAF TPS we now refer to his concept as "targeted depth." The new integrated curriculum was designed with the idea that approximately 10 core mathematical concepts keep reoccurring throughout the flying qualities phase curriculum. Those concepts are introduced at the beginning of the curriculum with minimal context. These concepts keep reoccurring throughout the curriculum where their application is called out to a specific application. This allows the student's conceptual knowledge to be reinforced with multiple applications. Further conceptual knowledge has a greater influence on procedural knowledge than the reverse[2,3]. By first introducing the conceptual knowledge to the students and then keeping it as a thread of learning throughout the curriculum, it can be reinforced by procedural knowledge (practical examples) that the students can use for direct application of their knowledge.

An example of this conceptual to procedural knowledge transfer can be found in the use of Euler's rotation theorem, and specifically rotation matrices. In order to simplify the procedural knowledge transfer the federated curriculum avoided at all costs the mention of a rotation matrix. Students were required to memorize procedural knowledge without the ability comprehend its interrelation and impact. Under the integrated curriculum Euler's rotation theorem and rotation matrices are now introduced at the beginning of the curriculum and then reinforced every time they are applied procedurally. Examples of procedural application of rotation matrices used in our curriculum include: coordinate system derivation, equations of motion choices for body versus inertial reference frames, inertia tensors, kinematic coupling for aircraft departure from controlled flight, finding principle stress and strain in an arbitrary body, aeroservoelastic interactions, parameter estimation, and aircraft engine-out performance. Students now have the opportunity to learn how all these applications are interrelated to a fundamental mathematical concept. Ultimately students are given the chance to connect all these practical examples together as logical applications of the same concept, instead of remembering discrete pieces of knowledge for a test, and then forgetting what appears to be individual concepts that have no logical connection.

The federated curriculum lent itself to a training mentality as opposed to an education mentality. Staff and students would teach to ensure students could pass an evaluation and then move on to the next event. Students would often refer to "flushing" material out of short term memory after an evaluation in order to make room for the next material for the next evaluation. With the integrated curriculum students are required to keep building on their knowledge, reinforcing the basic concepts through application, deepening their understanding with each procedural knowledge application.

Training versus Education

The skill set required to become a flight testing professional (pilot or engineer) requires both what would be considered vocational training and advanced education. There are some basic skill sets required of a pilot, such as being able to properly execute specific maneuvers, or demonstrate a high level of proficiency in a given type of aircraft in order to be an effective flight test professional. Flight Test Engineers must also have the ability to communicate on mission radios, conduct tests efficiently, and be able to function as aircrew when present on aircraft. While these skill sets are essential to being a flight test professional, there are other skill sets that are just as essential that can not be accomplished through training nor demonstrated through basic proficiency exams.

In order to "Produce highly-adaptive, critical-thinking flight test professionals" student's skill sets must be expanded into a higher level of Bloom's Taxonomy[4] than those found with a traditional training program. To meet this objective students must be able to understand the intention behind a set of requirements, synthesize a set of tests to evaluate an aircraft against those requirements, and then think critically about their own knowledge and the test plan they created. This critical thinking then requires the students to have basic metacognitive skills to asses their own abilities, and the validity of the tests they create. These skill sets can be taught to students through deeper learning and education of fundamental concepts in the aerospace engineering discipline as well as the testing discipline.

One analogy used at USAF TPS is the mentality of a short order cook versus that of a trained chef. The cook is only capable of following prescribed recipes, and is unable to venture beyond the bounds of his training. The chef, however, is capable of creating and synthesizing new dishes based on his knowledge of the ingredients. We aim to give our students the knowledge of the "ingredients" of flight test so that students are not confined to how previous flight tests were conducted. If the school was just interested in creating test professionals that could execute prescribed tests, then the USAF TPS could be nothing more than a vocational program that equips them to be "cooks." Instead the mission of the school requires our graduates to be able to create new testing procedures based on the needs of a given program. This synthesis requires our graduates to be "chefs" understanding the ingredients of a test, and then altering them to provide the desired outcome. This much deeper level of understanding requires a conceptual understanding on the basic test concepts covered in the school.

Building the Learning Objectives

Prior to the revision of the flying qualities phase at USAF TPS learning objectives were present, but were untouched for at least 10 years. Curriculum had diverged from the last documented set of learning objectives, and the learning objectives were focused on what the instructor should teach, instead of what the student should be able to demonstrate. Further, some learning objectives hindered learning, such as one found in the original Aircraft Equations of Motion class, which stated "Live through the next hour's untestable derivation." Also learning objectives were broken into two categories, "starred objectives" and "un-starred objectives." The starred objectives were considered important, and the only ones on which the student could be evaluated, which begged the question, why did the un-starred objectives exist?

Learning objectives for the entire flying qualities phase were rewritten so as to be measurable, focused on student learning as opposed to instructor teaching requirements, and reclassified into a single category, where students were responsible for every objective. Students are now informed that anything that is in a learning objective is fair game for the correlating evaluation/exam. Learning objectives were created with a resolution down to each student contact hour. These objectives are traceable back to higher level objectives for each course, so that students can see the "big picture" for each course as well. A Microsoft Access database was created to track all the learning objectives, and is used to provide students a list of learning objectives for each event they attend.

The new learning objectives were created using a methodology found in the Federal Aviation Administration's *Aviation Instructor's Handbook*[5]. Learning levels are described at four different levels found in Figure 1. These levels were used instead of the typical Bloom's Taxonomy levels because most instructors at our institution are familiar with the FAA's learning levels and not Bloom's Taxonomy's levels. While adding another layer of abstraction to the curriculum design, it did allow our staff to communicate internally on a more efficient level. To map the FAA learning levels to Bloom's Taxonomy the flying qualities phase created learning objective verbs found in Table 1.

The new learning objectives are designed to reflect increased student learning as students progress throughout the flying qualities phase . As new topics and concepts are introduced in academics

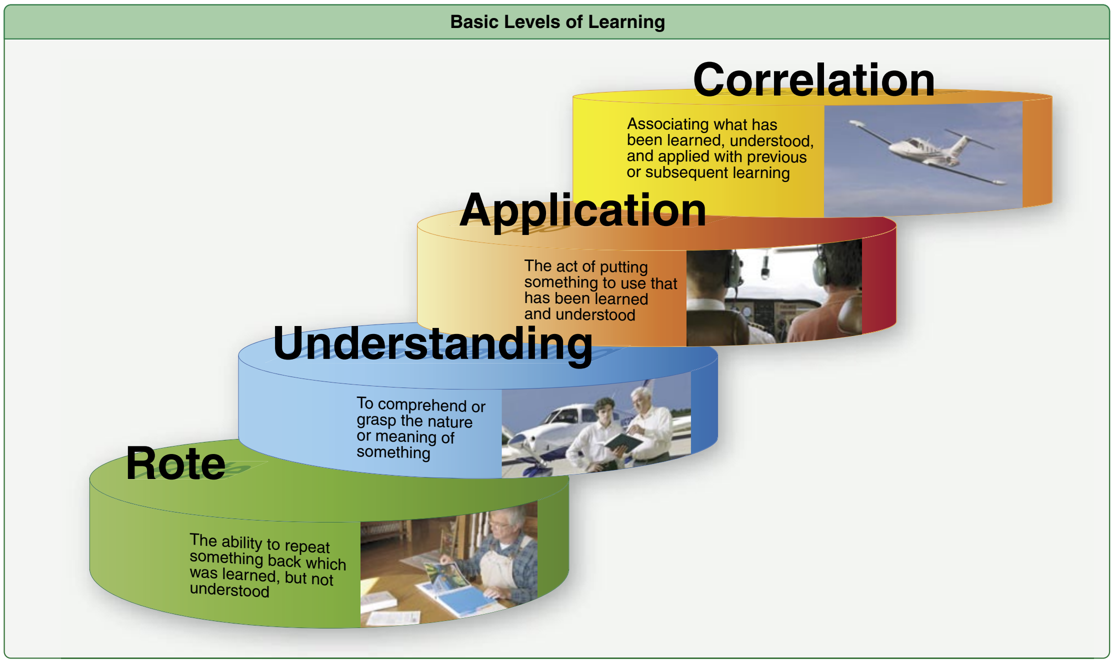

Figure 1: Levels of Learning listed in FAA *Aviation Instructor's Guide*[5].

Table 1: Learning Objectives Correlation Table

Level of Learning	**Example Event Learning Objective Verbs**
Rote	Identify, State, List, Label, Define, Launch (a program), Load, Locate
Understanding	Describe, Determine, Convert, Linearize, Demonstrate, Sketch, Draw, Generate (with MATLAB/Simulink), Excite (in the airplane), Collect (data), Execute (a maneuver)
Application	Plot, Calculate, Solve, Predict, Explain, Modify, Analyze, Estimate, Compare, Reduce (data), Provide (feedback), Present
Correlation	Model, Design, Evaluate (a system), Interpret, Translate

students are expected to have a rote level of learning. Depending on the level of emphasis in academics and the amount of homework or group study assigned a student may be expected to progress to an understanding level of learning by the time academics are finished. As students begin to use the material, specifically in a simulated or demonstration flight environment an understanding level of learning is expected. As students progress to performing project work, or collecting flight test data in a student only event an application level of learning is expected. For both practical and written final exams a correlation level of learning is expected.

Finding the proper level of student engagement

Most students at USAF TPS are atypical for a university environment. Entrance to the school is highly selective, and as such most students already possess at least one post graduate degree, have advanced study skills, are extremely competitive and motivated, are usually in their late 20's or early 30's, and all have shown significant military career progression potential. Student pilots are considered experts in their particular aircraft type, may be type rated in multiple aircraft, and have often been instructor pilots before attending USAF TPS . The flight test engineer students often are less experienced, but they also have more technical depth than their pilot counterparts, with some engineers already possessing a PhD in their discipline before attending USAF TPS . Open since 1944, USAF TPS has approximately 3000 graduates of which over 110 have become general officers, 62 have become NASA Astronauts, and many go on to be influential leaders in the aerospace industry to include vice presidents, directors of engineering, and presidents in both government and private industry. Approximately half of the students have a technical background in aerospace engineering, which proposes a challenge in educating the entire class to the same level of technical ability. To illustrate this challenge the USAF TPS has in the past admitted flight test engineers with technical backgrounds in biochemistry, operations research, and solid state physics.

Traditionally most engineering students fall into the Myers-Briggs category of sensors[6]. This is especially true for USAF TPS students, since they have spent a considerable amount of their time before coming to USAF TPS in an operational military environment. They have been trained to learn information quickly that is useful to their current task, and to filter out everything else. This student mindset requires a very specific type of instructor that has significant practical experience as well as a firm theoretical underpinning of the subject matter. An instructor that knows the theory behind the subject but cannot provide real-world examples of the concept they are teaching is just as likely to lose credibility as an instructor with significant experience that can not adequately explain the fundamental concepts of their discipline. Even in a traditional university setting, student excitement over solving real-world problems can be easily lost if the instructor is not considered an expert in the field.[1] It is not enough to be an academic expert in the field; real-world problems can only be accurately posed by those who have real-world experience. The real-world experience allows the instructor to pose the problem correctly and ensure that proper emphasis is placed.[7] Without real-world experience and "war stories" an instructor quickly loses credibility with USAF TPS students, just as easily as an instructor that has real-world experience but no theoretical backing to his knowledge. Students have in the past raised a "BS" flag, begun actively probing an instructor's knowledge through penetrating questioning bordering on interrogation, and ultimately devaluing any information presented by the instructor that does not have the right balance of theoretical and applied knowledge.

Finding the right instructor for a class is further underscored by a desire to have students continue to explore the fundamental concepts of the curriculum. This exploration is aided by practical examples, but is important that the instructor does not lose sight of the fundamental concepts as applied to a particular topic. We want to encourage the students to begin to think in terms of the Myers-Briggs category of intuitors. Many of the USAF TPS students are latent intuitors that have become accustomed to operating in a sensor mindset. By making the learning environment balanced between intuitor and sensor, the students' natural tendencies begin to emerge, they become more comfortable at receiving complex topics at a fast rate, and they stay engaged in the learning process, taking ownership of their learning. There is an even more important reason for ensuring a balance in stimulating both intuitors and sensors. We have witnessed first hand the lack of emphasis on metacognition leading to the Dunning Kruger effect[8,9]. The students must be challenged to think about how a specific test technique is relevant to a larger picture and where it is appropriate to be used and when not. Only by challenging students to do synthesis within the context of metacognition can responsible expertise be formed[10].

Creating the Proper Learning Environment

The compressed timeline, coupled with the loss in execution efficiency created by making an integrated curriculum, necessitates that the curriculum maximize efficiency with the amount of material that is required to be covered. According to *How People Learn*: "There needs to be alignment among the four perspectives of learning environments. They all have the potential to overlap and mutually influence one another. Issues of alignment appear very important for accelerating learning both within and outside of schools"[1]. A diagram of these different learning environments can be seen in Figure 2. Leveraging this work, USAF TPS uses a mix of all four learning environments as found in Figure 2.

In a learner centered environment students bring a variety of cultures with them. In the military, each type of aircraft pilot is rooted in the culture associated with their aircraft. Engineers that attend USAF TPS bring a technical background that is often without a flying / operator background. These different cultures in the military can easily cause barriers to communication in a learning environment. We start students from various backgrounds working together in a team environment early to ensure they begin to overcome cultural barriers and see the value of working together. When students begin to see that their varied backgrounds and experiences are valuable, they begin to leverage learning from each other. We also have students perform roles outside of their military background where possible in order to encourage appreciation of the different roles in the flight testing community. The students quickly learn that pooling all their varied backgrounds and abilities allows them to work more efficiently as a team throughout the year of schooling. We can not allow them to pick and choose their own assessments or define their own syllabus as in some learner centered programs. This is due to military structure and limited time for instruction and limited staff availability.

In a knowledge centered learning environment information is presented with the aim that students

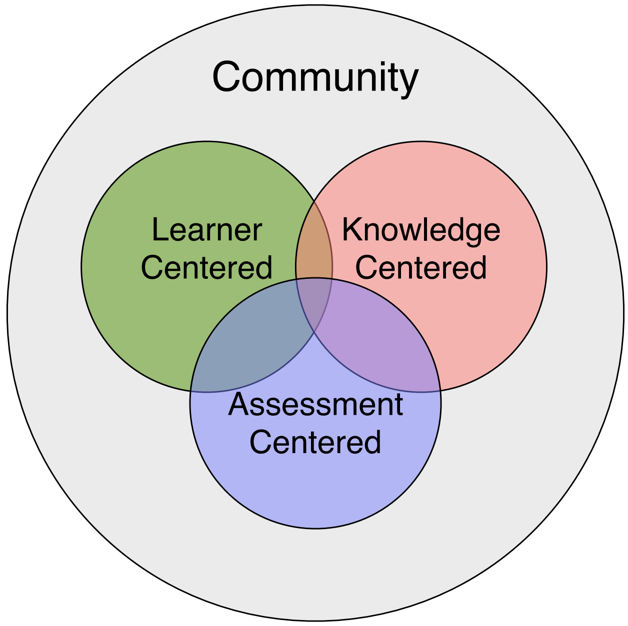

Figure 2: Integration of learning environments.[11]

gain a conceptual understanding of the disciplines of interest. As instructors we strive for our students to learn enough conceptual knowledge to allow metacognitive abilities of our students to be encouraged. Our school aims to give our students a basic foundation in flight testing with a skill set to learn more about flight testing as their career progresses. We want students to explore in a responsible fashion the discipline of flight testing, and all the various disciplines that support flight testing, and then be capable of finding resources to aid in their future learning and job performance. We want to foster deep conceptual understanding that can eventually lead to deep technical understanding.

In order to address the assessment centered portion of the curriculum, both formative and summative assessments are used as students progress throughout the flying qualities phase of USAF TPS . Instructors are aware of the different forms of assessment required and use them as tools to encourage student learning progression. In a typical classroom setting summative assessment is primarily used. However simulator labs and demonstration flights are coupled with the formal classroom setting where formative assessment is the primary tool used. Further several class projects are given throughout the course, and each project is given in stages where formative assessment is given along the way during the project with a summative assessment given at the end of the project. The projects consist of both ground events as well as flight events. Demonstration flights are graded on a summative level to primarily assess training / skill level to perform specific tasks while formative assessment is given for the student's conceptual and technical knowledge in the form of instructor feedback during the flight and afterwards where an extensive debrief of the flight event is given. These debriefs can often be extensive, lasting longer than the flight event itself where each portion of the flight is dissected connecting the "hows" and "whys" with the "what we did" to enable students a chance to gain a broad perspective on the purpose of each event in a flight.

Combining Pedagogies

The curriculum designed uses a problem based learning approach that has been combined with cooperative and role based learning to enhance the learning experience. Utilizing the interconnections and strengths between these three teaching pedagogies approaches a realistic, yet safe environment for posing open-ended problems for our students.
Barrows[12] identifies six core features of PBL:

1. Learning is student-centered.
2. Learning occurs in small student groups.
3. Teachers act as facilitators or guides.
4. Problems are the organizing focus and stimulus for learning.
5. Problems are vehicle for the development of clinical problem-solving skills.
6. New information is acquired through self-directed learning.

Problem based learning lends itself well to cooperative learning. Smith et. al.[13] draw a distinction between structured cooperative learning and placing students into study groups. Formally structured cooperative learning groups must contain:

1. Positive interdependence
2. Face-to-face promotive interaction
3. Individual accountability/personal responsibility
4. Teamwork skills
5. Group processing

Students in a cooperative learning environment are encouraged to discuss the concepts presented to them by their instructor. By having an open discourse on the subjects they are learning deep learning is encouraged. The students no longer just accept information presented to them, they explore the topic and adopt principles only after they have been vetted within their peer group.[14] ‘The instructor’s role is no longer that of a teacher, but more a facilitator. Guidance for methods of facilitation can be found outside of traditional academia in programs that are designed to build high performance teams. Rohnke and Butler state that “the leader/facilitator doesn’t provide all the answers to the group; primarily the participants learn from each other.”[15] The authors go on to contrast leading versus facilitating by stating “*leading* the group – helping them to learn – or *facilitating* – helping them to learn from each other.”[15]

Role-based learning also lends itself well into integration with problem based learning. By introducing students to an environment that is modeled on what will be found when they enter the flight test community, the problems given to the students take on an added sense of realism. By giving students specific roles within a team environment to solve broadly defined problems the students are challenged to act like they will when they leave USAF TPS and enter the flight test community. Role-based learning allows the student to fully participate in the practices of a given discipline.[16,17] The risk associated with a student or group of students not achieving a desired goal is minimized while their perceived risk of not accomplishing a given task is still kept at a high level. The students are therefore allowed to work as an integrated flight test team while still in an academic environment. By being immersed in a professional environment while still being in an academic setting students learn to speak the language of their profession in a safe environment.

The primary means used to engage students in this hybrid pedagogy are four projects given to the students during different stages of the flying qualities phase . Each project aims to focus on reinforcing concepts taught in academics and skills learned during flying. These projects are group projects that can span anywhere from 2 weeks to 2 months, and all are based on real-life scenarios that students may encounter once entering the flight test community. The learning objectives in these projects do extend beyond what the students have encountered in the classroom. While resources are provided to the teams to aid in their learning, the students are expected to draw upon the resources of their team to continue their learning of a given subject. These projects often do not require the student's full attention, but do require some level of continuous attention during the entire length of the project. The projects are open ended, and require multiple engineers and pilots on a team. Students are expected to approach instructors for questions after they have discussed the assignment amongst themselves first, and instructors will often not give direct answers, except if the question is safety related. All projects are done with multiple deliverable items during the course of the project. Both written and oral presentation of work is required, and instructor feedback is given at each stage of the project. This feedback includes a formal grading of written work as well as a debriefing of the students from each oral event. It is expected that the students will improve their performance from each feedback session, and that their performance will improve at each stage of the projects. The projects are intended to be a chance for students to grow their newly formed knowledge with instructor oversight. The projects require the students to create test plans, gather data, and then make evaluations of the data they have gathered, both for technical adequacy as well as to generate conclusions about the system they tested based on their evaluations. Instructors then focus on the student's planning, evaluation, and assessment of their assigned project.

During the projects students are assigned specific roles according to their background, although some interchanging of roles is accomplished to ensure everyone has an appreciation for each specific job in a flight test organization. It is important that engineers have an understanding of how difficult some maneuvers are for pilots, just as it is important for pilots to understand why engineers may call for maneuver to be re-flown due to poor performance. Engineers must also have knowledge to how easily a pilot can become task saturated and when a seemingly harmless test change can lead to an unsafe condition, whereas pilots must realize the complex coordination that is occurring on the ground in a control room, and the need to have efficient and optimized tests to minimize programmatic costs.

Curriculum Execution Challenges

Each student day allows for 3 to 4 hours of academic instruction, with 1 to 2 flight events also scheduled during that day. A simulation laboratory, instructor feedback session, or oral report may take the place of a flying event as required. An academic event will often last 3 to 5 days, with a test given at the end of an event. Each academic event is part of a larger course that also includes flying and laboratory events. Ideally practical events such as flying or laboratories occur close to when an academic topic is introduced. Aircraft availability can often drive schedules to compress or expand, causing a less than ideal connection between teaching in the classroom and in flight. Usually students are flying an event that they learned in the classroom a few weeks prior. This means that students are learning new material in the classroom while trying to focus on an upcoming flight that covers material from two weeks ago.

While care is taken to keep practical and academic events linked as closely as possible, delays are common. Some of this delay is due to aircraft maintenance issues, or instructor availability. For example, each student class consists of 20 - 24 students. For each student to attend a 2 hour simulator session, 48 student contact hours are required to achieve that event. For a flying event, often a 2-hour pre-flight briefing, plus a 1-hour sortie, followed by a 1- to 2-hour debriefing is required. One flight event may take 4 to 6 hours per student, and must be repeated for all 24 students. The multiple events happening for students (flying in the morning and attending academics in the afternoon) require careful integration of the curriculum. The overlap can often be distracting, and it is important that each event is treated as building on other events. It is also important for each event to have a fundamental conceptual link to something previously presented to the student. This way students can always trace back to the origin of the concept. This clear path is required for students that need to review concepts and "relearn" something that may have been presented a couple of weeks prior that is now needed. Ideally this cycle aids in student reinforcement and not just repetition, or worse a new concept presented after students have formed a conceptual understanding of a subject in their minds. From a practical standpoint managing this schedule in the presence of competing resources and aircraft availability is a complex task that does not always occur as desired. This scheduling issue was the driving factor for the original federated curriculum. Careful schedule management has shown that the integrated curriculum is executable, but with more difficulty.

Another issue encountered is the transient nature of military instructors, who may only stay at USAF TPS for one year. This creates a constant turnover of staff that must be trained and qualified for different events by predominantly civilian staff that are present to maintain continuity. While this challenge in execution exists, there is a benefit to having a long term and short term staff. The long term staff retain the technical excellence and corporate memory of the organization, while the short term staff bring in fresh perspectives and operational relevancy to the school. Maintaining the proper mix of short and long term staff is key to keeping the curriculum flowing smoothly.

Current Student Performance

While formal comparison surveys of students have not been taken during the curriculum revision, several key indicators have been observed that point to improved student performance. Student final exams have been rewritten to test deeper understanding with fewer rote memorization questions. Students are now performing better on these new final exams than they used to perform on the older exams where rote memorization was the key to passing the exams. Student reporting and projects are also showing much more thought provoking results. Under the old curriculum students would only reproduce tests they had seen previously in the curriculum for their projects. Students are now inventing their own tests that leverage off of tests they were taught earlier, showing they have a much better conceptual understanding of why a test maneuver is used and when it is or may not be appropriate. The solutions students give during final and practical exams are also starting to diversify. Under the old curriculum solutions between student groups and individuals were almost all identical since they were just parroting back what they had been previously taught. Now students are synthesizing their own solutions to problems often offering novel approaches to solving problems. Instructors are also now encountering students more in their offices were students are asking "what if" questions, showing their curiosity and desire to ensure they connect the theoretical concepts in the curriculum.

One example of how student performance has increased can be found in the flying qualities phase test plan project. This project is a 3 phased project that lasts approximately half of flying qualities phase . Originally one of the chief goals of the flying qualities phase was to ensure students could recite that the model validation technique used for flight testing includes the concepts of *predict, test, validate*. Another goal was for the students to be able to recite that: *The enemies of handling qualities are phase lag and stick sensitivity*. Former graduates who return to our school are able to recite both of these things, but very few can articulate what they mean. This project's original purpose was to instill those concepts into the students through repetition, with three independent phases, while having the students work through a formal flight test planning and execution exercise. This project has been changed so that those concepts are introduced earlier in the classroom, and then the project serves to reinforce those concepts through solving a real-world problem, where all three phases are tightly integrated to provide progress through Figure 1. In the first phase of the project students are provided detailed requirements. Students are asked to plan and execute flight tests to gather data to demonstrate compliance or noncompliance with those requirements. Students are then required to write a simple report with their findings. In the second phase the students are given general requirements, and are required to derive requirements, justify those requirements as well as plan and execute flight tests to gather data to demonstrate compliance or noncompliance with the general requirements. In the final phase students are given an overall mission for the aircraft, and then asked to perform a handling qualities evaluation where they must create mission tasks to evaluate. The students must then plan and execute a series of flight tests. In their report students must use the information they gathered in phases one and two as well as the results from their phase three tests to come to a conclusion as to whether or not the aircraft is suitable for the assigned mission. The concepts of *predict and test* are reinforced in phases one and two and the concept of *validate* is reinforced in phase three. Further students must produce evidence in the form of Cooper Harper ratings and pilot comments that correlate with such things as measured *phase lag and stick sensitivity* as well as other metrics evaluated in the first two phases of flight. Unlike with the old project, the staff have noticed that different student teams are taking different routes to evaluate the aircraft for the same mission, students have begun questioning the validity of some of the requirements in current specifications, and asking detailed questions about how to trace results back to the aircraft's overall mission. Instead of just planning and executing a test, the students are now given a chance to critically think about the skills they have learned. Students have even begun creating their own flight test maneuvers that expand upon the basic maneuvers they have been shown in previous exercises.

The USAF TPS has also seen further evidence that recent graduates have gained a deeper understanding of the fundamental concepts behind aircraft flight test, as well as developing critical thinking skills required to evaluate the safety of a flight test program. This evidence has come in the observation of graduate performance while out in the test community, as well as continued graduate involvement with the school post graduation. While the students may not be subject matter experts in any given field, they have shown signs of being capable of critically evaluating test reports and test plans to ensure technical adequacy. They are also capable of creating complex, custom flight test programs for new aircraft, where traditional flight test strategies may not be applicable. This critical evaluation skill is a direct result of synthesis skills coupled with technical knowledge learned at USAF TPS .

Future Work

While significant work has been done to redesign the USAF TPS flying qualities phase curriculum, implementation of the full curriculum is still not complete. Almost all academic events have been rewritten to match the new curriculum design. All projects have also been rewritten, as well as all simulator laboratory events. Some flight events have been modified to interface with the new curriculum design, although most flying events still require significant revision. Ongoing work is being done to further align flying events to leverage learning in these events more closely with the ground events the students receive. As students continue to change and the needs of the flight test community continue to evolve, curriculum maintenance will also be required to ensure the material taught remains effective and efficient in its delivery.

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