EXAMINING THE EFFECTS OF LEARNING THEORY IMPLEMENTED WITHIN AN ONLINE AND SELF-PACED LEARNING PATH

THESIS

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Abstract

The United States military must continue to innovate and improve the way we fight and defend against our near-peer adversaries. Emerging technologies such as machine learning, artificial intelligence, and reverse engineering are paving the way for an increasingly complex security environment. A core tenant of winning in this new era of warfare is how we educate and train our military force. Many of the online trainings made available to servicemembers today fall short in the implementation of existing learning theories. This research identifies a gap in the current literature regarding common learning theories, noting that there is a lack of research regarding the implementation of active recall, spaced repetition, and elaboration into fully online and asynchronous learning paths (LPs). This research surveys the current literature regarding the topics at hand, produces a framework for LP development, develops a LP for Agile software development (an emerging topic of interest for the DoD), and examines the effects of three forms of learning theory within an online and self-paced LP through a human-subjects research experiment. A workshop and an associated LP are developed that implement and test the effects of these three learning theories. The results from the final assessment and pre- and post-workshop surveys showed a positive benefit for competence and confidence with presented material within the LP, but more research is necessary to determine how these three theories affect motivation.

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EXAMINING THE EFFECTS OF LEARNING THEORY IMPLEMENTED WITHIN AN ONLINE AND SELF-PACED LEARNING PATH

I. Introduction

1.1 Background

The United States is facing a growing power struggle between near-peer adversaries. The 2018 National Defense Strategy (NDS) [1] states that "inter-state strategic competition, not terrorism, is now the primary concern in U.S. national security." The document also states that "we are emerging from a period of strategic atrophy, aware that our competitive military advantage has been eroding." China's influence is growing throughout the globe through its military and economic power, and Russia has embarked on a "serious military modernization effort" [2]. Our near pear adversaries have increased their use of "gray-zone" tactics [3] such as information warfare and incremental aggression in order to erode U.S. power while keeping actions below the threshold of war. Emerging technologies such as artificial intelligence and machine learning are set to affect the future of warfare in unpredictable ways, leading to an "increasingly complex security environment" defined by rapid technological change [1].

These are just a few of the challenges facing the future of the U.S. military. Education is a core concept that underlies these issues. How we respond to emerging threats and rapidly changing technologies depends on how effectively we train and

educate our military force. The 2018 NDS also states that military education "has stagnated, focused more on the accomplishment of mandatory credit at the expense of lethality and ingenuity" [1]. This notion is echoed by Chief of Staff of the Air Force Gen. Charles Brown when he listed education and training as the first action order in his 2020 document "Accelerate Change or Lose" [4].

This thesis attacks a portion of education and training within a military context. Specifically, we research the effects of three existing forms of learning practices within an online and self-paced learning path (LP). This research can be thought of as an extension of previous research by Tomcho [5] that examined LPs through the lens of motivation and engagement. A core assumption present in this research is that the more time that was spent with learning materials, the more learned. This thesis addresses a portion of this assumption by asking: "How do we ensure learning is actually occurring within LPs?"

1.2 Research Approach

This research develops an Agile software development LP and implements it within an Agile workshop. The workshop, along with the LP that each participant followed, is completely online and self-paced. The online model was chosen because an online learning experience is simply the quickest way you can distribute information and education. We aim to investigate how we can improve this process.

We drew upon existing psychology and pedagogical research to select three learning practices (active recall, spaced repetition, and elaboration) to embed within the LP. The participants within the workshop are split into two groups: Group 1 (control

group) progressed through the Agile LP that did not have these three practices built within, and Group 2 (experiment group) whose Agile LP had implementation of the three theories. A final assessment was given to each group upon the conclusion of the workshop. We analyzed these results, along with results from a pre- and post-workshop survey, to address the following research questions:

RQ1: How do the learning theories of active recall, spaced repetition, and elaboration affect learning outcomes in online LPs?

RQ2: To what extent does employing active recall, spaced repetition, and elaboration affect confidence with presented material in online LPs?

RQ3: To what extent does employing active recall, spaced repetition, and elaboration affect user motivation within online LPs?

RQ1 attempts to understand how these three learning theories affect the amount of knowledge gained by each participant. This was measured by the final assessment present in both versions of the LP. We hypothesize that Group 2 (experiment group) will have better scores and learning outcomes than Group 1 (control group).

RQ2 investigates how these three learning practices affect confidence with the presented material. Do these three practices allow the participant to have a stronger sense of confidence regarding the material when compared to Group 1? Confidence is self-reported by each individual via the pre- and post-workshop surveys. The research team hypothesizes that Group 2 would report higher confidence levels upon the conclusion of the workshop.

RQ3 examines if there are any effects on motivation aided or caused by the implementation of active recall, spaced repetition, and elaboration. These three theories

are asking for more effort from the learner, at least relative to a baseline LP that simply presents the material and asks you to learn it. Does this increase or decrease motivation? The research team hypothesizes that there could be a negative effect on motivation for Group 2.

1.3 Assumptions and Limitations

The following assumptions are identified in relation to LPs and our Agile workshop:

- All participants are giving a genuine effort throughout the workshop, meaning that participants are attempting to learn and understand presented material. We also assume no one has any ulterior motives regarding the research.
- The quizzes and assessment questions given throughout the workshop facilitate learning and effectively cover the presented material.
- Our implementation of active recall, spaced repetition, and elaboration is pedagogically sound.

1.4 Contributions

Major contributions of this work include:

- A general framework for creating learning paths was created and presented.
- Learning paths were created for Agile software development beginners. This path covers the basics of Agile, Agile principles and practices, Agile technologies, and more. The Agile workshop, and associated LP, was able to provide education to 72 DoD members.

- Examined the effects of the learning practices of active recall, spaced repetition, and elaboration within a fully online and asynchronous LP. These results give insights into how existing learning practices can be integrated into LPs.
- Collected attitudes toward learning theory, motivation, online trainings, and more within the military community. These survey responses have implications for the future development of online education and training.

1.5 Document Overview

This thesis document is arranged in five chapters. Chapter II gives background information on learning paths, learning theory, existing learning management systems (LMSs), motivation, and Agile software development. Chapter III outlines the creation of the Agile LP and workshop, as well as the methodology for the human subjects research experiment. Chapter IV presents results and interpretations of the collected data. Chapter V summarizes the research, discusses its significance and implications, and provides recommendations for future research.

II. Background and Literature Review

2.1 Overview

This chapter gives background information and a literature review on relevant topics. Covered topics include: learning paths, learning theory, existing learning management systems, motivation (via the Octalysis framework), and Agile software development.

2.2 Learning Paths

A learning path (LP) serves as a roadmap that aids the user in navigating and orienting themselves within a particular topic. LPs typically consist of a sequence of learning activities that help users achieve specific learning goals [6]. The authors of [7] define a learning path as a sequence of learning tasks or activities designed to assist the student in improving their knowledge or skill in a particular subject.

The learning path's formality level must be considered [8]. Does the LP represent a formal training requirement, or does it represent a path of personal mastery to a topic? In the former case, it is often necessary that all nodes are satisfied. In the latter, an

individual could make decisions on how far they would like to progress within the LP based on their level of desired knowledge.

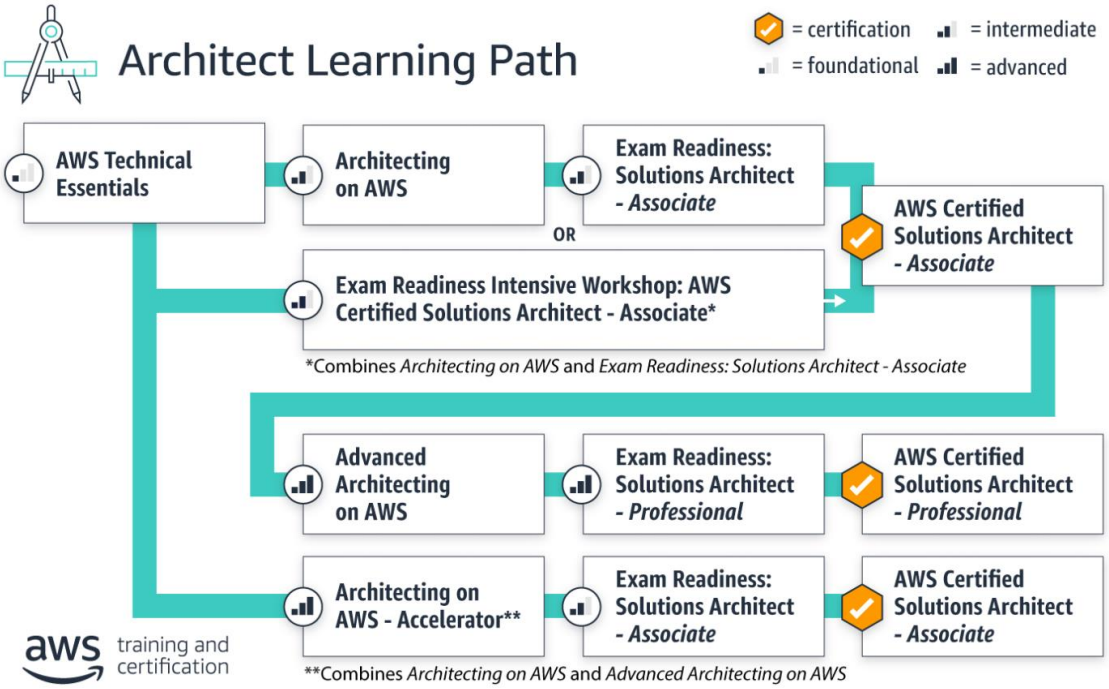


Figure 1: Sample Learning Path [9]

Figure 1 shows the path to different levels of AWS certifications. If a learner is interested in the "AWS Certified Solutions Architect- Professional" certification, they could take one of two paths to achieve the "AWS Certified Solutions Architect – Associate" certification, then continue along the path to achieve the Professional certification. This LP represents a formal path within an organization to achieve a desired level of knowledge. This figure is presented only to give a visual representation of what a LP can look like, not because it is a perfect LP.

In order to create a learning path, certain characteristics or attributes of the LP must be specified. Based on a review of literature in the fields of curriculum design and

lifelong learning, the authors of [10] state that LPs must consider the 10 characteristics listed in Table 1.

Characteristic	**Description**
Modular composition	LPs must be able to be built from units
Nested composition	LPs must be able to be composed of other LPs
Learning outcomes	LPs are defined in terms of learning outcomes
Entry requirements	It must be possible to specify entry requirements for a LP
Selection	It must be possible to specify which elements of a LP are mandatory and which are optional
Sequencing	It must be possible to specify a fixed order in which elements of a curriculum are to be completed
Temporal coordination	A LP specification must be able to express parallel programming of two or more learning actions
Completion	The requirements for completion of a LP must be able to be specified
Conditional Composition	It must be possible to specify conditions under which LP elements are to be included/excluded
Substitution	LP specification must enable description of substitution rules. Substitution rules describe which units in the learning path might be replaced and the criteria that exist regarding the substitute.

Table 1: Learning Path Characteristics [10]

These characteristics are used to develop a general framework for the creation of LPs that is presented in Chapter 3.

Rather than allowing the user to attempt to orient themselves within the topic, LPs allow the learner to focus on the actual material. Failure to contextualize the learning activities is one common pitfall to online learning environments [11]. The user spends too much time and energy finding material on their own and attempting to "connect the dots" between sometimes very complex concepts.

Other than a failure to contextualize the learning activities, learners face another problem. Too much information is available, and not all of it is true or reliable. The ubiquitous nature of present technology has enabled easy access to a plethora of information by anyone with an Internet connection [12]. Attempting to process all this information, especially with a topic they are not familiar with, is a strain on the learner [12]. This effect could be referred to as information overload, which occurs when the amount of input to a system exceeds its processing capacity [13] [14]. Information overload and the proliferation of information has imposed an overload on students [12] [15] [16]. The authors of [17] use the term "information anxiety" when it comes to students and their inability to effectively make use of necessary information. Dr. Will Thalheimer, an expert in the field of e-learning, states that the biggest mistake in instructional design is presenting too much information [18].

Information overload shares many similarities with cognitive load theory (CLT). CLT proposes that "an individual's brain has limited working memory with respect to the amount of information it can hold and process at one time without overloading its

processing capacity" [12]. CLT breaks down cognitive load into three categories, briefly defined below [19]:

- Intrinsic cognitive load – stress on working memory due to the difficulty of the learning material
- Extraneous cognitive load – stress on working memory due to instructional procedures
- Effective cognitive load – stress on working memory due to the presentation of information and learning activities

LPs aim to reduce extraneous and effective cognitive load by providing a framework of the topic to the learner. CLT is one of the most important theories in psychology as it relates to education and learning [20]. A more extensive overview of the topic can be found in [20].

2.3 Learning theory

This section presents three learning theories that are applied in the Agile Software Development LP. These theories (active recall, spaced repetition, and elaboration) are not novel discoveries and have been studied for some time. The authors of [21] provide a meta-analysis of 10 forms of learning theory, examining each theory on its degree of effectiveness. They ranked active recall and spaced repetition with high utility (the only 2 of the 10 with such a ranking), and elaboration received a ranking of medium utility (citing that the core reason for a medium ranking, rather than high, was the amount of research available on the topic). This thesis explores how to implement these three established learning theories into a fully online and self-paced LP. It is important to take

a research-based approach to teaching, as there is currently a preference for relying on intuition and what we think works when it comes to learning [22]. For example, the techniques of rereading, summarization, and highlighting all received a ranking of low utility from [21].

2.3.1 Active Recall

Active recall refers to bringing previously learned material back into memory. The learner is simply thinking about and recalling what they have previously learned. This type of learning practice is more efficient than re-reading material [22] [23], highlighting material, and summarizing material [21]. The testing effect [24] is a term used almost synonymously with active recall. The testing effect occurs when bringing information to mind when testing yourself, or when attempting to perform on a test or exam. Research has shown that the benefits of the testing effect are even seen when tests are open book [21] [25] [26]. Studies have manipulated the number and frequency of practice tests, with the simple conclusion being that the more frequent recall, the better [21]. However, the timing of the practice tests does have an impact, with research strongly concluding that the longer break between sessions is better than shorter breaks [27] [28] [29]. More information on this spaced effect is presented in the following section. The benefits of active recall have been shown to affect individuals of all ages, from kindergarten to old adults [21]. The authors of [30] even found positive results from active recall in individuals with Alzheimer's disease.

The testing effect is very similar to the definition of active recall, however active recall does not have to take the form of a test to be effective [22]. Even testing without feedback is beneficial [31] [32]. This makes sense, as even if you aren't being graded or

receiving feedback from a teacher, testing yourself allows you to see where the holes in your knowledge are.

Active recall isn't just about remembering. It has a direct effect on learning [22] [33], meaning that "when we bring information to mind from memory, we are changing that memory, and research suggests we are making the memory both more durable and more flexible for future use" [22]. Memorizing facts is important in some instances, but active recall also allows the student to use and apply the information more flexibly in the future [22]. Active recall has even shown positive effects on tests that "require inferences or the application of previously learned material" [21] [34] [35].

There is evidence that shows that providing short-answer questions rather than multiple choice questions might be more beneficial to the learner, but the difference seems to be small [36]. For more extensive information and recent reviews of active recall benefits see [32] [37] [38] [21]. The bottom line is that retrieval practice, no matter the form it takes, is beneficial.

2.3.2 Spaced Repetition

Spaced repetition is a simple concept. It refers to a method of study that spaces practice out over intervals rather than in one big chunk. Spaced repetition, or distributed practice, refers to a schedule of learning rather than the kind of learning [21]. This learning technique was first researched back in the late 1800s by German researcher Hermann Ebbinghaus as he examined his ability to retain made up syllables over a period of time. He would space out his practice over various time periods, and over the course of a few years was able to conclude that "with any considerable number of repetitions a suitable distribution of them over a space of time is decidedly more advantageous than

the massing of them at a single time" [22]. Most students understand that cramming material right before an exam isn't a good idea but tend to do it anyway [39]. This is a prime example of doing what feels good to us when it comes to learning, rather than doing what we know is more beneficial but maybe more effortful.

Spaced repetition has been explored in a variety of topics and settings [22]: vocabulary learning [40], learning from strictly text passages [41], problem-solving [42], learning related to playing a musical instrument [43], and pictures [44]. Of course, these are not the only areas in which spaced repetition has been proven to be beneficial. Hundreds of experiments have been performed that demonstrate the advantages of spaced practice [45] [46]. The benefits of spaced repetition are seen across the board, even when total study time is kept the same [45]. There is little doubt that spaced repetition produces more durable long-term learning than massed practice [47]. In fact, the authors of [48] reviewed over 250 studies involving 14,000 participants and found that "students recalled more after spaced study (47%) than after massed study (37%)" [21]. Most students who have crammed for an exam are familiar with this concept, as they might have remembered enough to pass the exam the next day, but that information that was "learned" is likely long gone soon after the test.

Data from [49] show that performance was best when the lag, or time between study sessions, was "approximately 10-20% of the desired retention interval." For example, to remember something for 1 week, learning episodes should be spaced 12 to 24 hours apart; to remember something for 5 years, the learning episodes should be spaced 6 to 12 months apart" [21]. Similar to active recall, the benefits of spaced repetition are seen across all ages [21].

The benefits of spaced repetition do not stop with memory. It has also been shown to aid in problem solving and the transfer of learning to new contexts [45]. Students performed better after spaced practiced, not just on memorization types of questions but also on questions that required them to apply their learning to new problems [45]. This is an important result. When teaching, the end goal is typically not for the student to have memorized material, but to have learned enough to be able to apply the material to new situations in the future. Spaced repetition can be combined with active recall to amplify the benefits that each technique gives on its own [45]. Spaced retrieval practice leads to better retention than spaced rereading, as shown in [50].

2.3.3 Elaboration

Elaboration involves expanding upon and adding to something in memory. The neurological processes that comprise memory are beyond the scope of this research; however, it is sufficient to say that "when new information is integrated and organized with information that was already known, this process makes it easier to remember the new information later on" [22]. Elaboration encourages the learner to think deeper about the material.

According to a framework given by [51] and [52], information is processed at various levels, and one will remember information better when it is processed at a deeper level [22]. Elaboration, or elaborative interrogation, enhances learning by "supporting the integration of new information with existing prior knowledge" [21]. There is evidence that the level of prior knowledge does seem to make a difference in the effects of elaboration, with the effects generally increasing as the level of prior knowledge increases [21]. In other words, profiting from elaboration without a baseline level of

knowledge of the material is difficult. Elaborations must be generated by the learner, rather than simply given to them to be effective [53].

The authors of [22] give a few examples of elaboration in practice. I will focus on the strategies of "elaborative interrogation" and "concrete examples." Elaborative interrogation is simply asking for *how* and *why* things work the way they do. Continuing to ask these questions until gaps are found in knowledge allows the learner to assess how much they know by causing them to think deeper and deeper about the material. Concrete examples, on the other hand, allow the learner to test themselves by making sure they actually understand the material rather than only understanding a specific instance of the material. Research shows that students often only remember surface details rather than the underlying structure [22]. Elaboration aids in remembering and understanding abstract ideas, as it is easier for humans to remember concrete information rather than abstract information [22] [54]. It is important to note that there are limited studies available on the durability of elaboration [21]. In other words, does elaboration facilitate increases in learning outcomes after meaningful delays? Further research is needed to determine if these benefits could easily pair with spaced repetition to increase durability.

2.3.4 Existing Learning Theory Implementation within Learning Management Systems

The research behind why these three forms of learning theory are effective, at least in a traditional classroom or experimental setting, is extensive. If these benefits have been established, it would make sense for existing learning management systems (LMSs) to have implemented these results into their online learning platforms. The authors of [55] provide a report to answer the question, "Do Learning Management Systems Really

Manage Learning?" The researchers specifically studied the four most widely used LMSs for K-12 education (Canvas, Google Classroom, Schoology, Moodle). They found that although some LMSs have generic features that can be used to implement certain forms of learning theory, there are typically no internal features that allow you, or teach you, to do so. They came to the conclusion that "due to the lack of features that specifically help learners learn according to the science of learning and development, I am inclined to favor the term "course management system" to describe these tools rather than learning management system, as identified by [56]" [55]. The researchers advanced past the four most common LMSs to study 23 others. They found that "0/23 have features designed around student needs for productive learning" and "0/23 contain framing for teachers on the science of learning and development" [55]. Instead, teachers and students are forced to not only have internalized relevant information and research on learning theories, but also must design their own individual processes to attempt to incorporate them.

This is not to say, however, that no tools exist that do implement common learning theories or learning practices. Anki, a common flashcard application, implements active recall, spaced repetition, and interleaving (a learning theory beyond the scope of this research, entailing studying or reviewing multiple subjects in one sitting to draw connections between them). Active recall is seen through the use of flashcards. Spaced repetition is implemented via an algorithm embedded within the application. Anki keeps track of a review schedule for each flashcard, with the review period resetting (or at least becoming more frequent) when you incorrectly answer a card. The time between reviews can extend over a long period of time. In a personal account found in [57], the author reports that he has created over 10,000 flashcards, with the average review period

between cards being 1.2 years. This is all kept track of by the application itself, allowing the user to offload this process.

Duolingo, an award-winning language platform, also implements common learning theories. Student models are created within the application, capturing what the student has learned and how well they could recall this information at any given time [58]. Students are encouraged to review material according to the timelines given by these models. Research by [59] suggested that "34 hours of Duolingo is equivalent to a full semester of university-level Spanish instruction."

These are only two examples of technologies that focus on applying learning theory to create better outcomes for learners. Applications like Anki and Duolingo could continue to be engineered and refined to improve efficiency and effectiveness. LMSs could create similar systems or incorporate existing applications into their sites to focus more on learning rather than simply course management.

2.4 Motivation

This research examines how participant's attitudes and motivation levels are affected by the three learning theories outlined above. The Octalysis framework [60] is utilized. This framework breaks down human motivation into eight core drives [5]. Octalysis is commonly used to explore the gamification of online systems, however this is not the focus of this thesis. The Octalysis framework was used to gauge what motivates each participant to aid in the analysis of experiment results.

The eight core drives that comprise the Octalysis framework are given in Table 2, with each of the core drives given in [60] and descriptions outlined in [5].

Core Drive	Description
Epic Meaning and Calling	"People are motivated because they believe they are engaged in something bigger than themselves."
Development and Accomplishment	"People are driven by a sense of growth and a need to accomplish a targeted goal." This core drive focuses on progress, seeing how far they have come and what they could possibly achieve.
Empowerment of Creativity and Feedback	This CD is emphasized by imagination and during "play". These users enjoy making their own decisions and experimenting with new designs and ideas
Ownership and Possession	"This CD represents the motivation people have to obtain something and consequently their desires to improve and protect it."
Social Influence and Relatedness	"This CD involves activities motivated by what others think, do, or say. Mentorship, competition, companionship, and group quests are all inspired by this core drive."
Scarcity and Impatience	"Wanting something because it is currently unavailable or simply because it is hard to obtain are the basic examples" of this core drive.
Unpredictability and Curiosity	This is the core drive behind "people's obsession with experience involving uncertainty and chance. This core drive also encompasses people's desire to explore the unknown in the search of surprises."
Loss and Avoidance	"This drive motivates people through the fear of losing something or having negative events occur."

Table 2: Octalysis Framework Core Drives [60] [5]

These core drives aim to explain what motivates individuals. Participants were surveyed in an attempt to gain insights into what core drives were more open to more effortful learning (through the use of the three learning practices of active recall, spaced repetition, and elaboration). These drives could also affect how participants feel towards learning paths and online trainings in general. Perhaps if we could begin to understand what core drives motivate the members of our command we could tailor their learning experience to support their internal motivations.

2.5 Agile Software Development

A learning path must have a topic. The research team decided on Agile Software Development because it is a technical topic of interest related to the DoD's Strategy on Digital Engineering [61]. More information on this decision can be found in Section 3.2.1. This section, instead, focuses on briefly describing Agile Software Development.

According to the Agile Alliance, "agile software development is an umbrella term for the set of frameworks and practices based on the values and principles expressed in the Manifesto for Agile Software Development and the 12 Principles behind it" [62]. Agile focuses on agility and adaptability [63]. The need for a more lightweight model of software development grew as frustrations with traditional models mounted. Traditionally, software development followed a very sequential approach, breaking down the project into phases, with each phase requiring the previous phase to be completed. This approach means progress only flows downwards from one level to the next, which is where the term "waterfall software development" originated [63]. Rather than focusing on long and sequential release cycles, Agile focuses on short sprint release cycles [64]. Aspects of Agile were beginning to creep into development teams in the 1990s, but the principles were not formalized until 2001 with the release of the Manifesto for Agile Software Development and the Twelve Principles of Agile Software. The Manifesto is given in Figure 2, and the Twelve Principles are listed in their entirety in Appendix E [65].

Figure 2: Manifesto for Agile Software Development [66]

A 2013 survey [67] concluded that “92% of respondents believe that agile approach assists them in managing changing customer requirements; 87% of them agree that agile approach helps improve their team's productivity whereas 70% believe that agile software approach accelerates the software development process” [68].

Agile software development is an umbrella term. Many different frameworks and methodologies can be implemented and applied according to project and personnel needs. For example, [69] gives a survey of 8 Agile software methodologies, focusing on how each approaches requirements engineering. A more exhaustive summary of prior research within an agile context can be seen in the survey by [70] and in a more recent “survey of surveys” about agile by [71]. The topic of Agile provided a breadth of material that gave

the research team opportunities to not only test memorization and recall of material but also provide opportunities to elaborate on a variety of Agile processes and practices.

2.6 Conclusion

Learning paths, learning theory, motivation, and Agile are all linked together via this research. This chapter provided descriptions and background information on each topic and explained how they each applied to this thesis. The next chapter, Chapter 3, outlines and describes the Agile workshop and human subjects research experiment.

III. Methodology

3.1 Overview

The methodology is divided into three distinct sections. The first section discusses the development of the Agile LP. The following section discusses the development of the workshop. The final section discusses the experimental methodology applied within the context of the workshop. To briefly summarize, an asynchronous, fully online workshop was developed to teach Agile Software Development using an experimental learning path that incorporated the learning theory techniques of active recall, spaced repetition, and elaboration.

3.2 Learning Path Development

3.2.1 Why Agile?

The topic of Agile Software Engineering was chosen because it is a technical topic of interest related to the DoD's Strategy on Digital Engineering [61]. The researcher recently completed a graduate course called "SENG 593: Agile Software Systems" and thus was familiar with the material. The experimental learning path leveraged portions of the graduate material to ensure currency of the topic. Furthermore, the entire set of learning path material was validated by the SENG 593 instructor and Air Force course sponsor.

The LP is designed for individuals who were previously unfamiliar with the topic of Agile. It attempts to cover introductory material and introduce the participants to avenues that could be explored further if it interests them or is required for professional

development. One of the design goals involved developing a curriculum with broad applicability to DoD affiliated personnel.

An LP made for Agile beginners also gives the additional benefit of laying the groundwork for supplementary LPs that have a narrower focus. The long-term goal involves hosting on Avolve, a crowd-sourced education and training platform for the Department of Defense. Avolve is interested in creating learning paths for topics important in the DoD.

3.2.2 Generalized LP Template

Leaning paths serve as a roadmap that aids the user in navigating and orienting themselves within a particular topic. They consist of a sequence of learning activities that guide a user toward a specific learning goal. A general framework for creating LPs was developed and is described as follows:

1) Brainstorm topics that should be included within the LP.
    - At this step, creating a mind map of the topic of interest could prove to be helpful. You are attempting to orient yourself within the topic and all that it entails.
2) Determine what the goals of your LP and what level of detail you would like to cover the topic in.
    - What is the educational end result for the user after completion of the LP?
    - Who is the target audience and what is your experience level with the topic? Ideally, the LP could handle users of many experience levels and allow them to orient themselves accordingly. However, for this LP and

this experiment, we are focusing primarily on individuals who are unfamiliar with Agile.

3) Determine the structure or general outline of the LP.
    - Is there pre-requisite information that must be learned beforehand? If so, should this be included in the LP or is the topic large enough that a separate LP is warranted?
    - Is the subject divisible into "pillars" that represent different aspects of the subject?
    - Could there be multiple entry points within the path or does it only make sense for the user to start in a specific section? Can learning objectives still be achieved if users start at different parts of the path?
    - This step will likely be an iterative process.
4) Determine how you plan to teach the material
    - Online? In-person? Are slides/videos/articles going to be presented?
    - Are there any specific forms of learning theory that you would like to include within the LP?
5) Elicit feedback, consult SMEs, refine.

3.2.3 Learning Path Structure

The LP that was created is visually represented as a graph with nodes and edges. Each node represents a topic of Agile. The edges connecting the nodes represent the relationships and learning sequence between topics. In this simple LP, the users are asked to follow a specific order, and the order is presented with edges connecting the topics.

This decision to have a singular path through the LP was necessary from an experimental perspective because it ensured all participants progressed through the same material. If individuals had the option to pursue (or not pursue) certain topics, this would introduce additional variables to the experiment. The learning path that was created is shown in Figures 3-5.

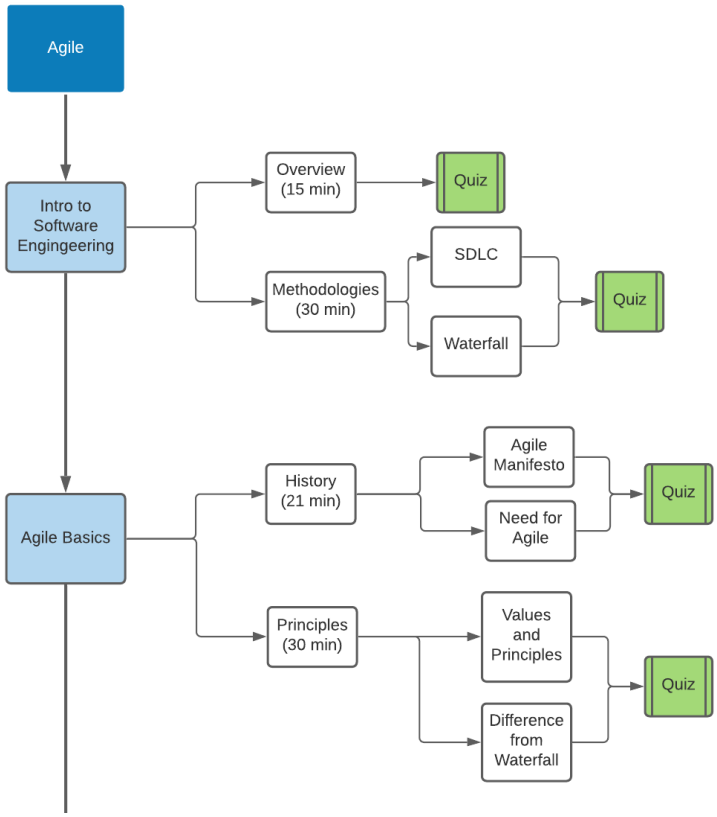


Figure 3: Agile LP (Part 1)

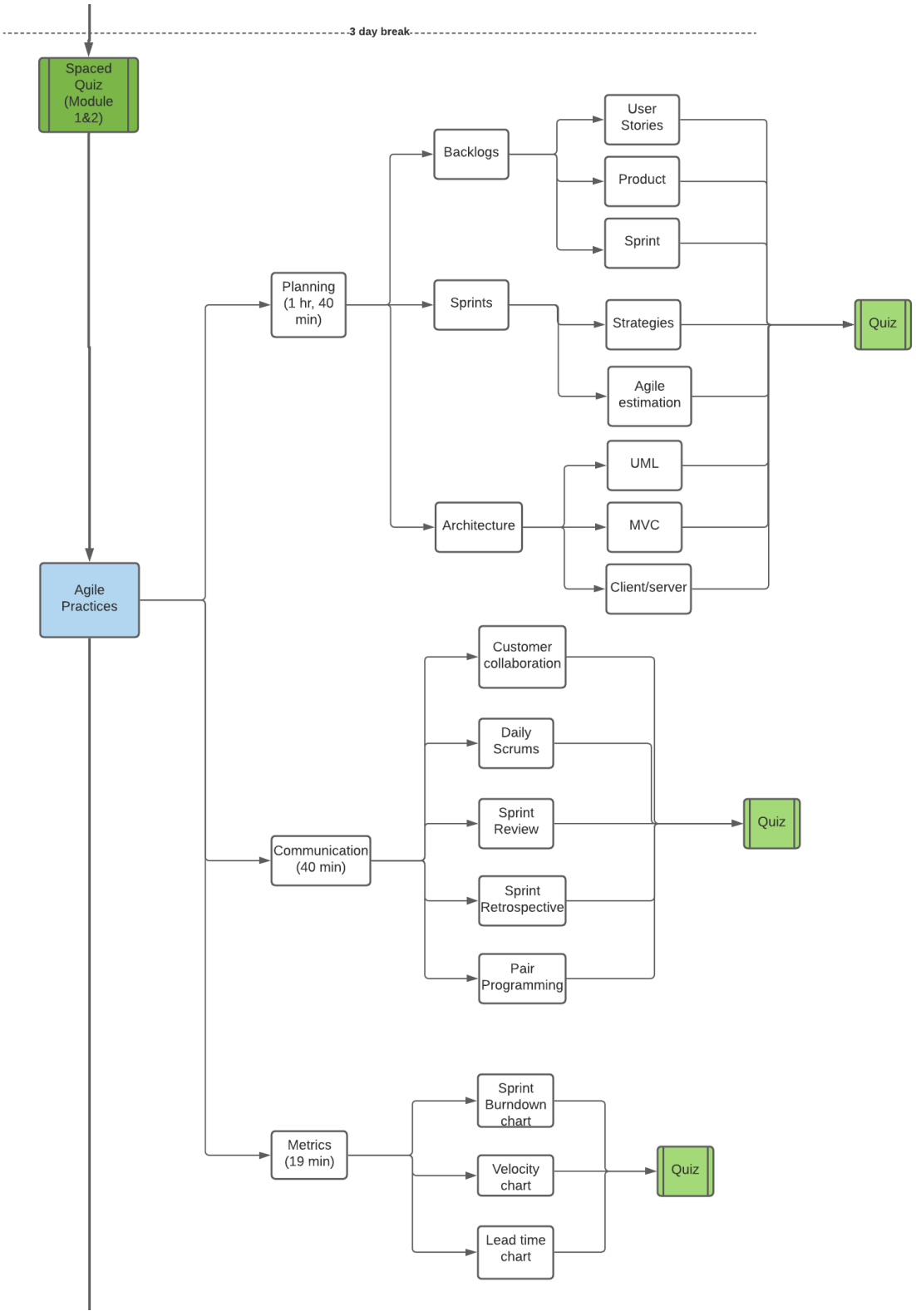


Figure 4: Agile LP (Part 2)

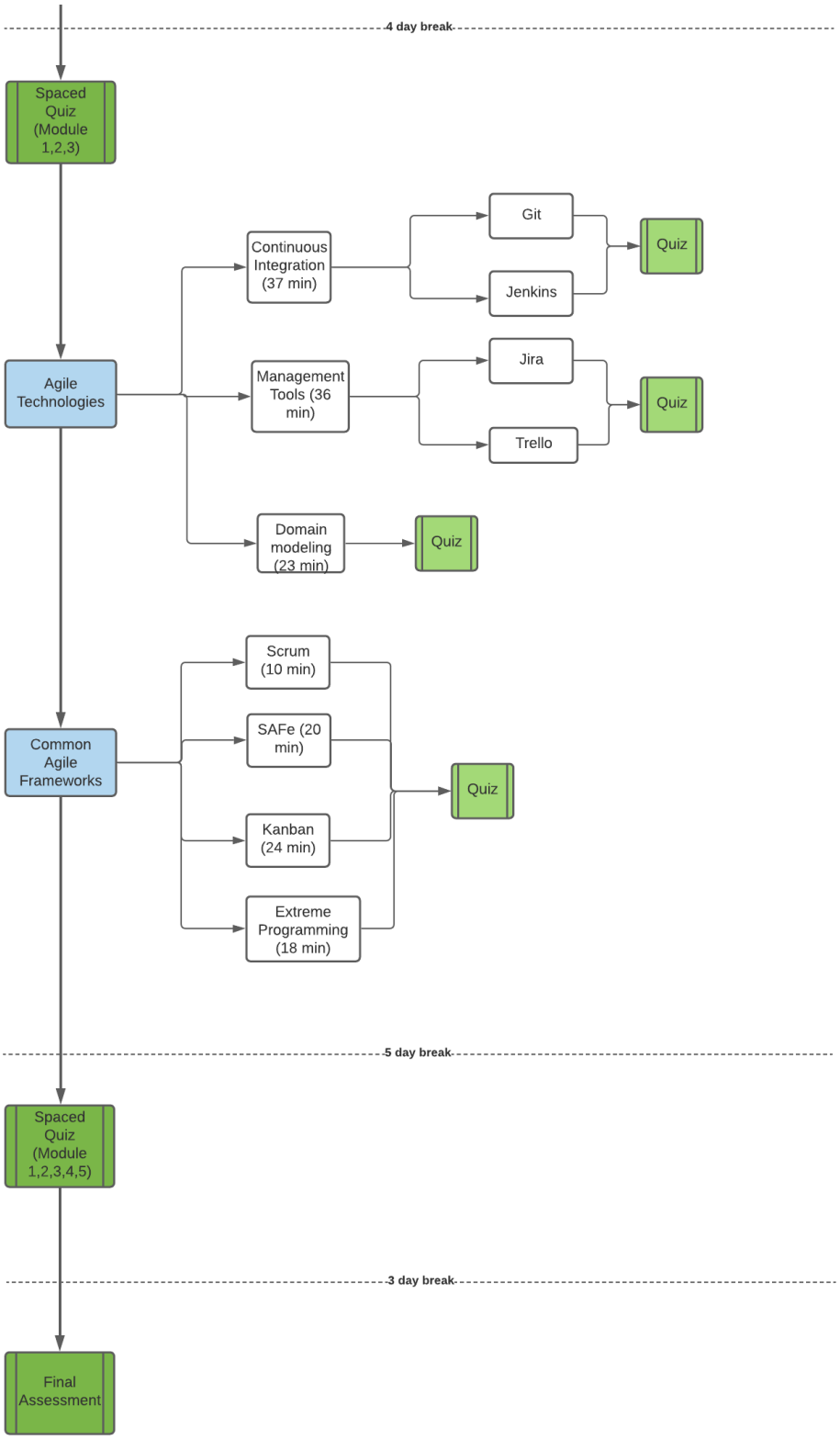


Figure 5: Agile LP (Part 3)

The five main nodes, or pillars, that are covered within the LP are Intro to Software Engineering, Agile Basics, Agile Practices, Agile Technologies, and Agile Frameworks. These nodes are shown in blue. Each pillar is subdivided into a number of nodes that represent the specific learning material that is presented. Each sub-node has an estimated time to completion. There are also assessments and reviews present throughout the LP, which will be discussed in the following section. The smaller assessments are shown in light green, while the larger assessments that cover one or more pillars are shown in a darker green.

The content for each node was sourced from SENG 593 and relevant Internet media on the topic. An effort was made to keep the course length short enough to attract and hold participant attention but long enough to allow the user to gain a breadth of experience with Agile concepts. The content contained within the LP totals just over seven hours. This does not include time taking quizzes, time reviewing material, time spent on the final quiz, or pre- and post-surveys. This course length was consistent with similar Air Force Institute of Technology (AFIT) workshops.

3.2.4 Learning Theory Implementation

The learning theories of active recall, spaced repetition, and elaboration are important learning theories that were crafted into the LP. An extensive recap of each theory can be found in Section 2.3. To briefly summarize, these theories are backed by hundreds of studies supporting their effectiveness, with a meta-analysis of 10 common learning theories found in [21] giving active recall and spaced repetition a ranking of high utility (the only two of the 10 with such a ranking) and elaboration a ranking of medium utility (citing that the core reason for this ranking, rather than high, was the amount of

research available on the topic). In addition to their effectiveness within traditional learning environments, these three theories were chosen for a couple of reasons. The first reason being their ease of implementation. It isn't particularly difficult to find ways to implement these theories into a curriculum. This is an extremely positive aspect because if positive results were found from these theories, it doesn't require much effort from practitioners across the DoD to implement them within existing trainings. Another reason these three theories were picked is the ease at which they work together. Their implementation within the LP is now presented.

3.2.5 Elicitation

After each short module, users are presented with a low-stakes (or no-stakes, more precisely) quiz. These quizzes function as knowledge checks for the user and give opportunities for the user to think deeper about the topic that was presented. The questions were all open-ended, elaborative questions. The questions encourage the user to think about the "why" or think beyond the surface level of the topic. Simple multiple choice or fill in the blank questions were not utilized in the low-stakes quizzes. These quizzes are represented in the LP with a light green shade.

Review sections are also built within the LP. These reviews present the takeaways and other important material from previous sections. Before reviewing the material, however, the users are encouraged to take a review quiz that covers all previously learned material. This gives the user another opportunity to think about and attempt to recall material that they might have forgotten. This quiz is represented by a darker green shade. Having each user complete this review quiz **before** looking at the presented review gives the dual benefit of practicing the retrieval of previously learned material and also

allowing the user to understand where their knowledge could be lacking. They could focus on these areas during the review.

The frequent, low-stakes, elaborative quizzes combined with the periodic reviews and review quizzes on a set schedule (more to follow on the schedule in 3.2.6) provide our implementation of active recall, elaboration, and spaced repetition. Every quiz and review question asked can be found in Appendix D. The aim is to use these theories within the LP to give each the user the benefits of each theory that were presented in Chapter 2.

3.3 Workshop Development

3.3.1 Workshop Setting

A fully online, asynchronous workshop was chosen as the workshop setting. Participants were never asked to be present at a set meeting time for presentation of educational material. The research team made this decision for several reasons. Firstly, this is consistent with how many military trainings are currently presented. The goal of this research was to perform an experiment that could lead to real improvements across the DoD. Performing an experiment that utilized a typical classroom setting could have been useful, but the results would have been difficult to apply to the online trainings that come with being a member of the DoD.

Secondly, an online workshop allows members from all around the globe to participate. This is a benefit not only for the participants who are interested in learning about Agile, but also from a research perspective. The workshop being asynchronous allowed participants who might have specific conflicts on specific dates the opportunity

to still participate. It also allows our sample to come from all DoD members, rather than specifically individuals located at Wright-Patterson AFB, for example. This increases the number of available participants and remains consistent with most online DoD trainings.

3.3.2 milUniversity

The LP curriculum was fully online and hosted on milUniversity, a division of milSuite, which is a tool that provides applications to support secure communications within the DoD [72]. The milUniversity platform provides a secure set of applications that functions as a learning management system, or LMS. The provided tools allow individuals to create courses that contain quizzes that support multiple types of questions, survey instruments, commenting, emailing, and more. milUniversity also provides the ability for classroom owners to collect and receive data reports about the users and their progress. The data that is collected and reported for each user of each course is shown in Figure 6.

user_id	This is a number associated with the user in the site.
name	From the users profile
email	From the users profile
course_id	A number assigned to the course in the site.
course_title	The Course Title
steps_completed	The steps the user has completed in the course. This includes Course, Lesson, Topic and Quiz
steps_total	The total number of steps in the course. This includes Course, Lesson, Topic and Quiz
course_completed	Yes or No to indicate if the user has completed the Course.
course_completed_on	If course was completed, displays the completion date
course_started_on	If the course was started displays the start date.
course_total_time_on	Indicates the total time spent on the course.
course_last_step_id	Displays a number associated with the last step the user has taken in the Course
course_last_step_type	Displays the type: Course, Topic or Lesson of the last step.
course_last_step_title	Displays the title of the last Course, Topic or Lesson.
last_login_date	Displays the last login date for the user.

Figure 6: Collectable data from milUniversity

Similar data is collected for each Lesson, Topic, and Quiz within the course. These metrics are used to monitor progress. This data was useful to gauge progress and participation throughout the sessions but was mostly extraneous and proved unnecessary in the final data analysis.

milUniversity was employed for several reasons. Firstly, milSuite is a fairly common suite of applications amongst military members. If the users are familiar with the site and how to interact with it, this gives them the ability to focus on learning the material rather than worrying about the user interface and site navigation. Additionally, milSuite is secured by CAC authentication, meaning that it supports unclassified government data and is also accessible from home or within DoD offices.

3.3.3 Utilizing AFIT/LS WKSP 0678

The Air Force Institute of Technology's School of Logistics (AFIT/LS) had already created an Agile workshop titled "WKSP 0678: Making sense of Agile, DevOps & DevSecOps." Although sessions were not currently running at the time of this research, multiple sessions had already occurred. There are a few differences between this instance of the workshop and the workshop that the research team created. Firstly, this previous workshop was completely online but was synchronous. Participants joined a web conference and were taught by an Agile SME through PowerPoint slides and a few videos. The workshop lasted roughly 4 hours. The second difference is that the previous version of the workshop did not focus exclusively on Agile, as it also had DevOps and DevSecOps material presented. Aligning the LP and experiment with an existing workshop allowed the research team to avoid the administrative effort of crafting a new course.

3.3.4 Consultation with SMEs

The research team included two Agile SMEs. They each provided valuable insight and guidance into the development of the Agile LP and the content itself that was hosted within the workshop. The team reached out to five additional Agile SMEs to request feedback on the LP and the curriculum within the workshop. The previous instructor of WKSP 0678 provided instruction on how he orchestrated the previous versions of the workshop and also provided valuable insight into aspects of Agile that are necessary to mention because of our work within the DoD and all that entails. This encouraged the research team to make multiple additions and edits within the workshop to present more application specific information and better reflect the projected needs of the audience.

For example, certain aspects of Agile might be different when working with multi-billion dollar embedded weapons systems when compared to a traditional business case where the stakes might not be as high or there are fewer stakeholders involved in the process.

Reaching out to additional SMEs also persuaded the research team to reconsider our timeline of the workshop. The workshop totals roughly 10 hours, with each participants having two full work weeks to complete all material. After a discussion with SMEs, the allotted time increased to three weeks, as the closing months of each year can prove to be extremely busy for many individuals. The objective is for all participants to have ample time to finish the workshop, so the decision was made to increase the length of the workshop to three full work weeks. There is more information to come on the schedule in a following section.

3.4 Experiment Protocol

3.4.1 Overview

This research aims to 1) examine the effects of three learning theories (active recall, spaced repetition, elaboration) on comprehension and understanding of material that is presented in a fully online and asynchronous learning path, and 2) understand how these three theories affect motivation, confidence with presented material, and attitudes towards learning, learning paths, and more.

The experiment protocol randomly split participants into two groups. Group 1 (control group) and Group 2 (experiment group) are exposed to the same Agile material throughout the workshop. Group 2's learning path, however, implements the three

learning theories of active recall, spaced repetition, and elaboration, while Group 1's LP does not. Each participant was encouraged to take a pre- and post-survey as well.

3.4.2 Recruitment

The workshop was available to any member of the DoD, including military, contractors, and civilian employees. The Agile SMEs helped in the recruitment of participants by reaching out to organizations that they felt might be interested in learning Agile. Sample email recruitment messages and slides advertising the workshop are shown in Appendix F.

3.4.3 Inclusion/Exclusion Criteria

The only requirements from the participants is that they had a Common Access Card (CAC), as a CAC is required for the use of all milSuite applications, and a computer and Internet connection to reach the site. Although this LP was geared towards Agile beginners, interested participants who were already familiar with Agile were not turned away. One of the pre-survey questions asks about familiarity with Agile concepts. This aided in analysis of results from these individuals. No other exclusion criteria were present.

3.4.4 Setup

Each workshop had a length of three full work weeks. The research team decided to run three sessions of the workshop, with the beginning of each session separated by two weeks. Once the participant list for each run of the experiment was gathered, the research team randomly divided the members into 2 groups. Group 1, or the control group, would progress through the Agile LP without any of the three learning theories (active recall, spaced repetition, elaboration) implemented. Group 2, or the experiment

group, would progress through the Agile LP that has all three theories implemented within.

Each participant was emailed a link corresponding to their randomly assigned group. Because the workshop was fully online and asynchronous, there was no other setup required.

3.4.5 Execution for Control Group

A sample schedule for the control group is shown below:

Workshop Schedule (Control Group)
Day 1 (Nov 15) – Access to WKSP given
Day 19 (Dec 3) – Course closes

Table 3: Sample Workshop schedule for Group 1

The control group receives access to the whole course on Day 1 of the workshop. To reiterate, they are proceeding through the Agile LP that does not have implementation of the three learning theories. All other workshop content is the same. The participants are free to explore the material and proceed through the course in any way they see fit. Each participant is asked about their study strategies in the post-workshop survey.

Because this group is not required to complete periodic quizzes and reviews, it is expected that students will spend less time with the course overall when compared to the experiment group. The research team considered putting a "timer" on each lesson that required the user to spend a certain amount of time on each module. This timer would simulate the amount of time that the experiment group would spend on that module, as the experiment group might have to proceed through reviews and quizzes. However, this

idea was scrapped as the team decided it would likely become a source of frustration for users, and potentially cause a large decrease in overall satisfaction with the workshop, decreasing the chances of completion. Instead, the participants in this group proceeded as they wished with no restrictions. This simulates how the DoD implements many of their online trainings today.

3.4.6 Execution for Experiment Group

The experiment group is asked to adhere to a specific schedule to examine the effects of spaced repetition. A sample schedule is shown below:

Workshop Schedule (Experiment Group)
Day 1 (Nov 15) – Modules 1 and 2 (Intro to Software Engineering and Agile Basics)
Day 5 (Nov 19) – Review, Module 3 (Agile Practices)
Day 9 (Nov 23) – Review, Modules 4 & 5 (Agile Technologies and Agile Frameworks)
Day 15 (Nov 29) – Review
Day 19 (Dec 3) – Course closes

Table 4: Sample WKSP schedule for Group 2

The modules were not open until the corresponding dates, so the user was not permitted to "work ahead." The schedule was given to the participants upon workshop registration, posted on the course homepage, and they were also notified via email when the new modules opened up. Group 2 also, as mentioned before, progressed through short quizzes and reviews throughout the workshop. This totaled 14 short content quizzes, and 3 review quizzes.

The experiment protocol requires at least four days in between the release of the new modules. Sometimes, simply due to how days fell within weekends or holidays, the amount of time was extended to five or six days. The research team was aware that each

participant would likely not be able to adhere exactly to the schedule requested. The idea was to be able to observe the effects of some sort of spaced repetition of material, even if the exact amount of space between each individual was not equal.

3.4.7 Data Collection

A pre- and post-workshop survey (full surveys in Appendix A, B, and C) provides a variety of information about each participant. The pre-survey collected data to establish learner profiles, Octalysis profiles, attitudes towards existing DoD trainings, familiarity with Agile concepts, and more. The pre-survey was the same for both groups. The post-workshop survey collected data that corresponds to attitudes toward learning paths, attitudes toward the implementation of (or lack thereof, depending on which experiment group the participant was in) the three forms of learning, estimated confidence level with Agile concepts, study strategies used (for Group 1), and more. One question querying participants on their estimated level of Bloom's Taxonomy when it comes to Agile topics appeared on both the pre- and post-workshop surveys. This metric was used to give insights into how the learning theories could have impacted confidence with presented material. Additional specific survey questions that were asked to glean insights into each research question are given and discussed in Chapter 4.

The main quantitative measurement used in the analysis of results is the final assessment. This assessment was the same for both experiment groups. It consisted of 25 questions total, with 15 of them being multiple choice, and 10 of them being essay/open answer questions. The research team, along with a panel of Agile SMEs, graded each essay question and assigned it a score of 0-3. The results for each question were averaged

out and this was used as the score for that question. Two Python scripts were created and used in order to help with this process.

The research team hoped to utilize a “time spent on workshop” metric, as this could potentially point toward interesting conclusions regarding differences in motivation between experiment groups. It could also be interesting to examine if an overall increase in time spent on the site corresponded to an increase in final assessment performance. However, due to the way milUniversity reports time spent on their site, this was not possible. There is a time reported for each individual on each task within the workshop, however this simply reports the time between when the task was opened and when the task was marked complete. For example, if an individual opened a task on Wednesday morning but then couldn’t finish the task until Friday morning, milUniversity reports that it took ~48 hours to complete that task. Situations like this arose very often within analysis and would clearly skew results, so this metric was discarded.

3.5 Conclusion

The data collected from the surveys and assessments allowed the research team to analyze performance and attitudes on a variety of scales. Relationships were examined between Octalysis core drives, learner profiles, final assessment performance, attitudes towards LPs, and attitudes towards the three learning theories. This allowed us to draw conclusions not only about the effectiveness of the three learning theories, but also investigate questions about how to make online asynchronous trainings more appealing to different types of individuals while keeping learning theory in mind. The results of the experiment are presented in Chapter 4.

IV. Analysis and Results

4.1 Overview

This chapter discusses the results from the human subject research experiment performed within WKSP 0678. The experiment consisted of three parts: a pre-workshop survey, the workshop itself, and a post-workshop survey. The results are discussed within the context of each research question. Additional insights from the survey questions that do not directly relate to a specific research question are discussed in Section 4.6. Statistical significance tests were performed for a number of questions. In every case, we used an unpaired two sample t-test with the standard confidence interval of 95%. The null hypothesis, or H_o, for each question was that there was no difference between the two groups. We also used the two-tailed version of each test to ensure we could test for an effect in either direction. Statistical significance was unable to be reached for any question, however the p value associated with the significance test was reported each question in which we performed a test. The data that was gathered still provided us with information to answer RQs 1-3 and also lead us towards additional information that could prove valuable to the military community.

4.2 General Workshop Notes and Statistics

4.2.1 Scheduling Issues

Three sessions of the workshop were completed. Each session was intended to last three weeks, however, variations in the specific length were allowed. Roughly 1/3 of the participant list was unable to start the workshop on time. This was due to a variety of factors. Specifically, many participants did not receive word about the opportunity of the

workshop until the session they were interested in had already started. Because each session lasted three weeks, the decision was made to allow individuals to join up to one week late rather than force them to join a later session (which might not have been available or might not have worked with their specific work schedule). This delay in start date could also have been caused by individuals failing to check their email on time or the fact that they simply could not start on the specific start date because of their work schedules. This is a largely unavoidable issue caused by hosting completely online and asynchronous workshops.

The decision to allow people to join late propagated into many individuals within the experiment group (Group 2) not following the requested schedule of the workshop. This is an important note, as spaced repetition was a core aspect of the research. Because the majority of participants did not follow the requested spaced repetition schedules, this limits our ability to attribute results to a specific spaced repetition timeline. For example, each module was meant to be separated by four or five days, but because this spaced break varied wildly between participants, we cannot attribute results to the specific spaced timeline. We can, however, attribute results toward the general learning practice of spaced repetition.

The condensed timeline that many participants in the experiment group faced very well could have impacted experiment results. For example, some individuals within the experiment group reported that they were frustrated with the number of repetitive questions they were asked to answer within the workshop. One participant stated, “Too many short answer quizzes...one after another….” This participant had been unable to adhere to the spaced schedule and decided to proceed with much of the course in one

sitting. Because of how the learning path was structured, and how spaced repetition was an integral part of the LP, this meant that the participant answered similar questions back-to-back in one sitting when the design was for these questions to be asked and answered multiple days apart. This was a common theme among many of individuals in Group 2. Another participant reported “I did not follow the program specifically as listed due to competing mission requirements, so please take this into consideration as you work your thesis.”

4.2.2 VPN Challenges

All videos within the workshop were hosted via YouTube. Many participants reported that they were encountering errors when trying to access the videos. One participant stated, “At my training location … we were blocked from watching youtube videos, had to sign off VPN, watch video, sign back into VPN to continue learning.” One other reported “Some of the videos didn't' work in the browser.” Another stated, “I had difficulty accessing the embedded videos and used several browsers to discover and follow the links.” Lastly, one participant stated, “Videos, etc. could not be opened in VPN environment. Difficult jumping back and forth between environments / machines.” In every case, this was because the participant was attempting to watch the videos from a network or VPN that blocked access to YouTube. The solution was simply to disconnect from the VPN or connect to a different network when accessing the course (milUniversity) and associated content (YouTube). This extra hurdle to jump over certainly could have impacted motivation within participants.

4.2.3 milUniversity Challenges

At least one instance of milUniversity network failure occurred during the experiment. This very well could have happened multiple times throughout the three sessions, eliminating the ability for participants to proceed and likely causing an increase in frustration. There also seemed to be an issue with milUniversity "timing out", specifically during quizzes. One participant noted "The only thing that I would critique (but found a work-around) was the time milSuite would allow. Most of the quizzes I took, I had to retake, but wouldn't know until submitting my answers at the very end. Milsuite would go inactive at some point during the questions if I took too long, but I wouldn't have any idea until submitting my answers at the end where I would need to refresh the page only to find out it looked like I never took it. I got in the habit of saving my answers in a word document for when this happened though to retake those quizzes again, but thought I would mention!"

This extra workaround should not be necessary. A handful of other individuals reported that the site timed out upon completion of the final assessment. There was no way to fetch their submitted answers, so they were asked to take the 25-question quiz again and resubmit. This may have affected performance.

4.2.4 General Statistics

Participants were drawn from across the DoD. Most participants came from organizations within the Air Force or Space Force who were interested in Agile software development topics. Participants included military members, DoD civilians, and contractors. The workshop was advertised as an introductory Agile workshop, however

no interested participants were turned away, regardless of Agile experience. Statistics for workshop participation are shown in Table 5.

Session #	Group 1	Group 2	Total
1	1	2	3
2	7	9	16
3	26	27	53
	34	**38**	**72**

Table 5: WKSP participation statistics

The total number of participants across three sections was 72, and these participants were nearly split evenly into two groups. The aim was for the two groups to have the same number of participants, however due to odd numbers in individual sessions and one individual joining the wrong course, Group 2 ended up with four more participants than Group 1. Session 3 had the largest amount of participation by a large margin. This was simply a result of having more time to advertise the workshop.

Approximately 78% (56/72) of participants completed the pre-workshop survey. Roughly 82% (46/56) provided a name on the pre-workshop survey. Approximately 53% (38/72) who signed up for the workshop completed all required modules. There were a handful of individuals who never began the workshop after signing up. This could be because mission requirements no longer gave them time for the workshop, they went on leave or TDY and could not access the workshop, they simply changed their mind about the workshop, or for a variety of other reasons. 34/38 (89%) of those who finished the workshop submitted a post-workshop survey. 27/38 (71%) of those who finished the workshop and submitted the post-workshop survey provided a name.

Because each participant had the option to provide a name on the surveys, this limited our ability to connect data between the pre-survey, final assessment, and post-survey. Only 10 individuals in Group 1 (29%) and 9 individuals in Group 2 (24%) submitted a named pre-survey, completed the final assessment, and submitted a named post-survey. The majority of questions asked on the pre- and post-workshop survey utilized a 7-point Likert scale, with a "1" corresponding to "Strongly disagree", a "4" corresponding to "Neutral" and a "7" corresponding to "Strongly agree".

4.3 RQ1: How do the learning strategies of active recall, spaced repetition, and elaboration affect learning outcomes in online LPs?

Learning outcomes for each individual were measured via performance on the Final Assessment. The assessment was closed book/closed note and consisted of 25 total questions, with 10 of them being open ended/free response. Each question was graded by two members of the research team and one additional Agile SME. An average was constructed for each question and used as the grade for the free response portion of the Final Assessment. Unfortunately, results indicated that two participants pulled many answers either directly from notes they took or directly from other internet sources. Because we are interested in gaining insights into how much each individual actually learned, the scores from these two students were not used in analysis. Also, one individual in Group 2 did not answer any free response questions, citing a lack of time due to mission requirements, so their score has not been considered in this analysis. We are also assuming that everyone gave a genuine effort on the final assessment. Each participant knew beforehand that there was not a required score to complete the

workshop, so it is possible that some individuals simply tried to complete it as quickly as possible. Statistics for assessment scores for each group are shown in Figure 7.

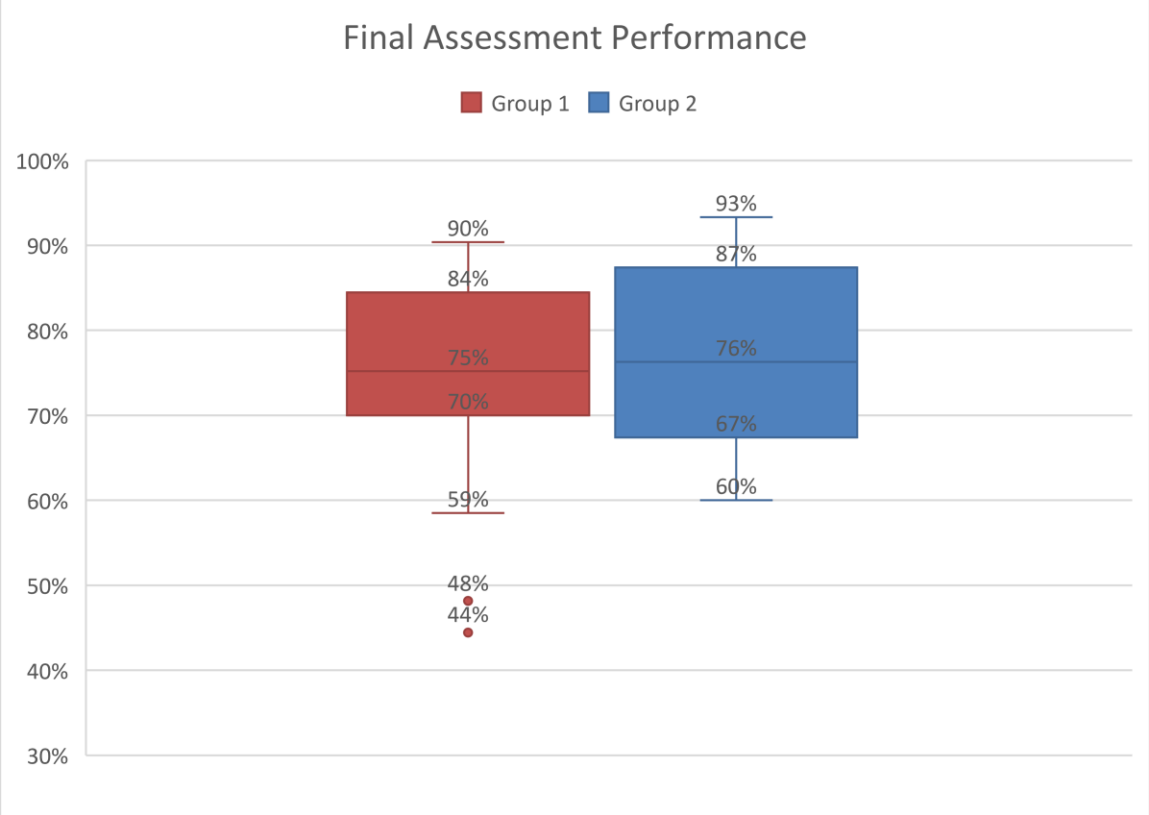


Figure 7: Final Assessment Performance for each Group

Group 2's (N=11) median was slightly larger than Group 1's (N=24). This is a standard box-and-whisker plot, with the edges of the box representing the first and third quartile, the line inside the box representing the median, and the "whiskers" representing the min and max. Outliers are represented with dots outside of the box-and-whisker plot. We also saw a higher interquartile range for Group 2. Group 1 did have two outliers. Group 2's average score and standard deviation was 77.8% and 11.1%, respectively. Group 1's average score and standard deviation was 75.1% and 12.0%, respectively. This means that the learning path that employed active recall, spaced repetition, and

elaboration gave slightly higher averages than the learning path that did not. The results from the t-test prove that our results are not statistically significant ($p = 0.52$). The small sample size (and the variation in sample size between groups) impacted our ability to reach statistical significance.

Participants in each group were asked in the post-workshop survey if they felt learning paths helped them in learning the material. The results are presented in Table 6, which lists the summary statistics of mean, standard deviation, the minimum score that participants responded with, and the maximum score that participants responded with.

	Group #	Mean	Standard Deviation	Min	Max
"Having a learning path helped me to learn the material."	1	6.21	0.92	3	7
	2	6.07	0.92	4	7
"I learned more using the learning path than if I had attempted to learn about the topic on my own."	1	6.42	0.77	4	7
	2	6.14	1.17	3	7

Table 6: Summary statistics for post-survey LP questions

In this case, both groups at least "Agreed" with each statement. It is worth noting that Group 2 did respond at a slightly lower level than Group 1 for each question. This is an interesting result considering how much more involved Group 2's LP was relative to Group 1's. The research team hypothesized that we would see the opposite effect. The learning paths in general, however, seemed to elicit positive responses. Trainees seem to appreciate when the information is laid out for them in a structured manner, especially in

the beginning stages of learning about a topic when attempting to orient yourself with all that the subject entails is very challenging.

Participants in Group 2 were asked to rate each of the learning theories in terms of how much they felt they helped them in learning the material. Of course, it is sometimes difficult to point to specific things that aided your learning, so the point of these questions was more to survey attitudes towards the learning theories. A brief explanation for each theory was provided and the questions shown in Table **7** were asked.

"I feel as if ___ helped me in learning the material."	Mean	Standard Deviation	Min	Max
Active Recall	5.28	1.14	3	7
Spaced Repetition	5.5	1.02	4	7
Elaboration	5.43	1.02	4	7

Table 7: Summary statistics for post-survey learning practice question (Group 2)

On average, participants were between "Slightly agree" and "Agree" for each of the three theories. This was particularly surprising when surveyed about spaced repetition. As mentioned before, the majority of participants were not able to follow the exact spaced repetition schedule. This meant that often times they were presented with review material that they might have just now learned about, causing them to answer similar quiz questions back-to-back. The research team expected this to cause frustration.

On a different, qualitative note, one individual responded on the post-survey that "Course organization was useful aid to learning and retention", with another noting, "I definitely think these elements (the three learning theories) played a role in this workshop, especially active recall. During the final assessment, I felt fairly confident as

there were trigger words that jumped out at me that sparked my memory on the subjects and criteria I learned that made easier to answer the questions and have a better understanding on the topics and even how I can relate it to my own job."

4.4 RQ2: To what extent does employing active recall, spaced repetition, and elaboration affect confidence with presented material in online LPs?

The research team was interested in knowing how the implementation of active recall, spaced repetition, and elaboration affected confidence with the material at hand. Does asking more of your students/trainees throughout a learning path allow them to feel more confident with the material?

Both the pre- and post-workshop survey asked participants to classify their abilities within Bloom's Taxonomy. We measured how this metric changed between Groups 1 and 2.

	Group #	Mean	Standard Deviation	Min	Max
Bloom's Taxonomy Response (Pre-Survey)	1	1.5	1.41	0	4
	2	2.9	1.80	0	6
Bloom's Taxonomy Response (Post-Survey)	1	2.74	1.45	1	5
	2	4.14	1.29	2	6

Table 8: Pre-and Post-survey Bloom's responses

Table 8 presents the results for both the pre- and post-survey Bloom's questions. The scale was between 0 and 6. With a "0" corresponding to "I have no knowledge of

this topic" and 1-5 being each level of Bloom's Taxonomy, with a "5" corresponding to the highest level, "Create".

Group 2 reported a much higher ending score on Bloom's of 4.14, with a 42.8% increase from the pre-survey. Group 1 reported a final score of 2.74, an 82.7% increase. These percentages do not tell the full story, however. The individuals who provided names on the pre-survey and belonged to Group 2 gave an average score of 2.9, almost twice as high as the respective group in Group 1. However, some individuals that completed the pre-survey did not complete the final assessment (or did not complete the post-survey). This means that the average scores from the pre-survey for each group are affected by individuals who did not respond on the post-survey. Also, reporting a higher beginning score on Bloom's Taxonomy makes it harder to increase multiple levels. For example, if you categorize yourself as a "4" on the scale (corresponding to "Analyze") you only have two levels to possibly climb before you're at the top. Because the pre-survey was the same for both groups, this large difference in mean response (1.5 vs 2.74) is likely due to chance. This trend would likely not continue as sample size increased.

Rather than solely looking at the above data for insights into the increase in Bloom's levels, it makes sense to directly look at the individuals who submitted named pre- and post-workshop surveys, as well as completed the final assessment. Improvement can then be measured on an individual scale. Of these individuals, Group 1 improved an average of 1.3 levels (standard deviation of 0.67), while Group 2 improved an average of 1.43 levels (standard deviation of 2.30). The standard deviation was much higher in Group 2 because of the small sample size, as well as the fact that one individual responded that they decreased two levels after completing the workshop. This was an

interesting result. Perhaps the participant was far too confident in their abilities before they were presented with a breadth of Agile information. After going through the workshop, this participant might have realized that there is still much that they don't know, so they reported a lower score. This should still be looked at as a positive result for this individual.

Only one individual in Group 1 reported no change in Bloom's level upon completion of the workshop. Two individuals in Group 2 reported no changes, however one individual reported a 6 on the pre-survey so it was impossible for their response to improve. A larger sample size is needed to draw statistically significant conclusions, however, it does seem like there is some evidence that Group 2's learning path enabled them, on average, to improve their confidence levels with the subject matter at a higher level than Group 1's.

The post-workshop survey also asked each participant to rate the question, "I feel as if I could apply what I have learned in an Agile management role." This question was another way to ask about each individual's confidence level with the subject matter. The results are shown in Table 9.

	Group #	Mean	Standard Deviation	Min	Max
"I feel as if I could apply what I have learned in an Agile management role."	1	5.52	1.12	3	7
	2	6	0.68	5	7

Table 9: Post-survey Agile management question

These results were not statistically significant ($p = 0.17$), however Group 2 did have almost half of a point increase over Group 1. Also, nobody in Group 2 responded with anything lower than a 5, or "Agree". Two individuals in Group 1 responded with a 3, or "Slightly disagree". This points toward an interesting result. Often with military trainings we are not only concerned about increasing in a certain area on average, but also concerned with each individual passing or improving their knowledge base. The data shows that learning paths with active recall, spaced repetition, and elaboration could potentially aid in improving each individual.

Participants were also asked to rate the question, "Having a learning path allowed me to feel more confident with the material." The results are shown in Table 10.

	Group #	Mean	Standard Deviation	Min	Max
"Having a learning path allowed me to feel more confident with the material."	1	5.89	0.88	5	7
	2	6.00	1.04	4	7

Table 10: Post-survey LP confidence question

Group 2 reported a slightly higher score than Group 1. For both groups, this confidence factor likely relates to how LPs guide the user to an end goal rather than have each individual attempt to find their own way. It is not surprising that having an instructor present you with a path allowed users to feel a sense of confidence.

4.5 RQ3: To what extent does employing active recall, spaced repetition, and elaboration affect user motivation within online LPs?

Participants were asked a series of questions in the pre-survey in order to gain insight into what their motivators were. The Octalysis framework provides 8 core drives that motivate us towards certain behaviors. These core drives are as follows:

1) Epic Meaning and Calling
2) Development and Accomplishment
3) Empowerment of Creativity and Feedback
4) Ownership and Possession
5) Social Influence and Relatedness
6) Scarcity and Impatience
7) Unpredictability and Curiosity
8) Loss and Avoidance

The research team aimed to use this framework in order to connect the dots between motivation and more effortful forms of learning (specifically active recall, spaced repetition, and elaboration). Is there an impact on motivation towards online training when more effortful learning is asked of the trainee? Does this change depend on what the trainee's strongest core drives are?

There were two questions asked in the pre-survey relating to each core drive. The specific questions asked for each core drive can be found in Appendix A. The average of those answers was taken and a score for each core drive was assigned to each participant. Summary statistics for each core drive are shown in Table 11.

	Mean	Standard Deviation	Min	Max
CD 1: Epic Meaning and Calling	5.66	1.11	2.5	7
CD 2: Development and Accomplishment	5.68	0.98	3.5	7
CD 3: Empowerment of Creativity and Feedback	5.56	0.97	3.5	7
CD 4: Ownership and Possession	5.36	0.96	3	7
CD 5: Social Influence and Relatedness	4.94	1.08	2.5	7
CD 6: Scarcity and Impatience	4.16	1.08	1.5	7
CD 7: Unpredictability and Curiosity	5.27	1.24	3	7
CD 8: Loss and Avoidance	4.31	1.26	1	7

Table 11: Octalysis Framework Summary Statistics

"CD 6: Scarcity and Impatience" and "CD 8: Loss and Avoidance" reported the lowest scores. Not one individual that was surveyed reported either drive as their strongest motivator. These results should be kept in mind when designing future military training platforms. The plan for these questions was to attempt to correlate specific motivators with assessment performance, attitudes towards the learning theories, and more. However, because many individuals had multiple core drives tied for their number one motivator (some respondents had 7 out of 8 of the core drives tied for the same score), this was not possible. It could be a wise decision for future iterations of similar surveys to ask each respondent to create a numbered list of the core drives in terms of which motivates them the most rather than having them rate each core drive individually.

Individuals in Group 2 were asked two questions regarding their motivations in the post-survey. The results are shown in Table 12.

	Mean	Standard Deviation	Min	Max
"The challenge of more effortful forms of learning … motivated me to continue"	5.21	1.37	2	7
"Seeing progress or improvement throughout the course motivated me to continue"	5.79	1.12	3	7

Table 12: Post-survey motivation questions (Group 2)

The fact that the response for each question was between "Slightly agree" and "Agree" is an encouraging note. There is little doubt that asking more of participants throughout the workshop via the three learning theories discussed adds more effort on their part. However, according to their responses this, on average, somewhat motivates them. We must note that many individuals in the second group were unable to adhere to the spaced repetition schedule asked of them. This could have affected responses. This result seems to clash with the fact that 24/34 (71%) of individuals in Group 1 but only 14/38 (37%) of individuals in Group 2 finished the workshop. Looking at the latter statistic alone could allow you to reasonably conclude that the more effortful forms of learning had an adverse effect on completion percentage (and thus motivation). However, when combined with the fact that participants "Slightly agreed" these forms of learning motivated them to continue, we must look for other possible reasons for this statistic. It could almost be guaranteed that individuals in Group 1 spent less time on the course that individuals in Group 2 (although we are unable to verify this with hard data because this

metric was not available via milUniversity), so perhaps the difference in completion percentage between groups could simply be attributed to the amount of time that each participant had to devote to a voluntary workshop.

We also must keep in mind that the individuals who responded in the post-survey were all individuals who completed the course. Considering the amount of people who did not complete the course in Group 2, if the same question was asked of all participants in Group 2 (rather than only those who completed the course) it is very possible that the average response would go down. Of course, we cannot state this with certainty. Regardless, it seems like there is at least somewhat of a negative relationship between motivation and the implementation of these three learning theories. More investigation is needed to determine exactly where this line is. A participant's interest in the topic likely effects their feelings towards more effortful forms of learning as well. For example, if someone is very interested in a topic they are probably more open to attempting to elaborate and expand on their knowledge than someone who is completely disinterested. These results should be applied when developing future versions of online training.

The second question asked, "Seeing progress or improvement throughout the course motivated me to continue" was a general motivation question. This most closely relates to the second core drive, "Development and Accomplishment". Individuals in Group 1 were also asked this question in the post-survey. They reported an average score of 5.63, meaning Group 2's average score of 5.79 was slightly higher. This makes sense, as individuals in Group 2 had many more opportunities throughout the course to test themselves and see improvement as their knowledge of the subject increased. Group 1 was still, of course, able to see improvement as they progressed through the learning path

via the progress bar present within milUniversity, however they were never asked to test themselves or elaborate on what they have learned. This means they couldn't see proof of actual improvement in their knowledge of the subject.

Individuals in Group 2 were also given the opportunity to provide any additional comments regarding the implementation of active recall, spaced repetition, and elaboration within the workshop. One individual stated "I understand the concepts you were trying to incorporate but there were way too many short answer quizzes too close to the presented material to be able to go into that detail adequately. Also, end of step quiz, review quiz, and final were actually frustrating - probably because I have a basic understanding of the topic and not an in-depth understanding to be able to adequately answer some of the questions." This participant noted that the elaborative types of questions that were asked in the quizzes or reviews caused them frustration because they didn't feel they were able to adequately answer them. This is an important comment for future instructors. If they do choose to incorporate frequent elaborative questions in their courses, they should explain the "Why" behind the learning theories. They should explain that these quizzes are very low-stake and that perhaps the participants might not even be expected to successfully answer all of the questions. The main idea is to give the trainee opportunities to think deeper about the topic and show themselves what they do and don't know. Allow the trainee to see the gaps in their knowledge so they can address them.

One other respondent noted "I don't think the course should stop at certain times until the next block of education. I like to take courses straight through the entire course and not stopping. It was frustrating I had to wait a couple of days to get to the next block of education." This shows that spaced repetition was a source of frustration for them,

liking affecting their motivation levels. This could potentially be alleviated by explaining the idea and existing science behind spaced repetition. Interestingly, this individual did however "Agree" that the implementation of spaced repetition helped them in learning the material.

Participants were asked two questions regarding interest in future courses and interest in Agile specific courses. The results are shown in Table 13.

	Group #	Mean	Standard Deviation	Min	Max
"I would be interested in taking another course that followed a structured learning path."	1	5.95	1.13	3	7
	2	6.07	0.83	4	7
"I would be interested in learning more about Agile software development."	1	5.63	1.16	3	7
	2	5.71	0.73	4	7

Table 13: Post-survey future interest questions

Group 2 reported a slightly higher score for both questions (although Group 1 had a higher range). Because the sample size for each group was relatively small, we cannot say for certain that the implementation of the three learning theories in Group 2's path caused these responses. However, the results seem to be trending in that direction.

4.6 Additional Statistics

The pre-workshop survey asked a series of questions that were not directly used in the analysis of the research questions. The questions that relate to this area of study and show interesting results are presented in this section. The section begins, however, with a figure showing the relationship between estimated levels of Bloom's Taxonomy

and Final Assessment performance.

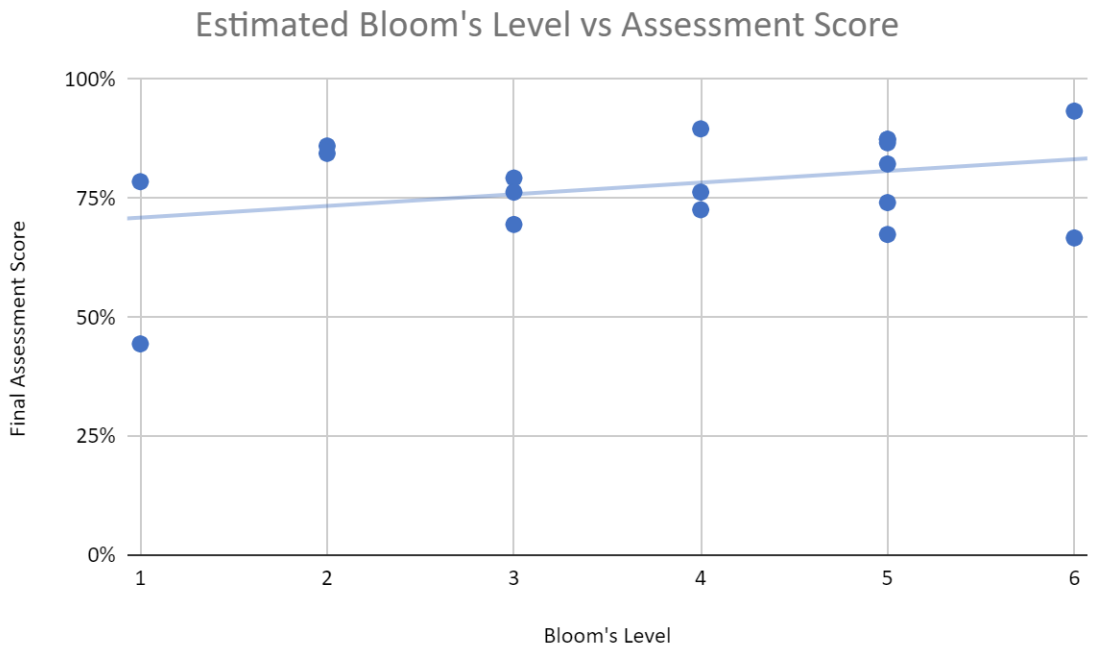


Figure 8: Relationship between assessment score and self-estimated Bloom's level

Figure 8 shows the relationship between the two variables. Pearson's coefficient was used, which shows the strength of a linear association between two variables. This coefficient is denoted by *r* and is represented on a scale of -1 to 1, with a -1 showing a perfect negative correlation, a 0 showing no correlation, and a 1 with a perfect positive correlation [73]. For this data set, $r = 0.21$. This means that there is a slight positive linear correlation between the variables. One would reasonably expect this relationship to be even higher, however this slightly positive correlation is not at all uncommon in the literature regarding self-assessments [74]. Students tend to overestimate their abilities when compared to assessment performance or a teacher's perception. However, this area of research is difficult because of the number of variables present. For example, who is to

say that the assessment given to students actually measures performance in an effective manner? Also, how are we sure that instructors aren't biased in their ratings of students? In our case, the problem of "not knowing what you don't know" is likely also present. If the learner is legitimately an Agile expert, then they are well versed in the topic but also realize there is much that they don't know. They might rate themselves lower on Bloom's Taxonomy than they deserve. If the learner is a beginner, however, they might think they have a strong grasp of the subject simply because they are unaware of the complexities of the topic. Learning paths, of course, attempt to address some of these issues, but this effect is likely still seen in this research.

Participants reported a score between "Agree" and "Strongly agree" for the prompts "I consider myself to be a lifelong learner" and "I enjoy learning in my free time" (shown in Table 14). This shows that individuals within the DoD (or at least within technical communities in the DoD) are eager to learn, so research relating to improvements in how we teach and train our members is well worth our time. It seems to be worth their time, as well.

	Mean	Standard Deviation	Min	Max
"I consider myself to be a lifelong learner."	6.29	0.91	2	7
"I enjoy learning in my free time."	6.16	0.80	4	7

Table 14: Pre-survey learning questions

Summary statistics for two questions relating to existing military trainings are shown in Table 15.

	Mean	Standard Deviation	Min	Max
"I learn and retain information from current online military trainings."	5.61	0.89	3	7
"I feel as if improvement could be made to current online military trainings."	5.48	0.99	4	7

Table 15: Pre-survey military training questions

These questions presented the research team with somewhat interesting results. The first question, "I learn and retain information from current online military trainings", gave a much higher average response than expected. We expect that this is likely a result of how the question was worded. Worded as is, some participants could have seen this as a personal question that asks if it is possible for them from current online trainings. Participants were not likely to respond that they are completely unable to learn from online trainings as they currently stand. A more specific question asking if current online military trainings teach concepts in an effective manner might have been a more accurate way to word the question. The vast majority of respondents did at least slightly agree that improvements could be made to current online trainings.

There were two questions relating to learning paths presented in the pre-survey. They are presented in Table 16.

	Mean	Standard Deviation	Min	Max
"I feel confident in my ability to learn about a topic from scratch."	5.61	0.86	3	7
"I would rather learn about a topic on my own than follow a structured "learning path" for the topic"	4.32	1.24	2	7

Table 16: Pre-survey LP questions

These results seem to show that participants were generally somewhat confident in their ability to learn about a new topic on their own, and some tend to prefer the freedom of free form learning rather than following a type of structured path. Only one individual responded less than "Neutral" to "I feel confident in my ability to learn about a topic from scratch." Although the research was explained to participants before the workshop began, it is possible that they did not know exactly what was meant by a learning path. Learning paths could have an element of freedom to them, allowing the user to "choose their own adventure" depending on their current knowledge level of the topic and what their desired knowledge level is. The fact that many users appreciate freedom when it comes to how they learn should be considered when constructing future learning paths.

4.7 Conclusion

This chapter provided the results of the human-subjects research experiment. Analysis and interpretations of results were given for each research question. Major

takeaways, ideas for improvement, and recommendations for future research are presented in the next chapter, Chapter 5.

V. Conclusions and Recommendations

5.1 Overview

This thesis explored and gave background information on all relevant topics, including learning paths, learning theories, motivation, and existing learning management systems. The construction of the Agile workshop and the methodology of the experiment were given in Chapter 3. Chapter 4 presented results and the interpretation of data. This chapter concludes the thesis by summarizing the research, explaining why it is significant, offering suggestions based on research results, and providing a discussion of future work on the topic.

5.2 Research Conclusions

We were not able to arrive at any statistically significant conclusions. However, the research revealed the following observations:

- The fact that we were able to measure a higher mean and median score for Group 2 (the experiment group) is an encouraging sign for the implementation of the active recall, spaced repetition, and elaboration within online and self-paced LPs. This is especially encouraging considering that most participants were not able to use spaced repetition to their advantage.
- These three learning practices did seem to allow users to feel more confident with the material at hand. This is likely because the participants in Group 2 had more opportunities to prove to themselves what they do and don't know. This is a positive effect on both fronts. As a student, it's good to know that learning is

occurring as you progress through the path, but it's also good to know when you're struggling so you can look for ways to alleviate your struggles.

- More research is necessary to determine exactly how more effortful online trainings (with the implementation of these three learning practices) affects motivation. Although users "Slightly agree" that these theories motivated them, we cannot ignore the fact that 71% of Group 1 (control group) but only 37% of Group 2 (experiment group) completed the workshop.

5.3 Research Significance

Although the term "Agile software development" has been around for over 20 years, its implementation within the DoD has lagged. There is ample Agile learning material available via books and sources on the internet (and a 10-week graduate course available at AFIT), however the DoD has struggled to provide accessible Agile education to the software community at large. This has caused many of the Agile implementations within the DoD to be "Agile in Name Only" [75]. The Defense Innovation Board has concluded that the DoD's "current approach to software development is broken" and that it is a "leading source of risk to the DoD" [75]. The DoD has also struggled to incorporate existing research on popular learning theories into many of the online trainings that are offered or required. This workshop and associated learning path attempted to begin to address these issues.

This research created and analyzed an Agile software development workshop and provided four major contributions:

- Provided a general framework for LP development

- Created a LP for Agile software development, providing 72 DoD members with Agile training
- Examined the effects of three learning theories within a fully online and self-paced LP
- Collected attitudes towards learning theory, motivation, online trainings, and more within the military community

This research presents implications for Agile education, existing online trainings within the DoD, and learning path/workshop development.

5.3.1 Agile Education

There is a need for Agile education. Many individuals responded in the post-workshop survey that they needed some type of formal Agile education. The DoD released a guide titled, “Detecting Agile BS” in March of 2019 that lays out common signs that your Agile implementation isn’t really Agile [75]. However, it would be wise for the DoD to attempt to establish some sort of guidelines for implementation on top of these common Agile missteps. Obviously, the manner in which Agile is implemented is going to change depending on the exact product or process being engineered, but a starting baseline of Agile knowledge and processes could be a worthwhile step in the right direction. This is especially true because Agile implementations within the DoD differ from normal civilian implementations because of not only the nature of our work (business systems vs. weapon systems) but also because of the bureaucracy that is present within large government systems.

5.3.2 Existing online trainings

More research is necessary to draw conclusions on the balance between learning practices and effects on motivation. However, the research suggests that our implementation of active recall, spaced repetition, and elaboration increase competence and confidence with presented material. Intuition would tell us that the more motivated someone is to learn about something (such as an interest of theirs compared to a formal training requirement), the more likely they are to being open to effortful forms of learning.

5.3.3 Learning path/workshop development

Teamwork across organizations within the DoD is crucial. The workshop development and recruitment would not have been possible without the Agile SMEs. This collaboration should continue to be garnered in order to develop Agile guidelines for DoD implementation.

Learning paths demonstrated value to the participants. All questions regarding LPs were responded to in a positive manner in both surveys. In many ways, these LPs take much of the guesswork out of learning. Learning practices can be embedded within LPs so that they not only provide a framework and structure for the topic, but also use science-based learning tools in the instruction.

Workshops can be a great option for DoD members to learn about a topic, however you should be careful when choosing a host and schedule. In many aspects, the host and schedule generated problems for participants and induced negative responses from participants.

5.4 Future Work

Ideas for future work regarding Agile, learning practices, and education are provided below:

- Additional Agile LPs could be created for intermediate and advanced learners. These paths could give users more freedom and flexibility to learn about topics that interest them (or topics they need to be well-versed in depending on mission requirements). Also, these paths could have options for learners depending on the medium in which they'd like to learn. For example, LPs could utilize serious games or collaborative learning to teach rather than simply presentations, videos, and articles. These LPs could also be crafted based on the core drives that motivate each individual.
- A similar experiment to the one presented in this research could be ran that test users after an extended period of time. For example, one month after workshop completion the participants would be asked to take an assessment over workshop material. This would give a much better picture into how these learning theories did or did not affect performance. A paired sample t-test could be performed for each individual to examine how much information was forgotten over a specified period of time between each group.
- Experiments that analyzed each learning practice individually could also be worthwhile. In our case, we only examined how the three practices combined affected performance. Individually studying each theory within an online and self-paced LP could be worthwhile.

- Along this same vein, the DoD should educate the force on the value of these learning practices. They are not extremely difficult concepts to understand, and existing research on each is extensive. There are few things more important than the education of our force. Educating our personnel on the value of these practices could go a long way into improving learning, both inside and outside the workplace.

Appendix

Appendix A. Pre-Survey

What is your first initial and last name? This will only be used to attach survey results to your unique userID from milUniversity.

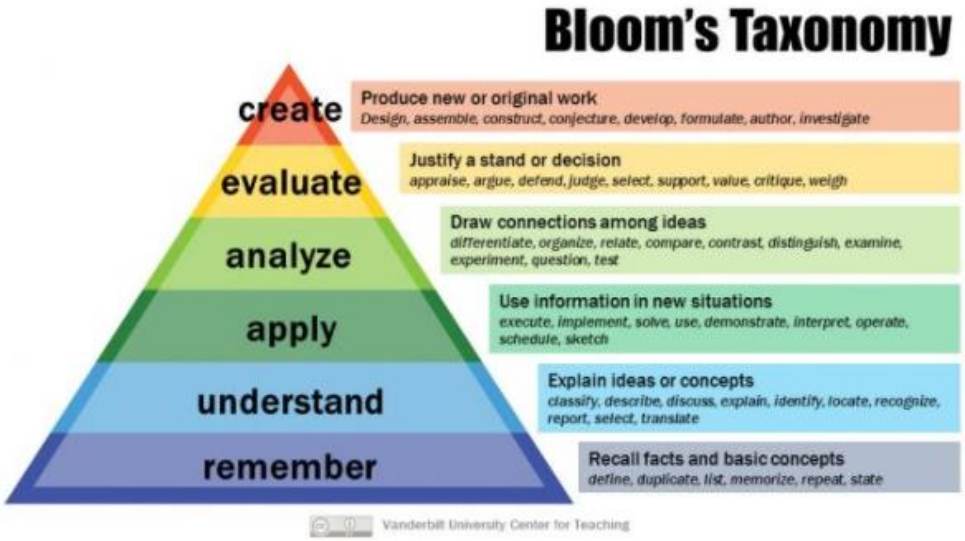
Your answer

Rate each of the following: *

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I am familiar with agile software development concepts	○	○	○	○	○	○	○
I consider myself to be a lifelong learner	○	○	○	○	○	○	○
I enjoy learning in my free time	○	○	○	○	○	○	○
I learn and retain information from current online military trainings	○	○	○	○	○	○	○
I feel as if improvements could be made to current online military trainings	○	○	○	○	○	○	○
I feel confident in my ability to learn about a new topic from scratch	○	○	○	○	○	○	○

I would rather learn about a topic on my own than follow a structed "learning path" for the topic	○	○	○	○	○	○	○

Bloom's Taxonomy is an educational tool that allows us to classify our ability and knowledge within a specific topic. Where would you rank your ability when it comes to Agile software development topics? *



- ○ I have no knowledge of this topic
- ○ Remember
- ○ Understand
- ○ Apply
- ○ Analyze
- ○ Evaluate
- ○ Create

Rate each of the following: *

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I choose to do things that make me feel like I am serving a higher purpose than myself	○	○	○	○	○	○	○
I choose to do things that make me fee l like I am fighting for a greater good	○	○	○	○	○	○	○
I choose to do things that make me feel like I am developing myself	○	○	○	○	○	○	○
I choose to do things that allow me to track my accomplishments and show progress	○	○	○	○	○	○	○
I choose to do things that make me feel empowered to use my creativity	○	○	○	○	○	○	○
I choose to do things that give me feedback on how I am doing	○	○	○	○	○	○	○
I choose to do things that allow me to own things	○	○	○	○	○	○	○
I choose to do things that allow me to customize things	○	○	○	○	○	○	○

Appendix B. Post-survey (Group 1)

What is your first initial and last name? This will only be used to attach survey results to your unique userID from milUniversity.

Your answer

Rate each of the following: *

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
Having a learning path helped me to learn the material	○	○	○	○	○	○	○
Having a learning path allowed me to feel more confident with the material	○	○	○	○	○	○	○
I learned more using the learning path than if I had attempted to learn about the topic on my own	○	○	○	○	○	○	○
I felt focused during the workshop	○	○	○	○	○	○	○

This research was focused on how the learning theories of active recall, spaced repetition, and elaboration affect learning outcomes in online, self-paced learning paths. A brief explanation of each theory is presented below. The learning path you followed had very little implementation of the three learning theories. Please review the definitions and rate each of the following: *

Active recall – the process of retrieving information from your memory. Defers from passive learning (such as simply re-reading information). Commonly found in low-stakes quiz questions or through the use of flashcards.

Spaced repetition – the practice of reviewing or retrieving the same or similar information, typically over a specified period of time.

Elaboration – the practice of asking HOW or WHY things work the way they do. Usually involves explaining or describing.

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I am familiar with the learning theory of active recall	◯	◯	◯	◯	◯	◯	◯
I would enjoy/appreciate curriculum that employed active recall	◯	◯	◯	◯	◯	◯	◯
I am familiar with the learning theory of spaced repetition	◯	◯	◯	◯	◯	◯	◯
I would enjoy/appreciate curriculum that employed spaced repetition	◯	◯	◯	◯	◯	◯	◯
I am familiar with the learning theory of elaboration	◯	◯	◯	◯	◯	◯	◯
I would enjoy/appreciate curriculum that employed elaboration	◯	◯	◯	◯	◯	◯	◯

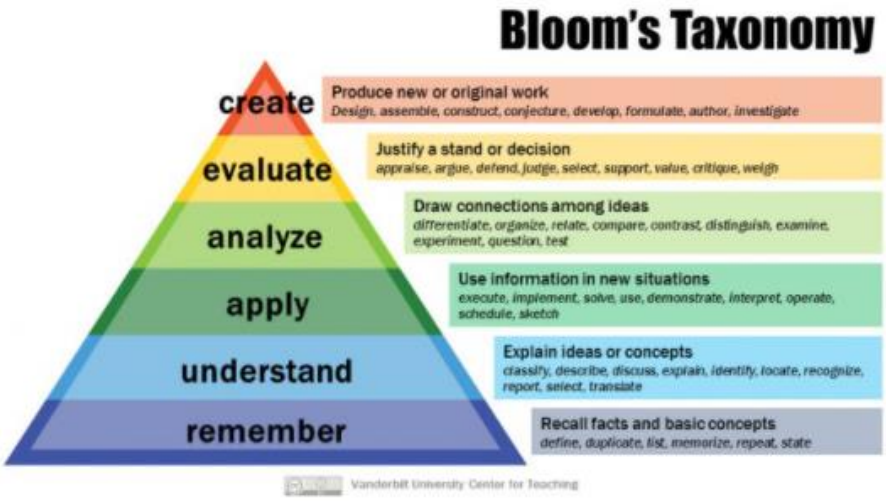
Please describe how you tackled the material of the workshop. Did you have a strategy? Did you study or review for the final assessment?

Your answer

How much effort did you feel you gave throughout this training?

	1	2	3	4	5	6	7	8	9	10	
No effort	○	○	○	○	○	○	○	○	○	○	Extreme effort

Bloom's Taxonomy is an educational tool that allows us to classify our ability and knowledge within a specific topic. Where would you rank your ability when it comes to Agile software development topics?



- ○ Remember - Recall facts and basic concepts
- ○ Understand - Explain ideas or concepts
- ○ Apply - Use information in new situations
- ○ Analyze - Draw connections among ideas
- ○ Evaluate - Justify a stand or decision
- ○ Create - Produce new or original work

Rate each of the following: *

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I feel as if I could apply what I have learned in an Agile management role	○	○	○	○	○	○	○
I would be interested in learning more about Agile software development	○	○	○	○	○	○	○
I would be interested in taking another course that followed a structed learning path	○	○	○	○	○	○	○
Seeing progress or improvement through the course motivated me to continue	○	○	○	○	○	○	○

Do you have any additional comments/concerns regarding the workshop or research?

Your answer

Appendix C. Post-survey (Group 2)

What is your first initial and last name? This will only be used to attach survey results to your unique userID from milUniversity.

Your answer

Rate each of the following: *

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
Having a learning path helped me to learn the material	○	○	○	○	○	○	○
Having a learning path allowed me to feel more confident with the material	○	○	○	○	○	○	○
I learned more using the learning path than if I had attempted to learn about the topic on my own	○	○	○	○	○	○	○
I felt focused during the workshop	○	○	○	○	○	○	○

This research was focused on how the learning theories of active recall, spaced repetition, and elaboration affect learning outcomes in online, self-paced learning paths. A brief explanation of each theory is presented below. Please review the explanations and rate each of the following: *

Active recall – the process of retrieving information from your memory. Defers from passive learning (such as simply re-reading information). Commonly found in low-stakes quiz questions or through the use of flashcards.

Spaced repetition – the practice of reviewing or retrieving the same or similar information, typically over a specified period of time.

Elaboration – the practice of asking HOW or WHY things work the way they do. Usually involves explaining or describing.

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I am familiar with the learning theory of active recall	◯	◯	◯	◯	◯	◯	◯
I feel as if active recall helped me in learning the material	◯	◯	◯	◯	◯	◯	◯
I am familiar with the learning theory of spaced repetition	◯	◯	◯	◯	◯	◯	◯
I feel as if spaced repetition helped me in learning the material\	◯	◯	◯	◯	◯	◯	◯
I am familiar with the learning theory of elaboration	◯	◯	◯	◯	◯	◯	◯
I feel as if elaboration helped me in learning the material	◯	◯	◯	◯	◯	◯	◯

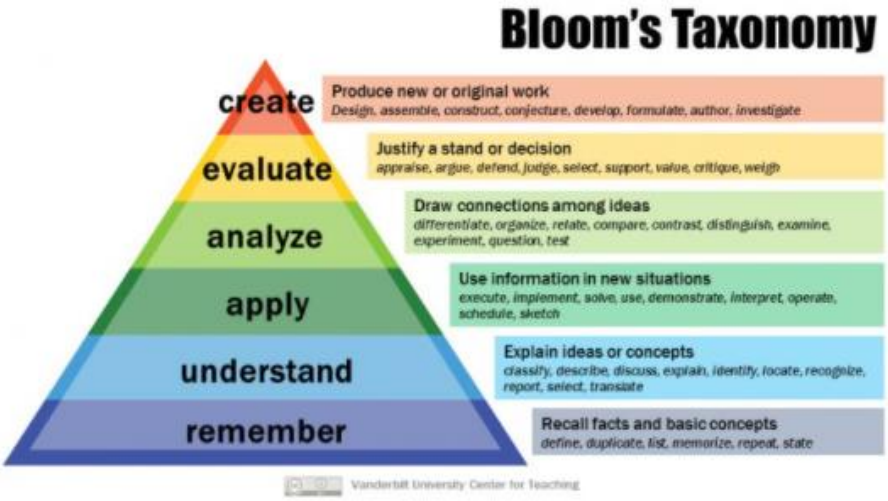
Do you have any additional comments regarding the implementation of active recall, spaced repetition, and/or elaboration?

Your answer

How much effort did you feel you gave throughout this training?

	1	2	3	4	5	6	7	8	9	10	
No effort	○	○	○	○	○	○	○	○	○	○	Extreme effort

Bloom's Taxonomy is an educational tool that allows us to classify our ability and knowledge within a specific topic. Where would you rank your ability when it comes to Agile software development topics?



- ○ Remember - Recall facts and basic concepts
- ○ Understand - Explain ideas or concepts
- ○ Apply - Use information in new situations
- ○ Analyze - Draw connections among ideas
- ○ Evaluate - Justify a stand or decision
- ○ Create - Produce new or original work

Rate each of the following: *

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I feel as if I could apply what I have learned in an Agile management role	◯	◯	◯	◯	◯	◯	◯
I would be interested in learning more about Agile software development	◯	◯	◯	◯	◯	◯	◯
I would be interested in taking another course that followed a structed learning path	◯	◯	◯	◯	◯	◯	◯
The challenge of more effortful forms of learning (active recall, spaced repetition, elaboration) motivated me to continue	◯	◯	◯	◯	◯	◯	◯
Seeing progress or improvement through the course motivated me to continue	◯	◯	◯	◯	◯	◯	◯

Do you have any additional comments/concerns regarding the workshop or research?

Your answer

Appendix D. Quiz and Assessment Questions

Overview Quiz

- Explain the benefits of using functions and classes while programming.
- In your own words, describe object oriented programming.
- Why is it important for developers to provide detailed documentation in their code?
- What is an Integrated Development Environment and how are they useful to developers?
- What is the difference between a coder and a software engineer?

Software Development Methodologies Quiz

- What are the six stages in the software development life cycle?
- Do the six stages of the software development lifecycle have to be followed in order? Why or why not?
- Give three reasons why the Waterfall model typically fails to deliver.
- Are there any software projects in which the Waterfall method might be appropriate? Why or why not?
- What advantages would a more iterative approach to software development give when compared to a sequential approach such as Waterfall?

Agile History Quiz

- What caused the need for Agile to arise?
- What are two benefits of building working software quickly and getting it into the hands of end users?
- Explain what is meant by each line of the Agile Manifesto:

a) Individuals and interactions over processes and tools

b) Working software over comprehensive documentation

c) Customer collaboration over contract negotiation

d) Responding to change over following a plan

Agile Principles Quiz

- Why is Agile often referred to as a lightweight model of software engineering?
- Choose three of the Agile principles and elaborate on why they're important and how they differ from something you might see in a Waterfall model.
- Explain how Waterfall methods and Agile methods differ when it comes to eliciting user requirements.
- Why is the 10th principle (shown below) important in Agile environments? Can a project ever be over-simplified? Why or why not?

"Simplicity - the art of maximizing the amount of work not done - is essential."

- Based on the 12 principles, describe how would you approach a management position within an Agile team. Would you be more hands on or laid back? Why?

Agile Planning Quiz

- What is a user story? How do they relate to requirements for the software product that are given by the customer?
- What is the difference between a product backlog and a sprint backlog? Do all items on the product backlog have to be completed? Why or why not?
- Generally speaking, where is the line between too much planning and not enough planning in Agile? How would you know if your team crossed it?
- What are the steps to a successful sprint planning meeting?

- Why is it important for all members of the team to be familiar with the type of software architectures implemented within the system?

Communication Quiz

- What does "customer collaboration over contract negotiation" mean?
- What are the benefits of pair programming?
- What is the purpose of daily scrum meetings? What should and shouldn't be discussed?
- What is the difference between the sprint review and sprint retrospective meetings?
- Should the customer be part of the sprint retrospective or sprint review? Why or why not?

Agile Metrics Quiz

- What is the purpose of each of the three metrics we reviewed? (sprint burndown chart, velocity chart, cumulative flow diagram)
- The sprint burndown chart requires the ideal effort to be estimated at the beginning of this sprint. How is this calculated? What are the consequences to over or under-estimating?
- Describe what an "ideal" cumulative flow diagram would look like.

Continuous Integration Quiz

- Explain how a tool such as Git helps in software development.
- What is the difference between a tool like Git and a tool like Jenkins?
- What Agile principles do tools like Git and Jenkins help enable? How?

Management Tools

- What specific tools does Jira have in place for Agile teams?
- You will learn about the Kanban framework in the following lesson, but generally speaking, what could a tool like Trello be used for in the management of Agile teams?
- One of the 12 Agile principles is "The most efficient and effective method of conveying information to and within a development team is face-to-face conversation."
- In your opinion, has this changed with the advent of software tools designed specifically for Agile teams? Why or why not?

Domain Modeling Quiz

- Should the domain model be able to change as the software project progresses? Why or why not?
- How do domain models help to manage the complexity of large software projects?
- What is the relationship between domain models and user stories?

Agile Frameworks Quiz

- Which of the frameworks presented are better for small-scale Agile? What about large-scale? Why?
- What relationships can be drawn between the 5 core values of Scrum and the 12 Agile principles?
- What about the 10 SAFe principles lends itself well to large-scale Agile teams?
- What comparisons can be drawn between Kanban and Scrum?
- Explain the relationship between the 5 XP values and the 5 XP principles.

Review Quiz #1

- What are the key differences between Agile and Waterfall methods of software development? When might it be appropriate to use each?
- What is the software development life cycle? What are the steps?
- Elaborate on why the need for Agile came about. What are the core components of the Agile Manifesto?

Review Quiz #2

- Name 3 Agile principles and elaborate on how they are put into practice.
- What is a user story and how do they relate to backlog items?
- What are the steps to a successful sprint planning meeting?
- Elaborate on key similarities and differences between the 4 Agile ceremonies (sprint planning, daily scrums, sprint review, sprint retrospective).
- Why are Agile metrics important? Pick one of the three metrics we discussed and give an example in which it would prove useful.

Review Quiz #3

- Name 3 Agile principles and elaborate on how they are put into practice.
- What is a user story and how do they relate to backlog items?
- What are the steps to a successful sprint planning meeting?
- Elaborate on key similarities and differences between the 4 Agile ceremonies (sprint planning, daily scrums, sprint review, sprint retrospective).
- Why are Agile metrics important? Pick one of the three metrics we discussed and give an example in which it would prove useful.

- What is the difference between Git and Jenkins? Elaborate on what each helps you accomplish.
- Is it necessary that you only choose one Agile framework and stick with it the whole time? Why or why not?
- Does Jira or Trello lend itself specifically well to any of the Agile frameworks covered? If so, how?

Final Assessment

- Why was the Waterfall method an attractive option to management in the early stages of software development?
- What is the main output of the sprint review?
- Name one difference between the Scrum and Kanban frameworks.
- It is typical to have various business stakeholders be part of the sprint retrospective meeting.
    - True
    - **False**
- Give two benefits, one for the team producing the software and one for the customer, of building working software quickly and getting it into the hands of end users.
- Describe the difference between Git and Jenkins.
- Which of these assumptions about software development is correct?
    - Requirements are not likely to change
    - **Requirements might change**
    - The customer will know exactly what he/she wants in the beginning stages

    - The design in the beginning stages of development is almost always the same design in the end.
- [76] Velocity is
    - Measured in task hours
    - **A measure of a team's rate of progress**
    - A metric used to compare team performance
    - Not effected when a change in scope is made
- [77] When was the Agile Manifesto written?
    - 2010
    - 1991
    - **2001**
    - 2015
- When calculating velocity, it is okay to count partially finished work (such as code produced but not yet tested)
    - True
    - **False**
- What is a user story?
- Agile concepts can be applied in a variety of organizations. It isn't simply for the development of software in tech organizations. How could you apply Agile concepts or techniques within your organization?
- Agile uses working software as the primary measure of progress.
    - **True**
    - False

- Why does the Agile Manifesto de-emphasize extensive documentation early in the process? [1]
    - Software must be working before documentation can be written
    - Not enough requirements are known to write documentation
    - **Changing requirements would make the documentation outdated**
    - Documentation can only be written after testing
- Agile assumes you become more knowledgeable about the project as you continue working on it.
    - **True**
    - False
- [2] Which of the following is **NOT** one of the 4 Agile values?
    - Individuals and Interactions
    - **Planning and Meeting**
    - Customer Collaboration
    - Working Software
- [2] Agile values: Customer collaboration over _____
    - **Contract negotiation**
    - Processes and tools
    - Technical collaboration
    - Following a plan
- [2] Agile values: Individuals and interactions over _____
    - Following a plan
    - Teams and reports

    - Contract negotiation
    - **Processes and tools**
- The sprint review is about the _____ and the sprint retrospective is about the _____
    - **Product, team**
    - Team, product
- Describe the difference between a programmer and a software engineer.
- Describe the difference between the sprint retrospective and the sprint review meeting.
- Which of these is **NOT** part of the software development life cycle?
    - Planning
    - **Communicating**
    - Building
    - Testing
- [2] Which of these should a team member **NOT** bring to the daily scrum meeting?
    - **Agenda for future meetings**
    - What I did yesterday
    - What my current blockers are
    - What I will do today
- Describe two common problems with the Waterfall method.
- Which of these does **NOT** occur during the sprint review meeting?
    - Cover what's done and not done
    - Demo of the work completed

- Review and revise the product backlog
- **All of these occur**

Appendix E. Agile Principles [67]

12 AGILE PRINCIPLES BEHIND THE AGILE MANIFESTO

1 Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.	2 Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.	3 Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
4 Business people and developers must work together daily throughout the project.	5 Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.	6 Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
7 Working software is the primary measure of progress.	8 The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.	9 Continuous attention to technical excellence and good design enhances agility.
10 Simplicity – the art of maximizing the amount of work not done – is essential.	11 The best architectures, requirements, and designs emerge from self-organizing teams.	12 At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

Appendix F. Recruitment Emails and Graphics

A sample recruitment email is presented:

"BLUF: You have the opportunity to participate in an Agile software development workshop that will introduce you to a variety of Agile topics as well as serve as a key component of a research experiment led by an AFIT student.

This workshop will implement a learning path that enables participants to receive an intro to many Agile concepts including Agile history, Agile principles and practices, Agile technologies, and more. The material will consist of articles, videos, and PowerPoint slides that are hosted within milUniversity. The workshop is completely asynchronous and is estimated to take ~10 hours to complete. Each participant will have 3 weeks to complete.

This workshop will also be central to Lt Trent Woods' research experiment that he is performing for his master's thesis at AFIT. His thesis focuses on how different forms of learning theory impact learning outcomes for students during online trainings. No identifying data will be used in results.

Regardless of research results, each participant has the benefit of progressing through an Agile learning path and being exposed to a curriculum that represents a breadth of Agile topics. Your participation 1) has the potential to impact results that could improve how online trainings and CBTs are implemented across the DoD and 2) could lead to being awarded an Agile digital badge, which can be used to showcase proficiency in a topic.

Please contact Lt Trent Woods at trenton.woods@afit.edu with any additional questions."

A sample advertisement graphic is also presented:

WKSP 0678: Making Sense of Agile, DevOps & DevSecOps

Who: DoD affiliated workforce

What: Self paced, asynchronous workshop (~10 hours) progressing through an introductory Agile learning path utilizing videos, articles, and slides

When: 15 Nov – 4 Dec and 29 Nov – 17 Dec

Where: Online via milUniversity

Why: Provides exposure to a variety of Agile concepts and ideas, an increasingly important focus area in military Digital Engineering

Questions/Registration: Email trenton.woods@afit.edu

1

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14. ABSTRACT

The United States military must continue to innovate and improve the way we fight and defend against our near-peer adversaries. Emerging technologies such as machine learning, artificial intelligence, and reverse engineering are paving the way for an increasingly complex security environment. A core tenant of winning in this new era of warfare is how we educate and train our military force. Many of the online trainings made available to servicemembers today fall short in the implementation of existing learning theories. This research identifies a gap in the current literature regarding common learning theories, noting that there is a lack of research regarding the implementation of active recall, spaced repetition, and elaboration into fully online and asynchronous learning paths (LPs). This research surveys the current literature regarding the topics at hand, produces a framework for LP development, develops a LP for Agile software development (an emerging topic of interest for the DoD), and examines the effects of three forms of learning theory within an online and self-paced LP through a human-subjects research experiment. A workshop and an associated LP are developed that implement and test the effects of these three learning theories. The results from the final assessment and pre- and post-workshop surveys showed a positive benefit for competence and confidence with presented material within the LP, but more research is necessary to determine how these three theories affect motivation.

15. SUBJECT TERMS

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