How to Make Military Training STICK
(Superior Task Implementation of Core Knowledge)

Richard Arnold
Arnold Performance Training Group, LLC
Fairfax, VA
RichArnold1982@gmail.com

Professor Anthony Jones
Tidewater Community College
Newport News, VA
avjones@tcc.edu

ABSTRACT

How fast do students forget what they learned? The old saying "Use it or lose it" describes the knowledge and skill erosion that rapidly begins after training, especially for tasks that are difficult, infrequent, or not immediately performed due to delayed application (e.g., transfer). Combining spaced repetition and reinforcement of key training content/objectives can significantly foster retention of new skills and knowledge. Spaced repetition and reinforcement (approximately 5-minute question/learning interactions delivered over a 5-6 week period) significantly increases a student's ability to retain what they learned in training without the need for lengthy just-in-time job site training, hard to schedule/deliver refresher courses, or mobile training teams that pull the recipient from normal duties. Applying this approach to military knowledge and skills development can increase post-course memory recall while simultaneously supporting a more effective retention and transfer of new knowledge and skills from training to the job site. This process is based on proven research about memory: Knowledge and skills that are not quickly applied after initial training significantly erode. Spaced repetition of previously learned info/skills in small chunks repeated over time greatly improves retention. Spaced repetition is delivered directly to the performer as part of their normal daily routine. Spaced repetition is not a refresher course or a short form of an existing course. Instead, key performances and their associated knowledge and skills are reinforced via a simple direct targeted multi-week campaign. The result: Improved long-term knowledge and skill retention with a subsequent boost to performance, especially for challenging tasks (i.e., infrequent yet complex systems repair, language training, safety and security tasks that are a function of a non-primary duty, new system training, and competency development). Industry research and A/B test research support this approach.

ABOUT THE AUTHORS

Richard Arnold is a Human Performance Technologist with 40+ years of experience leading operations focused teams, organizations, and training units across military/law enforcement, government, commercial, NGO, UN, and international sectors. He has conducted small team to national level military, professional development, and law enforcement development projects based on job tasks, training needs, and organizational, and occupational analyses. Use results to develop organizational structures, and equipment selection, and deliver operational, safety, and support performance improvement solutions including individual and team training, job aids, checklists, training guides, doctrine / TTPs, etc. Corporate experience ranging from Program Manager to Chief Learning Officer across small to large companies; former Adjunct Faculty and Darden Fellow for Old Dominion University; Past President of the Federal Government Distance Learning Association; and Past President of the Military Chapter of the International Society for Performance Improvement. He currently advises businesses on using performance and training technologies to improve and sustain performance.

Anthony Jones is a technical instructor and educator with 30+ years of teaching and curriculum development experience for colleges and commercial Apprenticeship Programs. Professor Jones not only graduated from the Newport News Shipbuilding Apprentice Program but after completing a Master's Degree from Old Dominion University served as an Academic Instructor for the Apprentice School where he developed training programs for Apprentices slated to work aboard United States nuclear aircraft carriers and submarine new construction and overhauls. Programs included Ship Power Plants, Ship Construction, Algebra, Geometry, and Physics. Currently, Professor Jones is a Professor of Engineering and CADD at Tidewater Community College (TCC), where he delivers undergraduate courses, develops curriculum, and manages the Norfolk Naval Shipyard Apprentice program for Tidewater Community College.

How to Make Military Training STICK
(Superior Task Implementation of Core Knowledge)

Richard Arnold
Arnold Performance Training Group, LLC
Fairfax, VA
RichArnold1982@gmail.com

Professor Anthony Jones
Tidewater Community College
Newport News, VA
avjones@tcc.edu

INTRODUCTION AND TEST HYPOTHESIS

This paper describes the potential for applying the spaced repetition and reinforcement process first credited to Dr. Hermann Ebbinghaus (*Ebbinghaus, 1913*) and supported by industry research (*Rohrer, 2004*) to reduce the knowledge and skill erosion of trainees after they complete their training. Applying this method can also increase retention (*Penon, 2024*). Reduced erosion / increased retention can significantly benefit the military training system assuming the concept is applied within a replicable and manageable approach. Our test program examined the hypothesis that: *A spaced repetition and reinforcement campaign will reduce post-training erosion and increase student retention of key course objectives*. We examined the spaced repetition and reinforcement concept and tested the approach across two different programs. We used the Hermann Spaced Repetition and Reinforcement platform to provide us with a systematic and remote delivery capability. The tests examined trainee performance for a U.S. Department of Agriculture (USDA) National Agriculture Statistic Service (NASS) *Instructor Development Course* (IDC) and key course content from a Tidewater Community College (TCC) NAS115 *Science in the Workplace* undergraduate course for Norfolk Naval Shipyard Apprentices. The tests examined the ability of the method to help students a) reduce post-delivery retention loss (erosion) and b) increase performance over initial course completion levels (retention). Both tests featured a spaced series of short (3-5 minute) reinforcement challenges/learning events within a 4-event campaign. These events reinforced the instructor-led content tied to key performance objectives and align with research that spacing can improve retention and enhance memory (*Cowan, 2024*). Students volunteered to receive the campaign. This paper describes the tests, provides test results, and includes recommendations regarding using this type of approach to boost training system effectiveness. Key test results and conclusions include:

- Students received a test after completing training. A training post-test / campaign pre-test set an initial post-training erosion / retention level. The *IDC* test group scored 81% correct / 19% incorrect with a post-campaign test score of 94% correct / 6% incorrect. The *Science in the Workplace* students campaign pre-test was 76% correct / 24% incorrect with a post-campaign of 85% correct / 15% incorrect. These test findings align with industry research that predict an initial erosion level that can be reduced or eliminated by a spaced repetition and reinforcement campaign (*Fahl, 2023*).
- Although both test group samples (thirteen students for the *IDC* and twenty-two students for the *Science in the Workplace*) are too small to extrapolate findings to the entire military training population, the campaigns are good leading indicators regarding the potential benefits of this methodology for other military training programs given test results and the alignment with related research.
- Full student participation required reinforcement and guidance by the instructors. This is a social / management issue more than a technical training one.
- A reliable and repeatable process to develop and distribute campaigns is required to make the methodology a workable process within existing schools, programs, and courses.

THE GOAL: PREVENT EROSION / BOOST RETENTION OF COURSE CONTENT / SKILLS

Goal Definition and Test Focus

Our primary goal focused on developing and testing a manageable and repeatable spaced repetition and reinforcement process to reduce erosion and boost retention. We focused on one aspect of training delivery: *Post-training erosion of knowledge and skills*. Research (and practical experience) tells us that knowledge and skill erosion immediately start after students complete a course, especially for objectives that are difficult, infrequent, and when they do not immediately perform what they learn due to delayed application or transfer (*Kohn, 2014*). Erosion typically begins

immediately after training and ranges from 20-50% within an hour of completing training and eventually plateaus at about 80-90% after a month, depending on post-training application and reinforcement (*Ebbinghaus*). Figure 1 depicts this erosion as the *Forgetting Curve*. Sponsors expect graduates to apply what they learn, thus getting additional retrieval and repetition as part of their jobs. However, infrequently performed objectives, complex objectives, and gaps between course completion and application may preclude on-the-job reinforcement and result in substantial retention erosion. Studies show that trainees forget a significant amount of what they learn, including critical skills (*Jastrzembski, 2017*).

Figure 1, Spaced Repetition and Reinforcement Impact on the Forgetting Curve

Erosion can also hamper the student's ability to leverage knowledge and skills developed in a foundational course in subsequent more advanced courses. Fixing this after a student completes a course requires additional instructor work, or extra study, or can adversely impact a student to the point that they cannot or do not want to continue in a program. Reinforcement and challenge / testing events delivered over an increasing spaced interval cannot only reduce the erosion associated with the forgetting curve but even increase final retention levels (*Scarf, 2017*).

Reliance on Massed Training

Based on reviewing course materials and observing delivery, both test courses reflected typical delivery time, instructor workloads, and cost constraints resulting in course structures that maximize delivery efficiency by using a content-heavy intensive training schedule to minimize costs and times. In other words, the courses represent typical delivery paradigms found across professional and skills development training and higher education courses. Although these processes are efficient, they confine repetition and practice to exist only within the course schedule. Delivery relies on *massed training* (compressed events within a focused program) with retrieval limited to the specific period of the course. Massed training does not include significant spacing between learning / performance events. Although trainees acquire the skills and knowledge they need to successfully complete training, courses may lack the retrieval practice, spacing, and post-training testing to result in long-term memory recall. Students may also suffer from *reactive inhibition*, where longer information-packed training sessions may cause fatigue and adversely impact their ability to concentrate / focus on their training. Courses, including the two test programs described in this paper, typically rely on massed training with intense focus on sequential topics with testing (*blocking*). Blocking can rapidly help trainees achieve proficiency (short-term memory) but does not typically result in long-term memory without additional support. The *IDC* and *Science in the Workplace* courses use massed training with a large amount of blocking delivered via an efficient system. Very few organizations leverage a spaced repetition and reinforcement model that begins after training is completed. Study and reinforcement occur as part of the initial delivery process or are relegated to post-delivery self-study. For example, in examining over three months of requests for quotes (RFQs) from the GSA MAS schedule, NAICS 511430 (*Professional and Management Training Development Services*), 50+ RFQs included training as a core performance requirement but did not include any sort of spaced repetition / reinforcement. They represent a wide range of agencies including the Department of Defense, Army, Air Force, Navy; Education, Energy, Health and Human Services, Homeland Security, Interior, Justice, State, Transportation, Treasury; Federal Acquisition Service, Federal Deposit Insurance Corporation, and the Small Business Administration. RFQs ranged from short courses to longer programs with simple to complex kinesthetic, cognitive, and affective domain objectives.

Leveraging Spacing and Repetition to Boost Retention and Reduce Erosion

As depicted by Figure 1, providing brief review / test events with increased spacing instead of relying *only* on massed training can significantly reduce memory erosion associated with the Forgetting Curve. The *spacing effect* is the observation that repetition and test events spaced in time tend to increase retention more than repetitions massed closer together in time. This effect boosts retention of all content, not just the content included in the repetition event. Research on the spacing effect dates to *Dr. Hermann Ebbinghaus* (1885) and his book*, Memory: A Contribution to Experimental Psychology*. The body of subsequent research shows that learners who recall information by taking a test right after training are less effective than those who take multiple tests over time (*events* in our test campaigns). The core principle of this approach: Retrieval practice and repetition spaced out over increasing time intervals help learners to convert short-term to long-term memory, significantly reducing erosion and boosting retention, including

"fixing" the initial 20% (immediately after receiving training) and 50% (within one hour of completing training) loss. Massed training programs often leverage *overlearning* to ensure students retain what they are learning. Overlearning consists of additional study or focus within their training session on content that the student has already learned. Although overlearning may promote better initial retention in the short term, it does not typically result in a high degree of long-term retention (*Rohrer, 2004*). Key approach elements are:

- Reinforcement needs to start as soon as possible after the participant completes the training program or course. This helps to arrest the rapid erosion that begins immediately after training is completed.
- Variability and spacing when combined can be more effective than relying on straight repetition over time. *Mnemonic variability* (creating different content, context, and meaning connections) when combined with spacing can improve retention of complex content while *associative memory* (simple connections, firmly linked content elements) is best served with spaced repetition and a lack of variability (*Cowan, 2024*).
- Overlearning helps with retention as does building new knowledge and skills on a foundation of existing competency (*Rohrer, 2004*) and (*Driskell, 1992*). However, overlearning alone does not result in long-term retention. Combining overlearning during training with a spaced repetition campaign that begins immediately after training can significantly reduce erosion and increase retention. Both test courses featured overlearning components during training coupled with post-training spaced repetition and reinforcement campaigns.
- Spacing intervals increase over time / over a campaign. The repetition and reinforcement challenge events help the learner to shift learning from shorter to longer-term retention. Distributing learning over longer time periods can generate better learning and retention than learning via intense massed training events delivered within a day or compressed schedule (*Scarf, 2017*).
- Reinforcement is tied to key performance objectives. Reinforcing these objectives has a retention boosting effect on not only the key objectives but also related content.
- Reinforcement in a campaign does not consist of simply reteaching the same content that was presented in the underlying course. Instead, reinforcement focuses on tight / short duration testing events with meaningful feedback. The content tested in these reinforcement and repetition events needs to leverage variability and application connections for more complex subjects and tasks (*Cowan, 2024*).
- Deliver reinforcement events within the normal workflow and not as gated out events that require going to a training facility or separate environment. A post-training campaign needs to be deliverable directly to the learner with a minimal amount of work-life disruption.
- Combine the approach with other elements into a holistic system. For example, overlearning (repetition) combined with immediate job-task application and building new knowledge and skills on a foundation of existing competency can help boost retention.

Spaced Repetition and Training Domains

We tested the spaced repetition and reinforcement methodology to reduce erosion and boost retention for cognitive objectives from the *Instructor Development* and *Science in the Workplace* courses. The *Instructor Development* course included psychomotor skills, but we were unable to test these after the campaign, focusing instead on the cognitive elements. Research studies indicate the methodology is an effective method to improve the retention of psychomotor skills. A 2023 study examined 1,662 publications to determine if "*Spaced training resulted in better performance scores and faster skill acquisition when compared to control groups with a single day (massed) training session.*" (*Fahl, 2023*). Although the authors noted that studies were too heterogeneous to substantiate outcomes, they were able to identify several instances of spaced learning performing better than massed training for hands-on skills. For example, they concluded that VR-based surgical training using spacing improved skill acquisition and retention more than comparative massed training. A different study of studies compared outcomes associated with spaced learning versus massed training (*Scarf, 2017*). The study identified a wide range of instances where spaced learning and repetition performed better than massed training. A diverse set of study examples include video games, interviewing, learning surgical skills, piano playing, electrical testing, alpha wave enhancement via bio-feedback, balancing, and golf putting.

CAMPAIGN DEVELOPMENT AND DELIVERY

Campaign Development.

We designed the *Science in the Workplace* and *Instructor Development* course test campaigns to combine repetition of key content with reinforcing short learning events or challenges (sets) delivered over increasing intervals (spacing).

For this approach to be practical, it must be relatively easy to create and use spaced repetition and reinforcement campaigns within existing training programs and systems. To meet that goal, we used a commercial off-the-shelf system to develop and deliver our campaigns. The instructors for both programs developed their campaigns after 30 minutes – one hour of coaching on applying the methodology and using the spaced repetition templates and tools. The time required to develop a campaign for a multiday course is minimal since the instructors were able to easily identify and reuse key content tied to course objectives. Both campaigns leveraged graphics and media from their respective courses and used a templated development tool to build campaign events and sets. The *Instructor Development* course is a stand-alone intensive multi-day training program designed to build instructor competencies for technical subject matter experts. The *Science in the Workplace* course is a multi-week undergraduate course that develops student competency to apply basic scientific principles within subsequent courses and their Apprentice program. The *IDC* campaign reinforced key delivery skills that are infrequently performed by many of the instructors. The *Science in the Workplace* campaign reinforced two primary objectives students need to succeed in subsequent courses. Table 1 captures the authoring sequence used to develop a campaign set. This sample depicts Question 1 variations that reinforce this key *Science in the Workplace* objective: "***Perform Unit Analysis Using the Scientific Method When Solving Problems***". Each set has four questions / test variations tied to this objective. Question variations included core content from the course and feedback regarding the answers. Table 1 is a sample completed development template. The instructor developed similar structures for other questions used in each set. The spaced repetition and reinforcement platform used the template and a scheduling tool to generate reusable campaign sets. The *IDC* campaign used the same approach. The platform converted the template into directly deliverable and reusable campaign sets. The templated process greatly reduced the time required to use the method, created events that students could easily access within their normal routines via email or mobile device texting, and automated development and distribution. This automated approach made the methodology easy to align with and reinforce existing courses without requiring instructional systems designers, technical staff, or additional scheduling / course management support.

Table 1, TCC Science in the Workplace Campaign Set Development Example

▼ (Topic1) **Newton's Laws of Motion. Estimated Duration**: 5 Minutes per Set.

　▼ **(LO1) Identify Newton's laws of motion.**

　　▼ **(Q1) Question 1**

　　■ **(V1) Variation 1**

Intro Text (optional): **Newton's First Law of Motion:** Every Object continues in a state of rest or uniform speed in a straight line unless acted on by a nonzero force.
Intro Media (optional):
Q Stem: Select the formula that represents Newton's First Law of Motion.
Q Distractors (Bold is correct):   ▪ F=ma   ▪ A = Net Force/mass   ▪ **P = mv**   ▪ I=Ft
Feedback Text (Do not include "Correct" and "Incorrect" verbiage, automatically included in header): **Solution:** Momentum is defined as the product of a system's mass multiplied by its velocity. In symbols, linear momentum p is defined to be p = mv, where m is the mass of the system and v is its velocity.
Feedback Media (optional):

　　■ (V2) Variation 2

Intro Text (optional): **Newton's Second Law of Motion:** Newton's second law states that the acceleration of an object depends upon two variables – the net force acting on the object and the mass of the object. The acceleration of the body is directly proportional to the net force acting on the body and inversely proportional to the mass of the body.
Intro Media (optional):
Q Stem: Select the formula that represents Newton's Second Law of Motion.
Q Distractors (Bold is correct):   ▪ F=mg   ▪ **a=F/m**   ▪ I=Ft   ▪ P=mv

Feedback Text (Do not include "Correct" and "Incorrect" verbiage, automatically included in header):
Feedback Media (optional): $a = \dfrac{F}{m}$, *is the formula to find acceleration from force and mass values.*
🟧 (V3) Variation 3
Intro Text (optional): **Newton's 3rd Law of Motion:** Newton's third law of motion states that for every action, there is an equal and opposite reaction.
Intro Media (optional):
Q Stem: Select the formula representing Newton's Third Law of Motion.
Q Distractors (Bold is correct):   **F=ma**   - P=mv   - I=Ft   - A=f/t
Feedback Text (Do not include "Correct" and "Incorrect" verbiage, automatically included in header): Momentum and force are defined mathematically as follows: p = mv (momentum = mass * velocity) F = ma (force = mass * acceleration)
Feedback Media (optional):
🟪 (V4) Variation 4
Intro Text (optional):
Intro Media (optional):
Q Stem: When a bowling ball strikes a bowling pin, which imparts a greater force upon the other? Which experiences a greater acceleration?
Q Distractors (Bold is correct):   **They impart equal force upon each other and the pin because it has less mass.**   - The bowling bowl has more force than the pin because of its greater mass and the bowling ball has more acceleration.   - The bowling pin has more force after being struck by the bowling ball and the pin has more acceleration because the pin has less mass.   - The bowling pins have more force being distributed when struck by the bowling ball and all of the acceleration force is transferred to the pins as well.
Feedback Text (Do not include "Correct" and "Incorrect" verbiage, automatically included in header): The bowling pins have more force being distributed when struck by the bowling ball and all of the acceleration force is transferred to the pins as well.
Feedback Media (optional):

Test Campaign Delivery

We used the **Hermann Learning Platform** to deliver the campaigns since it offered a proven, reliable, and repeatable off-the-shelf system to conduct spaced repetition and reinforcement campaigns. The platform delivered sets directly to students via their student or work emails. Other delivery options include mobile devices (text or email) or via Microsoft Teams. Participants receive a notification that their set is available, and they follow a simple link to the challenge event. Sets are designed to take about 3-5 minutes to complete and include immediate feedback. *Figure 2* depicts the campaign sets and actual spacing for the *Science in the Workplace* course. The campaign included four sets with event one beginning just after the last day of course content delivery with spacing originally timed to increase over the four sets. We adjusted optimum campaign spacing intervals to accommodate student schedules and to ensure full participation. We added an extra day to Sets 1-3 to ensure students were engaged / could take the events during their in-school labs. We compressed the campaign spacing to

Figure 2, *Science in the Workplace* **Campaign**

Figure 3, *Instructor Development* **Campaign**

ensure students completed their sets. Based on when students took an event within a 3-day window, this gave a 6-12 day space between Sets 1-2, 6-10 days between Sets 2-3, and 7-8 days between Sets 3-4. *Figure 3* depicts the four *Instructor Development* campaign sets delivered over an increasing interval with increasing spacing between sets. *Instructor Development* course graduates received their campaigns after completing the course and returning to their jobs and assigned duties. The instructor's job is a collateral function performed with their normal technical responsibilities. Graduates were not scheduled to immediately deliver training using their new skills after graduation.

TEST AND CAMPAIGN RESULTS

Spaced Repetition and Reinforcement Campaign Results

Table 2 displays the pre- and post-campaign results for the *Science in the Workplace* and *Instructor Development* courses. Both campaign post-tests indicate a significant reduction in post-training erosion compared to the pre-campaign / post-training test and an increase in retention based on reinforcement from campaign challenge events.

Table 2, Pre- Post-Campaign Tests Results

Course	Pre-Test (Correct)	Post-Test (Correct)	Remarks
Instructor Development	81%	94%	Pre-Test: All students were above the passing threshold. Post-Test: All students were at or above the 80% level
Science in the Workplace	76%	87%	Pre-Test: 5 of 21 students at or below passing, with most testing at 80% Post-Test: No students below passing, most at 90% or above.

The ANOVA single factor test (Tables 3 and 4) using Test 1 of the *Science in the Workplace* tests administered to both groups. The P-values for the Non- Hermann and Herman campaigns are 0.0304 and 6.348E-08 respectively. The null hypothesis (Ho) states there is no statistically significant difference between samples. The critical values for Non-Hermann and Herman campaigns are 3.7138 and 22.4780 respectively. ANOVA critical values for both groups are the same: 3.1588 and 3.1588. This supports rejecting the null hypotheses. The *Instructor Development* course pre- and post-tests did not track individual participant test scores and therefore we did not perform additional analysis for that test group. Instead, anonymous test results informed the mean for the group per the acceptable test parameters worked out with that client. Test results confirm the validity of the hypothesis "*A spaced repetition and reinforcement campaign will reduce post-training erosion and increase student retention of key course objectives*."

Table 3, ANOVA Single Factor Hermann Group

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Pre Test Receive Campaign	20	1430	71.5	339.7368421		
Post Test Receive Campaign	20	1670	83.5	129.2105263		
Test 1	20	1625	81.25	188.3815789		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1627.5	2	813.75	3.713893949	0.030468187	3.158842719
Within Groups	12489.25	57	219.1096491			
Total	14116.75	59				

Table 4, ANOVA: Single Factor, Control Group

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Pre Test No Campaign	20	1320	66	277.8947368		
Post Test No Campaign	20	1750	87.5	135.5263158		
Test 1	20	1829	91.45	87.31315789		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	7503.7	2	3751.85	22.4780927	6.34814E-08	3.158842719
Within Groups	9513.95	57	166.9114035			
Total	17017.65	59				

Post-Course / Campaign Pre-Tests

Participants received a post-training / pre-campaign test immediately after receiving course instruction. We did not report pre- / post-campaign performance by individual names for both courses since ***all*** testing was anonymous and the test team did not record or retain individual student names. Tests provided a basis to assess initial erosion / retention levels and subsequent effects of the spaced repetition and reinforcement campaign. Erosion, regardless of training topic or objective is significant and begins immediately after learner complete training. The *Science in the Workplace* campaign pre-test aligns documented an immediate level of erosion of about 24% as students completed training. Twenty-one respondents completed the ten-item test (210 responses). Pre-campaign test results:

- 159 correct answers or 76% of responses were correct (C).
- 51 incorrect answers or 24% of responses were incorrect (I).
- Pre-test Standard Deviation was 11.37.
- Highest score 90% (five students), lowest 50% (one student), with four students scoring below 70%. 70% is the Apprentice Program pass threshold. The most common score was 80% (seven students).

The *Instructor Development* pre-campaign test average was 81% correct. 18 respondents took the eight-item test (144 responses). Six of the eighteen respondents were not scheduled to receive the campaign but volunteered to take the pre-test.

- 117 correct answers or 81.25% of responses were correct (C).
- 27 incorrect answers or 18.75% of responses were incorrect (I).

Participant Engagement

A critical difference between the test approach and normal training delivery is the lack of control over participants engaged in the post-course spaced repetition and reinforcement campaigns. Whereas an instructor can direct student activity and course events during a training program, campaign delivery requires the active engagement and participation of the student or learner *after* they complete training. Participants in both test campaigns were volunteers. Although volunteers expressed a strong interest in receiving their campaign, actual engagement varied. Figure 4, Test Campaign Engagement, the right side pie chart depicts the engagement levels of the *Science in the Workplace* campaign participants. Twenty-two students received an invitation to take the Hermann campaign. Of those, four students took all four sets with thirteen students taking three sets (77% total) which we consider to be a fully active and beneficial engagement level. Two students took two sets at the end and beginning of the campaign, an active and beneficial engagement level. Two students took the final set, a somewhat beneficial but low engagement level. Figure 5, left side pie chart, depicts the engagement levels of the *Instructor Development* campaign participants. Ten of the twelve participants completed at least three events. Although the volunteer

Figure 5, Test Campaign Engagement

participants were enthusiastic, instructors from both courses needed to remind participants to complete their campaign events. We surmise that students may lose focus on completing spaced repetition events given that this method is not something they have received in previous courses, it is not routinely used in professional development or higher education programs, and campaign events are jockeying for attention within a daily barrage of normal work-life tasks. Training time is focused while campaign events occur within the framework of daily activity. Potential advocates or training system managers who wish to employ this method may need to develop strategies to enhance and proactively support high participant engagement levels to ensure spaced repetition and reinforcement campaigns are effective and achieve the desired results.
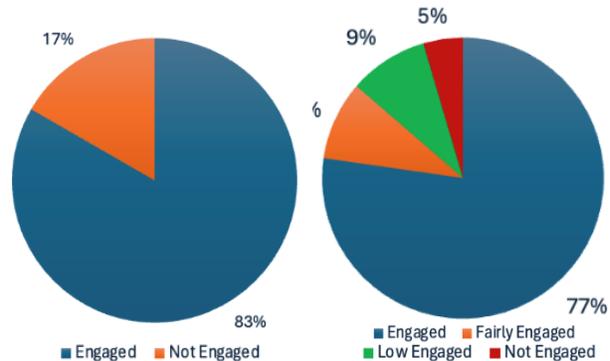
Spaced Repetition and Reinforcement Campaign Post-Tests

Instructor Development and *Science in the Workplace* campaign participants received a course-specific post-campaign test after they received their four campaign events. The post-test used different questions drawn from a test battery with the tests equivalent in complexity and focused on the same objectives as the post-training pre-campaign tests.

Nineteen participants of the *Science in the Workplace* course answered 10 questions for a total of 190 responses. Their aggregate score increased from a pre-campaign average correct score of 76% to a post-campaign average score of 85%. Of key interest, nine students who were at or below the normal passing threshold for their program raised their scores to at or above the passing level. Post-campaign testing results:

- 165 correct answers or 87% of responses were correct.
- 25 incorrect answers or 13.0% of responses were incorrect.
- Post-Test Standard Deviation was 11.08.
- Highest score 100% (one student), Mode/Most common score 90% (eleven students), Lowest score 70% (three students), no students below the 70% failure threshold.
- The student with the low score of 50% on the pre-test scored 80% on the post-test.
- Of the four students who scored below 70% on the pre-test, *all* scored above the pass threshold of 70% (one 70%, two 80%, and one 90%).
- Of the five students who scored 70% on the pretest, one did not take the post-test and the other four students scored 90% on the post-test.
- Two students who took a pre-test (80% and 90%) did not take a post-test (out sick).

Ten participants of the *Instructor Development* campaign answered 10 questions for a total of 100 responses. Their aggregate score increased from a pre-campaign average correct score of 81% to a post-campaign average score of 94%. Post-campaign testing results:

- 94 correct answers or 94.0% of responses were correct.
- 6 incorrect answers or 6.0% of responses were incorrect.

IMPLEMENTATION CHALLENGES AND LIMITATIONS

Our test results and the body of extant research on this methodology clearly indicate the potential benefits of reducing erosion and increasing retention. However, there are cultural and administrative paradigms that impact the method's acceptance and implementation. They include:

1. **Potential participation issues after course completion**. In a typical course, a student completes their training, is evaluated, and receives a certificate or graduation credit—they are done with the course. Even though a graduate may receive follow-on qualification training, localized training connected to their job, or follow-on advanced training, they tend to view the underlying course as completed. This method asks them to remain connected to the course over the spaced repetition interval even though they finished the underlying training and are no longer under the control of the school or course sponsor. This can adversely impact timely participation and campaign completion. Our initial discussions with participants and sponsors indicate the need to support implementation with associated administrative functions. For example, actual course credit may be assigned after completing the campaign instead of immediately after graduation. Although the time demands for refresher events are very low (typically less than 5 minutes), they still occur within the participant's daily post-course work-life environment. Our tests indicate the need to look at system and individual incentives to ensure full and active participation.

2. **Modification to the instructional design requirements**. The instructional design load is very low to use this method. Our campaign development required about 5-10% of the initial development time. Campaign developers reused content, media, and materials from the source course within the campaign. However, this small instructional design burden is predicated on the campaign sponsor accessing the source content and the cost-effective ability to leverage / reuse that content within the spaced repetition and reinforcement campaign. This should not be a problem for courses where the organization owns or has rights to the content but could pose additional costs or accessibility issues for content that is procured solely for the source course.

3. **Security vs. Accessibility**. The system we used for the test has an authority to operate (ATO) within government networks. However, security considerations may preclude participants from accessing campaigns via the tools they use in their daily lives (e.g., cell phones, tablets, and personal computers). Security considerations should be baked in during the initial design and development process including how students will access the campaign.

4. **Analytical processes to identify courses appropriate for spaced repetition and reinforcement**. The research indicates that spaced repetition can reinforce objectives across cognitive, affective, and kinesthetic domains (*Fahl, 2023*) and (*Scarf, 2017*). However, systematic use and implementation of the method across a broader enterprise indicates the need to consider the content during the initial analytical and design stages of course development. Asking questions such as: "*What are the key performance objectives that require reinforcement?*" and *"Where*

is skill and knowledge erosion adversely impacting field performance?" will focus methodology implementation on tasks that yield the most benefit to the organization. A campaign is not necessary to support tasks that are immediately performed after graduation while tasks that are not immediately performed but are critically important may be ripe for a campaign.

RESULTS AND RECOMMENDATIONS

Test results indicate a significant reduction in the knowledge and skill erosion typically associated with traditional massed memory teaching techniques used in an intensively focused course. Further, test results also show an increase in retaining key course content. Not only was erosion halted, but retention increased for students receiving the spaced repetition and reinforcement campaign. If applied across a curriculum, this approach and methodology can reinforce key content that is important for subsequent application in higher courses or within a student's job-task responsibilities. Test results yield the following preliminary findings and recommendations related to this approach:

1. **Test and apply this method within military training systems.** Military training organizations should conduct more extensive tests of this method to support key courses and learning programs, especially those where students graduate but do not immediately apply what they learn. For example, a graduate of a pipeline school may not get the opportunity to apply new knowledge and skills until they report to a new unit, or that unit receives new or upgraded systems. Improved student retention, especially for content that is critically important for subsequent courses and job applications, has the potential to reduce costs and improve performance on a wide scale, especially since spaced repetition and reinforcement methodology can improve the results of kinesthetic / psychomotor skills training (*Fahl, 2023*) in addition to the cognitive skills tested in our campaigns.

2. **Use spaced repetition and reinforcement in addition to the traditional approach used within schools, courses, and military training programs.** Spaced repetition reduced erosion and increased retention for students who completed courses that relied on massed training. The application of spaced repetition and reinforcement via a -- event campaign reduced student memory erosion and boosted retention. Pre-test scores align with research regarding typical erosion at the end of a training program and reflect a common level of immediate post-training retention. The post-test scores demonstrate not only halting post-training erosion but also boosting retention a full month after training. Of key interest, students who scored just at or below a normal passing threshold after initially receiving training significantly increased their scores to well above that level. This aligns with previously cited research that "*Spaced repetitions enhance the consolidation of memories to a greater extent than massed repetitions and providing time for memories to consolidate enhances the consolidation/reconsolidation of additional learning that can be fit into the same framework, resulting in faster learning and better retention.*" (*Scarf, 2017*).

3. **Leverage existing materials to minimize the workload associated with using this method.** Campaigns are easy to create and require far less development time than typical training programs. Campaigns should leverage media and content from the underlying course. Professor Jones, the TCC course instructor, required little assistance (30-45 minute coaching session) to use the *Hermann* platform to create a reinforcement and spaced repetition campaign for his students. Course developers can create a spaced repetition campaign directly from their source materials using system templates and tools. Use *COTS* platforms to minimize development and implementation costs.

4. **Ensure that students can easily access campaign events.** Test participants successfully accessed the Hermann system and could complete campaign sets without the need for external help or assistance. Delivery options include student email, mobile device texts, and delivery via MS Teams. This used email. An email link (after initial sign-up) directs the participant to their campaign set. Hermann can also support single sign-on (SSO) for ease of access.

5. **Research reinforces our initial results.** The spaced repetition and reinforcement campaigns demonstrated comparable results with different learners, content, and application settings. These results are supported by a review of current literature and other studies. The repetition and reinforcement associated with the method tie into the core principles of how people learn: Reinforcement and repetition can help us connect what we learn in training into effective actionable mental models for real-world application (*How People Learn II, Pg. 90*).

6. **Include an engagement plan.** Consider how often we receive emails, surveys, phone calls, visits, and other interruptions as part of our daily work. The time students needed to complete their spaced repetition and reinforcement campaigns was minimal: 5 minutes per event, 4 events per campaign, or less than 30 minutes over a month. Still, we needed to reinforce and request participation and completion several times despite the participants' enthusiastic initial volunteer. Applying this methodology requires more than simply developing the technical approach. Adopting it involves delivering events to students who may have already graduated from a

course and returned to their normal unit or job. Thus, the training system must adjust expectations and manage this change process. For example, perhaps a graduation certificate or service record entry does not occur until after the individual completes their campaign.

REFERENCES

Akresh-Gonzales, J. (2019, May 17). Spaced Repetition: The Most Effective Way to Learn. *NEJM Group education*. *https://knowledgeplus.nejm.org/blog/spaced-repetition-the-most-effective-way-to-learn/*

Cowan, E.T., *et al*. (2024), The Effects of Mnemonic Variability and Spacing on Memory over Multiple Timescales. *Psychological and Cognitive Science*, 121 (12) e2311077121 https://www.pnas.org/doi/10.1073/pnas.2311077121

Driskell, J. E., Willis, R. P., & Copper, C. (1992). Effect of Overlearning on Retention. *Journal of Applied Psychology,* 77(5), 615–622. https://doi.org/10.1037/0021-9010.77.5.615

Ebbinghaus, H. (1913). *Memory: A Contribution to Experimental Psychology,* (H. A. Ruger & C. E. Bussenius, Trans.). Teachers College Press.

Fahl, J.T., Duviver, R., Pierie, J-P. E.N., Reinke, L., & Schönrock-Adema, J. (2023). Towards Best Practice in Developing Motor Skills: A Systematic Review on Spacing In VR Simulator-Based Psychomotor Training for Surgical Novices. BMC Medical Education, Vol 23, #54. https://bmcmededuc.biomedcentral.com/articles/10.1186/s12909-023-04046-1

Jastrzembski, T.S. *et al.* (2017). Personalizing Training to Acquire and Sustain Competence Through Use of a Cognitive Model. In: Schmorrow, D., Fidopiastis, C. (eds) Augmented Cognition. Enhancing Cognition and Behavior in Complex Human Environments. AC 2017. Lecture Notes in Computer Science, vol 10285. Springer, Cham. https://doi.org/10.1007/978-3-319-58625-0_10

Kohn, A. (2014). Brain Science: The Forgetting Curve-The Dirty Secret of Corporate Training. *The Learning Guild*, https://www.learningguild.com/articles/1379/brain-science-the-forgetting-curvethe-dirty-secret-of-corporate-training/

National Academies of Sciences, Engineering, and Medicine. 2018. How People Learn II: Learners, Contexts, and Cultures. Washington, DC: *The National Academies Press*. https://doi.org/10.17226/24783.

Practical Psychology. (2020, April). Ebbinghaus Forgetting Curve (Definition + Examples). https://practicalpie.com/ebbinghaus-forgetting-curve/.

Rohrer D., Cepeda, N.J., Pashler H., Taylor, K., & Wixted J.T. (2004), The Effect of Overlearning on Long-Term Retention. *Applied Cognitive Psychology*, *Vol 19 Issue 3*. https://doi.org/10.1002/acp.1083

Scarf, D., & Smith, C.D., Spacing Repetitions Over Long Timescales: A Review and a Reconsolidation Explanation (2017). *Frontiers in Psychology*, 8: 962. IN National Library of Medicine, National Center for Biotechnology Information https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5476736/#B42

Spaced Repetition: Your Guide to Enhancing Memory and Retention, Penon, 13 Jan 2024 https://medium.com/@penon/spaced-repetition-your-guide-to-enhancing-memory-and-retention-36bbc18e5da2