Effective Durability and Damage Tolerance Training: New Methods for Modern Learners

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New Boeing structures engineers come from diverse backgrounds in terms of degree focus, culture, ethnicity, gender, language, values, social network, work experience, interests, and generational perspective. Our goal at Boeing is to create a more inclusive learning environment so that all engineers can move to proficiency more quickly. The idea is to leverage the diversity inherent in our employee population and better transition the learning to on-the-job performance. In the past, the new hire training for BCA structures engineers consisted of lengthy classroom lectures accompanied by printouts of PowerPoint slides. This more traditional lecture approach tends to be a very passive experience for the students. Today, modern learners entering our industry have grown accustomed to much more effective means of teaching. As a first step in an endeavor to transform this training series, we assembled a large team of technical experts, working in collaboration with our internal Structures University organization, to revamp the introductory durability and damage tolerance (DaDT) portion of the curriculum.

The BCA structures introductory DaDT course aims to cover, in a single day, the fundamentals of durability, fail-safety and damage tolerance, and how these concepts are applied at BCA. Engineers who will engage in DaDT analysis will go on to take more advanced and in-depth training classes. This introductory course is focused on providing those engineers, along with the larger workforce in other disciplines, a foundational understanding of DaDT. Recognizing that not all of our engineers will immediately encounter these concepts in their functions, we saw a heightened need to improve the effectiveness and knowledge retention of this training. The approach taken was to embrace modern learning methods. The new class, while still primarily instructor focused, relies heavily upon team-based and problem-based learning. In this paper, we share our learning architecture model, examples of modern learning approaches, testimonials from instructors and learners, and plans for the future.

The new class primarily takes advantage of two effective learning techniques: inductive learning and active learning. The first of these techniques, inductive learning (aka, backwards teaching), is inquiry-based, problem-based learning. The students are initially challenged with questions, observations, or data that they themselves must use to define the problem and the needs. The instructor can then provide lecture that introduces the students to the underlying theory, principles and methods. But finding the solution is a learner-centered activity, involving iterative loops as the students slowly gain the necessary tools, allowing them to refine their initial thinking or solution. For example, we begin the class by challenging them to look at a recent notable fatigue cracking event in which a 737-300 experienced an in-flight decompression event (Figure 1). We ask the students to imagine that they are on a team of NTSB investigators arriving on the scene, looking at the evidence to determine why and how the failure occurred. Group discussions also focus on identifying how the airframe avoided catastrophic failure (i.e., fail-safe design). One significant advantage of this approach is that it gives the students an immediate sense of purpose for being in the class.

Figure 1. Example of an in-service structural failure that is used for an inductive, team-based learning approach to fatigue cracking and the merits of fail-safe design [1].

The second technique that we utilize in this class involves the concept of active learning. At the most basic level, active learning is anything students do in class to learn material, other than listen to the instructor and take notes [2]. The key elements are activity and engagement. Learning that is hands-on and experiential tends to be more effective because the learner can do something and get immediate feedback. It is important to recognize that active learning is a spectrum; the class can still be primarily instructor focused on the active learning continuum (Figure 2). Active learning can be as simple as stopping the lecture periodically and giving the students the opportunity write down key learnings or notes about concepts where they might still lack clarity. These writings are then invited to be shared with neighbors, or the entire class for instructor-led class discussions. One good test of whether the student is learning is to see if he/she can turn around and explain these concepts in their own words. This approach is also quite valuable because it affords the instructor immediate feedback in the effectiveness of the lecture by directly engaging with the class, finding out what the students are (or are not) comprehending.

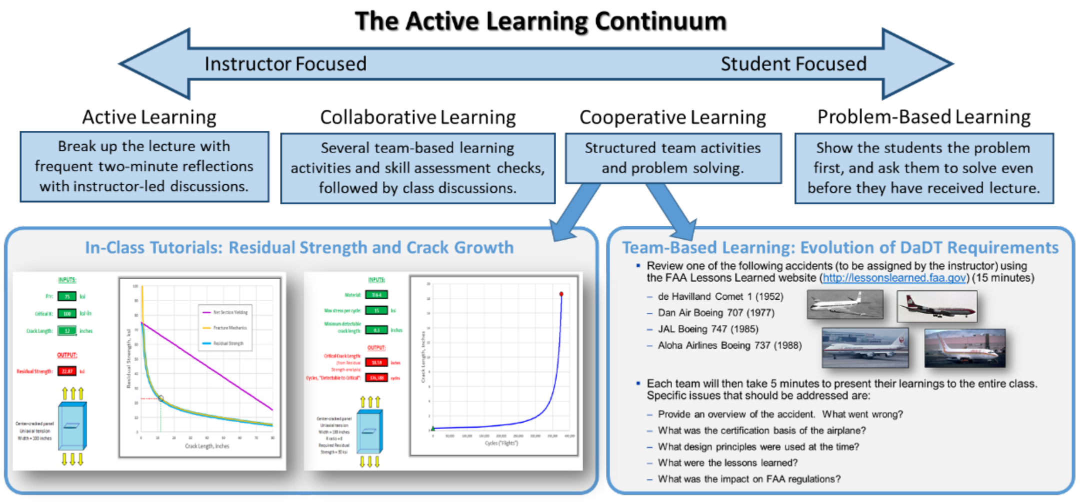

Figure 2. The active learning continuum [1], highlighting some examples in Boeing DaDT training.

The class also employs active learning by incorporating several structured team-based activities for collaborative and cooperative learning. For example, on the topic of residual strength, we begin with the problem – namely, net section yield criterion doesn't tell the full story. Then we introduce them to the basic tools (i.e., fracture mechanics) and then quickly dive into some hands-on tutorials, utilizing a simple Excel-based tool allowing the students to perform rudimentary residual strength analysis of center-cracked panels. With this tool in hand, they can quickly get a feel for the sensitivity to variables such as material properties and panel geometry. Moreover, this is a great means of providing the students a hands-on feel for the utility of the stress intensity factor, which can be an abstract concept for the uninitiated engineer.

Real-world cases studies are an important part of effective teaching. We work in a field where (unfortunately) in-service failures and lessons learned from any number of causes are not lacking. We take advantage of this by continually invoking case studies throughout the class. Near the end of the class, we completely flip the classroom by asking students to perform investigations of some notable accidents that have occurred throughout aviation history. The students break into teams and utilize the FAA Lessons Learned online library, which is a great repository of information about significant events that have helped shape current aviation safety policies. The teams work together to answer several pertinent questions about these milestone events and then get up in front of the class and share their findings (Figure 2).

By invoking modern methods of teaching, we have been able to develop an introductory DaDT class that enhances student learning and knowledge retention. We continue to see this course enrich not just our DaDT analysts, but also engineers across many disciplines where DaDT plays a significant role in the safety and economics of the airframe, including design, loads, manufacturing/production, liaison, fleet support and materials/process technology. We have successfully deployed this class at several Boeing sites (e.g., Everett, Renton, Charleston, Moscow and Kiev), with plans for further expansion.

Keywords: Fatigue, Durability, Durability, Fail-Safety, Damage Tolerance, Teaching, Training, Boeing

References:
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[2] Prince, M., "Does Active Learning Work? A Review of the Research," Journal of Engineering Education, 93(3), 223-231 (2004).