Can Backward-Chained, Ab-Initio Pilot Training Decrease Time to First Solo? – Take 3

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Abstract

This research updates articles recently published in the Journal of Aviation/Aerospace Education and Research (JAAER) Vol. 30, Issue 1 (Spring 2021), and Vol. 32, Issue 1 (Summer 2022) asking "Can backward chaining, ab-initio pilot training decrease time to first solo?" Previous results reported the experiential outcome of eight respondents, all without any previous flight time, who after completing backward chaining landing training in a flight training simulator, were able to complete three circuits in the traffic pattern on their first flight in an actual aircraft with little to no assistance. The current, updated, research placed four new respondents, again all without any previous flight time, into a forward chained flight instruction methodology for continued evaluation. The results (all completed unassisted circuits in the traffic pattern on their first flight) generally replicated the previous study; however, unlike the backward chained respondents, the forward chained respondents all had significant challenges landing the aircraft. If teaching landings to ab-initio student pilots is desired, backwards chaining in a simulator is recommended as more effective than forward chaining.

Key Words: Flight Simulation, Backward Chaining, Forward Chaining, Automation, Ab-initio, Pilot Training

Introduction

This research is the third iteration of Backwards Chaining research performed by Dr. Matt Vance, PI (Principal Investigator) and associated RA (Research Assistant). The overall objective of this research is to ask the question: Could backward chaining in a flight simulator accelerate a student pilot's (STD) ability to solo by reducing the amount of dual-instruction time required prior to solo flight?

Backward chaining in this context is teaching landings as the first component of flight instruction prior to solo, versus, the more traditional method of teaching landings as the last component of flight instruction prior to solo. And, specifically the employed backwards chaining method of teaching landings started the STD at 4' AGL altitude, and 80' behind the threshold of the standard Federal Aviation Administration (FAA) 1,000' Fixed Distance runway markings (on a 3° glide path), and successively iterated from there, in reverse around the legs of a standard, rectangular FAA traffic pattern. Forward chaining the instruction of landings would start a STD at a normal take-off position and fly the standard FAA traffic pattern in normal leg sequence, upwind climb, cross-wind, down-wind, base, then final approach.

The first research iteration, published in the Journal of Aviation/ Aerospace Education and Research (JAAER) Vol. 30, Issue 1 took place in the fall of 2019. This iteration of research incorporated four incoming flight STDs with no previous flight time or training. These STDs participated in two simulator sessions instructed by the PI. Upon completing the simulator sessions, these STDs were able to successfully fly and land an actual aircraft with little to no assistance from the PI (Vance, Gardner-Vandy, & Freihoefer, 2021). The PI considered this round of research an indicator but drew no strong conclusions. The PI further considered the research a “think piece” due to the small sample size and lack of syllabus progression data from the STDs as they continued their flight training in the university flight school program (Vance, Gardner-Vandy, & Freihoefer, 2021).

In the fall of 2021, the PI performed a second round of research using four new, incoming flight STDs, again each with no previous flight experience. The objective of this iteration was to continue gathering data and flesh out the merit to the above overall research question (Vance S. M., Gardner-Vandy, Pearce, & Gass, 2022). Changes from the first iteration to the second were minimal; however, the simulator sessions were changed from two, 1.5-hour sessions to three, 1-hour sessions. A few instructional differences were also made such as introducing the STD to using the trim wheel (a control that changes a flap on the elevator, making the plane pitch up, down, or trim for level independent from yoke elevator input). The secondary author of this paper (acting as a RA) participated in this second round of research, recording notes while the PI instructed in the simulator, and provided critical safety-of-flight situational awareness in the rear seat of the aircraft listening to Air Traffic Control (ATC) and watching for other aircraft at the airport. This allowed the PI to focus “inside the plane” with the STD, increasing safety. As with the previous research, correlation between backward chaining in the simulator and the ability to control an actual aircraft on their first flight was consistent (Vance S. M., Gardner-Vandy, Pearce, & Gass, 2022). The now eight STDs as a sample size were an indicator (but not a causation) suggesting the benefit of backwards chaining early in a flight training curriculum.

A wise criticism proposed from a peer reviewer of the first research installment was a STD’s success in controlling the aircraft may have been attributable to the simulator sessions, and not the backwards chaining itself. This was a factor the PI and RAs could not rule out. This peer reviewer comment was the basis for the current (third) round of research.

The third research installment followed similar methodological parameters: taking four STDs and convening as a group for an introduction presentation, then taking each STD individually through three simulator sessions. As with both prior research installments, at the conclusion of the third simulator session, all four STDs were given the opportunity to fly in an actual aircraft. The key difference was instead of being backward chained, these STDs would be FORWARD chained, or the "traditional method" of instructing landings. This would give a small control group sample size and a method to compare the results of the previous research.

The overall research question remains unchanged: "If a STD, with no prior flight-training experience, is first taught to land the aircraft in a simulator, via a backward-chaining approach, will this reduce their dual instruction hours required to solo in actual aircraft?" What changes in this research is the approach to the training to create a control group who were forward chained to compare to the eight STDs trained via backwards chaining.

Problem Statement

By completing four new STDs through a forward chaining method, is there a comparable difference to those trained via backwards chaining? What similarities or differences in performance/ability are there between these groups of STDs?

Literature Review

Chaining refers to learning by taking a complex task and breaking it into a series of individual steps (Olson, 2002). These steps can then be taught and mastered individually. Forward chaining is therefore learning by teaching the series of sequential tasks starting from the initial step, then teaching the additional steps in chronological order (Slocum & Tiger, 2011). This is how most teaching occurs: teaching from start to end in chronological order. This is how a standard FAA traffic pattern is taught in nearly every flight school (Olson, 2002). The opposing method is backward chaining: teaching the last step of the task initially, then progressing backwards through the chain, until the entire task is learned (Slocum & Tiger, 2011). The objective is to build upon previous success and develop a new chain that feeds into the already known chains. In the first two iterations of this research, backward chaining was utilized to teach the landings first (Vance, Gardner-Vandy, & Freihoefer, 2021).

The method in which flight instruction occurs has been changing in the last 20 years, from a historical task basis to a blend of task and competency basis (Fanjoy, 2002). This blend is commonly referred to as Competency Based Training (CBT) and focuses on the learner's ability to receive and respond to information to achieve competency. More specifically, it is "concerned with training to industry specific standards rather than an individual's achievement relative to others" (ACCI, 1992). The FAA has demonstrated this shift in their adoption of the Airmen Certification Standards (ACS) over the now out of date Practical Test Standards (PTS) (Federal Aviation Administration, 2017). The ACS "adds task-specific knowledge and risk management elements" (Federal Aviation Administration, 2017) to a pilot's certification requirements.

The use of forward chaining to accelerate time to solo has been studied previously. Goetz, et. al. (2013) looked to use simulation to accelerate a STDs progressing through the part

141 program. After completing data collection over twelve STDs, Goetz et. al. only observed an average 0.3 hours difference between the experimental group and historical data and therefore declared the data statistically insignificant.

Overall, no consistent methodological approach for utilizing and analyzing backwards chaining in ab-initio, pre-solo flight training was identified. Modern day uses of backward chaining are primarily used for machine learning (Al-Ajlan, 2015) and for the teaching of basic skills to children (Slocum & Tiger, 2011), though backward chaining has appeared as a training technique in aviation in the 1970's and 1980's. No published records of flight training utilizing backwards chaining were located after 1996.

Methodology

Overview

The methodology employed in this third research installment ~~(take)~~ was similar to the first two installments with a handful of minor methodological improvements and one potentially significant change – employing forward chaining only. The same research steps were accomplished in this order: 1) recruit and select non-flight experienced STDs, 2) orient selected STDs to research objectives and basic aircraft control in a ground session (a one-hour session), 3) fly the STDs in the simulator, and 4) fly the STDs in an actual aircraft. The identical iteration start point definitions and pattern profile was reused. The recruitment of Research Assistants/Safety Observers was a valuable lesson learned from the first research installment as a prudent and necessary safety enhancement and was used again as a best practice.

Participant Recruitment

Previous research has used four incoming flight STDs for the collegiate flight school program; however, this research occurred during the spring academic semester. There were no professional pilot program STDs that had not already begun or completed their initial flight training at that point in the semester. Thus, the research team was required to outsource beyond the collegiate flight program. Four engineering STDs were recruited and retained. Exact criteria for these STDs were unchanged from previous research installments as follows: a) STDs were required to be adults (18+ years of age), b) No previous flight training was permitted, c) minimal use of flight simulator games was preferred, and d) minimal exposure to light, General Aviation aircraft was preferred (airline travel was considered not a factor and thus was not included). For the applicants meeting all the above criteria, the PI and RA made the final selection by the applicant's schedule availability.

Student Orientation

Once the RA and PI selected the research participants, the next step was to orient the participants in a one-hour group presentation. This orientation covered basic flight controls, throttle and flaps levers, and the traffic pattern. The RA developed and used a different version of this PowerPoint presentation for the orientation compared with the two previous research installments. All points covered in the previously used PowerPoint presentation were still present, though the RA had modified these points. The RA removed points explaining the backwards chaining process. Additional slides added a) imagery depicting the aircraft in the downwind and on final approach (shown in figure 1), and b) a section demonstrating the difference between an automobile's steering wheel effects (hold the wheel left to turn left) and the aircraft's control yoke (the yoke changes the angle of bank—the yoke is returned to center once the desired bank is achieved), shown in figure 2.

Figure 1. Added image to the orientation presentation. This image depicts the aircraft on a short final to land (Pearce, 2022) Microsoft Flight Simulator 2020

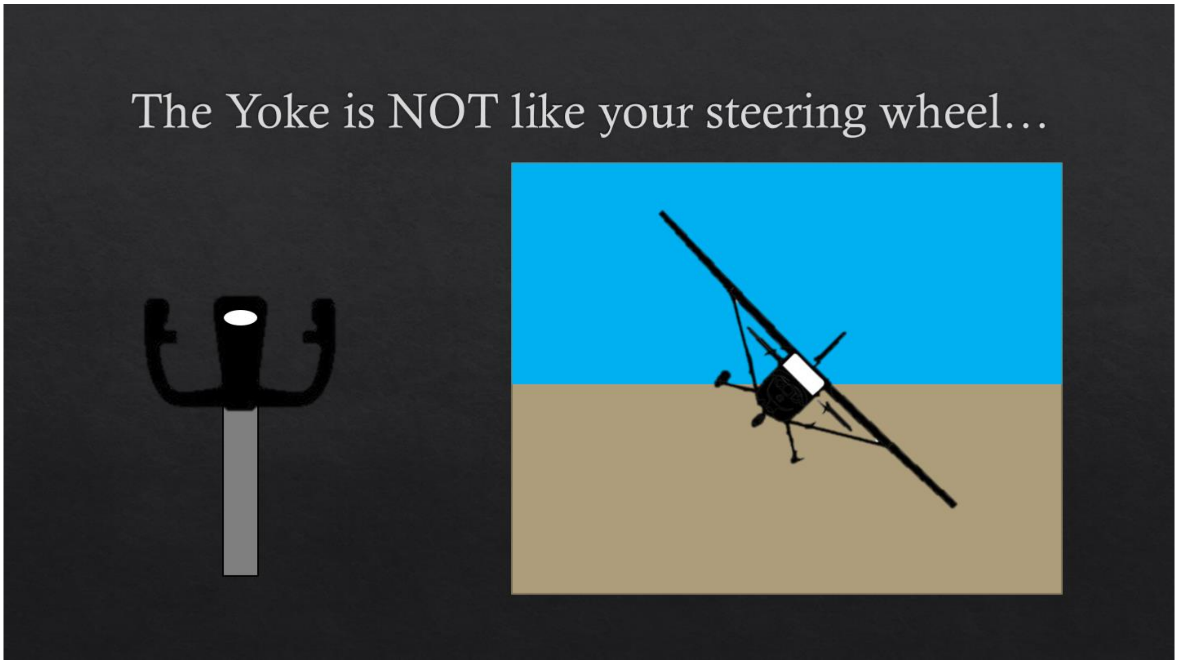

Figure 2. Slide from RA orientation depicting how a level yoke input maintains the current bank of the aircraft (Pearce, 2022)

Simulator Sessions

With the participant's orientation complete, each STD individually began their simulation training. Each STD received three simulator sessions, each an hour long, during a single week (about every other day scheduling dependent). The RA provided the instruction during these sessions, with the PI observing and providing feedback, as necessary. The simulator used was a Redbird MCX, configured as a Cessna 172/Garmin G1000 navigation system. This was identical as to what the STD would be using in the actual aircraft – and what was used in the previous pair of research installments. Unlike with the previous installments of backwards chaining research, the simulator sessions did not use starting points; instead, each lap in a standard FAA traffic pattern began on the runway at the touchdown point (or where the simulated aircraft had rolled during the previous landing) and concluded with landing back on the runway at the same touchdown point after completing a lap.

The RA focused the first session on orienting the STD to the simulator cockpit. The RA performed two landings in the simulator: the first, the STD merely observed while the RA verbally explained and performed the traffic pattern and landing. The second demonstration, the RA had the STD "ghost" the controls (hold the control to feel the inputs but provide no input themselves). The RA gave STD control of the simulator with the RA providing oral and physical inputs. The RA reduced physical flight control inputs as the STD's skill improved (this occurred on either session one or two depending on the progress of the STD). The RA did not add any winds on the first simulator session.

The second simulator session added a direct headwind of 8 KTS (winds traveling directly down the runway without any crosswind) and focused on improving the STD's skills. Depending on the STD's progress, the RA stopped physical inputs and relied only on oral assistance. With the core skills ~~being~~ acquired during the first simulator session, the STD could spend more time practicing traffic patterns and landings during the second and third simulator sessions.

The third and final simulator session focused on refining the STD's skills and preparing the STD to fly in the aircraft. The RA input the active winds and weather occurring at the Stillwater, OK (KSWO) airport at the time of the third session. In addition, the RA limited the amount of oral assistance to allow the STD to perform the traffic pattern and landing without assistance. On multiple occasions, the current weather conditions at KSWO were either outside of the flight school tolerances or deemed too severe by the PI and RA for an initial STD flight in an actual aircraft; thus, the flight portion was deferred. In the pair of cases where the environmental conditions warranted prudence, the RA and PI purposefully delayed the third simulator session so the flight could immediately follow the third simulator session.

Flying in the Actual Aircraft

Immediately following the third simulator session, the PI and RA would take the STD to the airplane, where the STD would perform three landings at KSWO. During the actual flight, the PI was in the front seat aiding the STD and providing instruction, while the RA remained in the rear seat to observe the STD and focus "outside the aircraft" listening to Air Traffic Control and watching for other aircraft traffic. The RA functioned as an additional situational awareness safety barrier to the flight – and was able to on multiple occasions apprise the PI of ATC radio communications requiring action. The allowed the PI to focus inside the aircraft and with the STD. The PI performed a single demonstration lap of the traffic pattern before handing the control of the aircraft to the STD. At all times, the PI could provide assistance up to and including resuming control of the aircraft. Figure 3 is an exemplar of the fleet aircraft used for flight.

Figure 3. C-172 G1000 aircraft used in the flight portion. Exact aircraft differed

Results

The table below depicts, by STD, the dates the simulator sessions occurred, and the number of landings performed during each session:

Table 1: STD Sim Sessions and Landings

	Sim Session 1	**Sim Session 2**	**Sim Session 3/ Flight Session**	**TOTAL Landings**
STD 1	March 28th 4 Landings	March 30th 8 Landings	April 1st 9 + 3 Landings	21 Sim Landings 3 Aircraft Landings
STD 2	April 4th 6 Landings	April 6th 7 Landings	*April 11th 7 + 1 Landings	20 Sim Landings 1 Aircraft Landing
STD 3	April 12th 5 Landings	April 14th 7 Landings	*April 19th 7 + 2	19 Sim Landings 2 Aircraft Landings
STD 4	April 18th 4 Landings	April 20th 5 Landings	April 21st 8 + 3 Landings	17 Sim Landings 3 Aircraft Landings
Average	5 Landings	7 Landings	7 Sim Landings	19 Sim Landings 2 Aircraft Landings

Notes:
a) Averages are rounded to the nearest whole number
b) * indicates a reschedule was required due to weather conditions
c) For the purpose of recording landings, approaches that resulted in a PI/RA-initiated Go Around were not counted

The trend in the number of simulator landings remained consistent between each STD for a given session. All STDs had less landings on the first session (Average 5 Landings) due to time taken for simulator orientation, and the RA performing the first two traffic patterns for demonstration.

All except one of the STDs experienced a learning plateau (occurs when a STD' s progress stop sand cannot progress in learning) during the second session. To remedy, the RA gave a brief break to debrief, then the RA performed the next traffic pattern and landing while the STD made corrections to the RA in a role reversal. This allowed the STD to not only take a break from controlling the aircraft, but also allowed the STD to observe the common mistakes the RA deliberately made. Every STD was able to exit the learning plateau and further progress following this role reversal.

With the rescheduling of the final session with STD 3, the RA was unable to attend due to scheduling conflicts. The PI performed the simulator session alone with the STD. For the flight, the PI found a CFI to take the place of the RA as the safety observer in the rear seat of the aircraft.

Regarding the lack of three actual landings for STDs 2 and 3: The winds during STD 2's flight were notably difficult with a strong crosswind and changing runways. One landing resulted in a PI-initiated Go Around, and the final landing the PI elected to maintain control of the aircraft. STD 3 successfully performed the first two landings but became motion sick during the final landing. The PI completed the landing for the ill STD. Table 2 shows the wind data for each STD during their actual flight.

Table 2: Actual Wind Data

	Wind Data during flight	**Wind in relation to Runway (RW)**
STD 1	170° at 10 KTS, Gusting 18KTS	Headwind:10 KTS (Gust 18 KTS) to RW 17 No Crosswind
STD 2	080° at 14 KTS, Gusting 21KTS	Headwind:11 KTS (16 KTS) to RW 04 Crosswind:9 KTS (14 KTS)
STD 3	160° at 18 KTS, Gusting 26KTS	Headwind:18 KTS (26 KTS) to RW 17 Crosswind:3 KTS (5 KTS)
STD 4	140° at 20 KTS, Gusting 25KTS	Headwind:17 KTS (22 KTS) to RW 17 Cross wind:10 KTS (13 KTS)

No STD escaped gusty winds. STD 1 was the most fortunate with having zero crosswind. STD 2 was the only STD to use runway 04, a shorter runway with a different sight picture during all phases of flight. While STD 2 practiced landings on runway 04 during the final simulator session, sessions one and two used runway 17.

Discussion

There are several critical data points to compare to the previous backwards chaining research. To start, the time spent in the simulator (total "real" time spent inside the simulator) was nearly identical, with the backward chaining averaging to 2:55 hours with each STD and forward chained STD spending an average total of 3:00 hours in the simulator. The simulator time (time spent with the simulator actively running) was significantly less with the backward chained STD as the forward chained STD saw the simulator running for nearly all the time during the session, while the backward chained STD was frequently paused when the simulator was reset to the next point in the backward chain.

The most notable data point is number of landings. With backward chaining the average number landings between all 8 STDs was 32. In this forward chained iteration, the average STD only completed 19 landings. This significant reduction in landings was noteworthy to both the PI and RA and was presumed to be negatively influential. This presumption was evidenced in the third-research installment STDs as all performed worse in the final approach corridor and landing flare compared to the backward chained research STD.

One area were the forward chained STDs did have superior performance was the take-off and initial climb. This is very likely due to exposure, as compared to the forward chained STD's average of 19 takeoffs, the backward chained STDs only experienced 5-7 takeoffs. The RA and PI both observed the forward chained STD were consistently smoother and had better corrections during their takeoffs, upwind and downwind legs.

As with the second research installment, there were unexpected behavioral outcomes presented by the STD in the third research installment that warrant discussion:

1) **STD 2 and development of the resignation hazard attitude -** It appeared from session one that this STD was struggling to remember important points such as airspeed, throttle, and flaps during specific phases in flight. The RA later realized that STD was freezing and would wait to be prompted to perform the next action (turn, start the descent, etc.). The RA attempted to combat this by prompting the STD to think ahead to the next task and mentally prepare for it. This issue was especially prominent to the RA during the final simulator session, where the difficult crosswinds were loaded into the simulator. It is the RA's observation that the stress was overwhelming the STD and "freezeing" the STD's mind to be unable to perform without the RA's prompts. This included requiring the RA to prompt the STD to return to altitude after deviating +200 ft. In the simulator and certain C172s, there is a chime that warns when you deviate +/-200 ft. The STD would be oblivious to the chime until prompted by the RA. This resignation—completely letting whatever happen, happen—continued into the flight. The STD would respond to oral prompts from the PI with an "Okay" but would not physically respond. The STD froze with stress: The STD's labored, rapid breathing could be heard by the PI and RA through the STD's microphone. Multiple times the PI had to input physical assistance to attempt to steer the aircraft in the correct direction. The STD required a PI-excuted Go-

Around on the second lap, and the PI provided nearly all the inputs to land on the third landing.

2) **STD 4's "need to impress"-** STD 4 was the only engineering STD not in the aerospace engineering program. Realizing this, the PI and RA should have been careful not to overwhelm the STD with excessive or extraneous knowledge. Unfortunately, before the simulator was in use at our designated start time for session one; therefore, it was opted to use the extra time to explain details about the research. The conversation quickly spiraled out of subject, and extraneous knowledge and questions were being asked of the STD for around 20 minutes. The intention of this discussion was to merely use the time and make conversation; however the RA observed the STD appearing nervous and a bit overwhelmed. It is the RA's belief the STD interpreted the small talk as important knowledge that the PI/RA expected the STD to know, when the reality was the opposite. When the simulator session started, it became obvious to the RA that the STD was very quick to agree with whatever was said, even if the STD did not understand what was being said. The STD developed the need to appear more knowledgeable than he was to not "disappoint" the RA nor the PI. This, along with the general stress of manipulating the controls of an aircraft in the simulator, was starting to overwhelm the STD. The RA worked to combat this issue by being reassuring to the STD. The RA also worked to create an environment that allowed the STD to fail, if necessary, and guarantee that the RA nor PI would be upset by failure or lack of knowledge. This issue overall improved for the STD, but even during the actual flight the STD was quick to agree with the PI before understanding what was being explained.

Conclusions

The purpose of this research was to provide a control group of forward chained STDs to answer the peer reviewer's critique that a STD's success in controlling the aircraft may have been attributable to the simulator sessions, and not the backwards chaining itself. Overall, if the objective is to teach landings first to an ab-initio STD, the data gathered from this research iteration favors backwards chaining over forward chaining. While the STDs from this iteration were able to fly the aircraft, the STDs who learned using forwards chaining required significantly more assistance in landing the aircraft than those who learned using backwards chaining. This was particularly evident during the final approach corridor sequence, to include the landing flare and touchdown

It is appropriate to consider this research result along with the previous iterations as "think pieces" towards the potential future of flight training. The now twelve respondents continue to be a positive indicator for backwards chaining but are still a statistically small set of results.

If your institution/flight school is interested in trying the backward chaining, pre-solo techniques this exploratory research has presented, the authors would be privileged to share any of the discussed methodologic steps and planning files as well as answer your questions.

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