

Teach Flying Skills That Last and Adapt

Research-backed habits instructors can use in the cockpit

Susan Tholen

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Executive Summary

The smoothest lesson is not always the most effective one. Students may look sharp when they repeat the same maneuver with constant coaching, yet struggle to reproduce it a week later or adapt when the wind, runway or airplane changes. Research across cognitive psychology, motor learning and aviation human factors suggests that durable learning often requires students to retrieve, experiment, make manageable errors, self-assess and adapt. The practical goal is not to choose one learning principle over another, but to combine them deliberately: space practice, vary conditions, require recall, reduce instructor guidance and use repetition where automaticity matters. Primacy and the avoidance of negative learning remain important, especially for time-critical actions, but an early polished performance should not be mistaken for learning that will last. Long-term retention and transfer must be evaluated in their own right.

1. Introduction

Pilots need two complementary kinds of skill. **Routine expertise** is fast, accurate execution of familiar tasks: a normal landing, a checklist flow or a standard radio call. **Adaptive expertise** is knowing what to do when the situation does not match the lesson plan—an unusual failure, a forecast that does not match the view outside or an unfamiliar airplane.¹

Training has to build both. A student must execute the basics without hesitation, and also recognize when the familiar script no longer fits. No single principle is sufficient by itself: repetition without variation can become brittle, while variation without a stable foundation can become noise. The practical task is to combine repetition, spacing, retrieval, feedback, variation and reflection so that skills remain available after the lesson and still work in a new situation.

2. Learning is not the same as performance

A student's performance during practice is a weak stand-in for what they will remember and use later.²³ Repeating one maneuver in a block, supplying constant feedback and catching every deviation can avoid building bad habits and make today's lesson *look* efficient. But it can also hide whether the student can retrieve the skill independently. Harder-looking practice—mixing tasks, allowing some errors, waiting before giving feedback and asking the student to make the first diagnosis—often produces better retention and transfer.

My first aerobatic lesson made this distinction vivid. With Rob Holland coaching from the back seat, my first aileron rolls in a Decathlon felt almost easy. A few weeks later, I tried one on my own in a Citabria, and it was decidedly ugly. The airplanes were not identical, but the larger lesson was clear:

I had performed well with expert prompts; I had not yet learned the maneuver well enough to reproduce and adapt it independently.

Concern about primacy and negative learning is legitimate: some errors should be stopped before they become habits, and first learning matters. The risk is treating those ideas in isolation. Immediate correction can produce a cleaner lesson and an early win, but if it prevents every safe-to-experience deviation, the student gets fewer chances to connect cause and effect, notice changing cues and exercise judgment. A useful boundary is simple: intervene immediately for safety, a rapidly compounding error or a time-critical response that must be learned correctly; otherwise, allow enough of the outcome to become observable, then debrief it. The aim is not error-free practice today, but accurate, adaptable performance later.

Instructor takeaway: Do not judge a lesson only by how polished the final repetition looked. Notice how much coaching produced that performance, then check what the student can do cold at the next lesson, with fewer prompts and under slightly different conditions. Treat in-lesson performance and long-term learning as related but separate measures.

3. Techniques for long-term retention

Spaced practice. Practice distributed over days beats the same amount crammed together, one of the most reliable findings in learning research. For flight training, several short sessions on a maneuver across weeks beat one long session of repetitions.⁴

Retrieval practice. Recalling information from memory strengthens it far more than re-reading or re-watching. In the cockpit (or in the preflight briefing) this means having the student talk through the emergency procedure or flow from memory before looking at the checklist, then checking. Or flying the traffic pattern without coaching and performing a self-analysis before the instructor provides feedback.⁵

Overlearning, with limits. Practicing beyond first success improves retention, but the benefit fades over weeks unless refreshed.⁶ Overlearning is worth it for critical procedures; it doesn't replace spacing.

Knowing what decays. A large review of skill decay found that skills fade with time unused, and that procedural, step-by-step tasks fade faster than continuous control tasks like steering. Aviation data match this: in a study of airline pilots, basic hand-flying held up reasonably well with automation use, while cognitive skills such as keeping track of position and recognizing failures declined more. The implication is that recurrent training should target thinking skills, not only stick-and-rudder skills.⁷⁸

A familiar example appears late in training when a student is asked for a power-on stall and responds, wide-eyed, "I haven't done one in six months—I'm not sure I remember how." The maneuver may have been satisfactory early in the syllabus, but satisfactory once is not the same as available on demand. Skills introduced early need deliberate retrieval later, especially when they will be tested or used under pressure.

4. Techniques for adaptability and troubleshooting

Mix and vary practice.⁹ Once the student understands the basic task, stop treating every repetition as identical. Alternate normal, short-field and go-around decisions; change runway, wind, weight or approach setup; and occasionally return to a maneuver after another task. Performance may look less tidy, but the student must select and adapt the right response instead of replaying the previous one.

Fade and delay feedback.¹⁰ Coach heavily while a skill is new, then deliberately reduce prompts. After a maneuver, ask the student what they noticed, what they would change and which cue triggered the decision. Add instructor feedback after they self-assess. The goal is not silence; it is to transfer the monitoring job from instructor to pilot.

I saw this during a stage check with a student nearing the practical test. The instructor was surprised when I reported that the student's short-field landings were weak; they had looked flawless in the previous lesson. As we talked, the instructor realized how often they had supplied small verbal cues—"use full flaps," "reduce power," "turn base". Each prompt was reasonable, but together they had become part of the maneuver. Without them, the student had not yet learned to monitor and correct the approach independently.

In addition, the coaching that had been provided was action oriented rather than judgment oriented. Instead of telling the student to turn base, a better prompt might have been to ask them how they would determine the right time to turn, or how the headwind would affect their planning.

Use errors as data.¹¹ Within safe margins, let the student see the consequence of a poor setup, late decision or missed cue. Then make the recovery and diagnosis the point of the exercise. Errors become dangerous when they are repeated without recognition or correction—not merely when they occur.

Let the student wrestle with the problem.¹² For concepts such as energy management, diversion planning or go/no-go decisions, give the student a bounded problem before explaining the preferred solution. A short struggle exposes assumptions and makes the later explanation more useful. This approach is less suitable for immediate-action procedures, where correct execution comes first.

Vary the time and place for each scenario.¹³ If every simulated engine failure begins at the same altitude and location, the student learns the setup as much as the response. Vary the timing, context and form of the problem. Sometimes thinking a bit and doing the right thing slowly is better than doing the wrong thing quickly.

One student I observed was polished at the familiar engine-loss drill: lower the nose, trim, choose a field and turn toward it. During a long climb, once we were at a safe altitude, I reduced the throttle without the usual setup. Instead of lowering the nose to protect airspeed, the student pulled harder and reached for nose-up trim as the stall warning sounded. The practiced sequence was there, but it was the wrong response for the different scenario.

A rough-running engine scenario exposes a related gap. Students sometimes jump straight to the complete engine-failure response because that is the only script they have practiced. I have watched students fly at partial power toward a poor field without trying to diagnose the problem. When prompted to troubleshoot, they often discover that a simple action—such as selecting the fuel pump—restores smooth power. I am not looking for a perfect diagnosis; I am looking for evidence that the student can distinguish “engine trouble” from “engine stopped” and choose a response that fits.

Functional understanding. Knowing just enough about why a procedure works lets the pilot predict when it will change or fail. This is what separates adaptive from routine expertise.¹⁴

5. Where rote repetition still belongs

Repetition is not the enemy. Some responses must become automatic because there is little time to deliberate under stress: stall recovery, the first steps after an engine failure and go-around technique. Under pressure, people tend to fall back on their most practiced response, so first learning should be correct and those responses should be well drilled. This is the sound core of the FAA’s “law of primacy.” But primacy answers only part of the training problem. Correct early performance still has to survive time, reduced prompting and changing conditions; repetition should therefore be spaced, retrieved and tested rather than treated as proof of permanent learning.

Motor-learning research also shows that skills learned with few errors, where the learner relies less on conscious rules, can hold up better under pressure.¹⁵ The two approaches are reconciled by what is being learned:

Skill type	Best approach
Time-critical memory items and emergency responses	Correct technique first, then repeated, spaced and tested under mild stress
Maneuvers and handling (landings, crosswinds)	Correct demonstration, then varied conditions and reduced feedback
Judgment, diagnosis, weather, go/no-go	Scenarios, productive struggle, student-led debriefs

The principles are complementary, not competing. Correct first learning protects time-critical responses; spacing and retrieval keep them available; variation and reduced feedback make them adaptable; and managed errors build diagnosis and recovery. The real risk is not that a student experiences an error, but that an error is repeated without recognition or correction—or that a polished, heavily coached performance is accepted as evidence of lasting learning.

6. Implications for flight training

The ideas above work best as a system, not as isolated techniques. They do not require a new syllabus; most can be built into lesson sequencing, cockpit questions and debriefs. The common

discipline is to protect safety and correct first learning while also checking, separately, whether the student retains and adapts the skill over time.

1. **Spread maneuvers out.** Revisit each maneuver briefly across many lessons rather than drilling it to perfection in one.
2. **Mix the lesson.** After initial learning, mix maneuvers and situations instead of flying ten identical landings in a row.
3. **Vary conditions on purpose.** Different runways, winds, flap settings, airports and airplanes.
4. **Quiz from memory first.** Have the student recall procedures and flows before referring to the checklist, then check.
5. **Fade feedback.** Coach heavily early, then less; ask "How was that?" before giving your own assessment.
6. **Let errors play out within safe margins.** Intervene for safety, not for polish, and debrief with the student leading the analysis.
7. **Make surprises real.** Present failures and scenarios unannounced and in different forms, not at the same point in every lesson.
8. **Teach the one sentence of why.** Tie each procedure to the minimum understanding needed to know when it changes.
9. **Drill the time-critical items hard and correctly.** Memory items and emergency responses get correct first learning and spaced, repeated practice.
10. **Judge progress over time, not within the lesson.** The best measure is how the student flies the maneuver the next week, cold.

7. Limitations

The evidence is strong enough to guide practice, but there is no single recipe.¹⁶ Much of the underlying research used laboratory tasks or relatively simple motor skills. Aviation studies are fewer and often involve airline pilots in simulators rather than primary students in light aircraft. Instructors should treat the findings as design principles to test thoughtfully, not as proof that one lesson format fits every learner.

Safety still sets the boundary. Some failures and errors belong in a simulator, on the ground or only within generous in-flight margins. Beginners usually need more structure; variation and reduced feedback should increase as they gain control and situational awareness. The test is whether the method builds independent performance without creating avoidable risk.

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