ABSTRACT

Title of Thesis: A NOVEL APPLICATION OF SELECT AGILE CONCEPTS AND STOCHASTIC ANALYSIS FOR THE OPTIMIZATION OF TRAINING PROGRAMS WITHIN HIGH RELIABILITY ORGANIZATIONS IN HIGH TURN-OVER ENVIRONMENTS AT EDUCATIONAL INSTITUTES AND IN INDUSTRY

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High-turnover environments have been extensively studied with the bulk of the literature focusing on the negative effects on business operations.[1] They present challenges to the resilience of the organization while also limiting the potential profitability from consistently having to spend time training new staff. Furthermore, in manufacturing environments

inexperienced staff are prone to mistakes and uncertainty, which can lead to increases in scrap materials and lower production rates due to a lack of mastery of the process. From an organizational standpoint a high-turnover environment presents an unmitigated risk to the organization from the continuous loss of institutional knowledge. This loss can present challenges to the organization in numerous ways, such as capital equipment that no longer has staff qualified or experienced enough to use it leading to costly retraining by the manufacturer or increased risk of a catastrophic failure resulting in damage to the equipment and or injury to the staff. Furthermore, the loss of institutional history leads to the loss of why operations are performed a certain way. As the common saying goes, "those who forget history are bound to repeat it." which can lead to substantial costs for the organization while old solutions that were previously rejected due to lack of merit are constantly rehashed due to a lack of understanding of how the organization arrived at its current policies. This thesis presents a novel framework to mitigate the potential loss of institutional knowledge via a multifaceted approach. To achieve this a specific topic was identified and used to frame questions that guided the research.

Mitigation of the negative impacts of high-turnover in manufacturing environments with a specific focus on the optimization of training programs.

This topic led to the formulation of the following research questions.

- What steps can be taken to reduce the chance of lost institutional knowledge in a high-turnover environment?
- What steps can be taken to reduce the time needed to train a high performing replacement employee, while maintaining strict performance and safety standards?
- What steps should be taken to improve the accuracy of budgetary projections?
- What steps need to be taken to enable accurate analysis of potential future investment opportunities in a training program.

The answers to the above research questions are compiled and presented with the aim to provide professionals, who are responsible for training programs in high-turnover environments that require a high organizational

reliability, with a framework and analysis toolset that will enable data-driven decision making regarding the program. Additionally this thesis provides a framework for addressing the continuous risk of loss of institutional knowledge. When contrasted with a standard training model, where a trainee is presented with new material and then tested for retention before moving to the next topic, the proposed model implements a schema that can be rapidly iterated upon and improved until the desired performance outcome is achieved, while increasing the potential accuracy of budgetary estimation by as much as 57%. Throughout the process, decision makers will have insight into the long term effects of their potential actions by way of running simulations that give insight into not only the expected steady-state cost of a program but also the rough volume of trainees required to achieve that steady-state.

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by

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Thesis submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirements for the degree of [Master of Science] [2023]

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1. Introduction

Background

The common belief is that high-turnover environments are a symptom of larger issues within an organization, e.g. poor management, poor compensation, poor working conditions, etc…, that have an accumulative effect of placing the venture at risk of losing profitability and possibly even failing. The research on the negative impacts of high-turnover environments is well documented.[1] This thesis will focus on mitigating a subset of the known negative impacts encountered in high-turnover manufacturing environments such as loss of institutional knowledge, reduced production yields, increased risk of injury to staff or damage to equipment due to inexperienced staff, and large variances in projected training costs. The distinction of this thesis is the underlying constraint that the high-turnover environment is immutable due to the nature of the business. As such there will be no attempt to address the causes or motivations that led an organization to experience high-turnover rates with staff. Instead, the proposed framework and toolkit endeavors to make "lemonade from lemons" by mitigating several of the most critical negative impacts outlined above. The reason for doing so is that under certain circumstances an organization may have no choice but to operate in a high-turnover environment and may have found itself in these circumstances due to factors outside of their control, which may not necessarily be rooted in a systemic organizational deficiency, but instead may be caused by external factors such as a highly mobile or transient workforce, such as seen on college campuses and on the United States border manufacturing industry.[2]

The heuristics derived from research findings are implemented in the proposed framework and toolkit in an effort to reduce the recurring direct and indirect costs associated with managing a continuous hiring and onboarding pipeline. To achieve this outcome, a specific approach is detailed that reframes and recontextualizes the underlying process by way of lateral thinking, which leads to optimizing the effectiveness of training programs. This approach uses a multifaceted framework that draws inspiration from Agile Project Management and stochastic analysis for addressing complexities in addressing the systemic risks inherent in organizations that demand rigorous training programs that require long-term retention of training materials in high-turnover environments. The framework implements research based heuristics integrated with stochastic analysis to give training program management a toolkit for making data driven investment decisions via simulation.

A prerequisite to the successful implementation of the proposed framework requires a holistic review of the roles and responsibilities within the organization. This necessitates stepping back and reviewing the starting point for most positions, the job listing. The standard conventions regarding job listings are that for a given job title there are typically a handful of primary responsibilities, i.e. job functions. For each area of responsibility a handful of specific tasks may be outlined that comprise the range of expertise needed to complete the job function. For example, a shift supervisor may have a primary responsibility to oversee the delegation of work orders to available staff while on shift. To execute this job function the shift supervisor would need to do several things such as work with an operations manager to ensure staff with the needed skills are scheduled appropriately and the required equipment is operational and available at the very least. In a typical work environment this level of detail may be adequate, especially if employees have sufficient time in their position to learn all of the nuances related to executing their job. But in a high-turnover environment, staff is more likely to be new to their position and won't necessarily know all of the specific policies, regulations, and requirements needed to identify when something is in the early stages of having a problem. To address this issue, the proposed framework includes a reenvisioning of the job listing into a "position hierarchy".

The position hierarchy builds upon the existing job listing model by expanding the scope to include sub-levels that introduce underlying the prerequisite skills needed to complete the tasks that comprise the job function. Depending on the complexity of the responsibility and underlying tasks, there could be several sub-levels that define the constituent skills, and knowledge needed to accomplish the next level up task. This model draws inspiration from systems engineering and project management concepts such as a work breakdown structure (WBS) to ensure all critical aspects of the job listing are captured. The reframing of the job as a project lends other opportunities for lateral thinking as well. Because job listings would be broken down to their smallest components, the entire scope of the training required to successfully execute the job is also defined. Furthermore, by leaning into the recontextualization of the job listing through the lens of project management, the full breakdown of the position now can take on the role of a backlog allowing for the implementation of elements of Agile which enable an iterative approach that has been demonstrated in industry to be an optimal method for rapidly building functionality. To fully take advantage of this concept the content of the overall program must be organized in a manner that facilitates the creation of subsets of training, in Agile this is known as minimally viable products (MVPs) but in the context of a job listing the subsets could be better described as microcredentials. Focusing the trainee on the acquisition of these microcredentials allows for the iterative building of skills which coincides with the optimal implementation of content, taking advantage of heuristics derived from the theory of cognitive load and the effects of temporal separation on the duration of content retention.

Just as with any other project, progress through the training program needs to be monitored and adjusted as needed.

The means for conducting this analysis is covered in detail in chapter 4.

Knowledge Gaps

The field of Transfer of Training is a subdomain of Industrial and Organizational Psychology and relies heavily on contributions from other fields of psychology and cognitive sciences. Researchers have long lamented an ever widening research - practice gap.[3]–[5] The thought experiment that provided the insight that a significantly more complex approach for the analysis was needed versus a simple linear product is summed up thus: If a trainee has the possibility of failing a portion of their training, then at some point in the lifetime of the program a trainee will fail. Thus being required to retake some portion of the training and thereby increasing the average cost of the training program above the linear product. As the number of lessons that are repeated increases, the less accurate the linear product calculation will become. To the best of our knowledge this is the first study to apply Markov Transition Matrices and Stochastic Modelling to provide insight into where the new average cost will settle into steady-state based on the observed pass/fail rates of the constituent training modules. Furthermore, the stochastic analysis includes estimates on how many trainees would need to go through the training before the average cost would achieve steady-state.

State of the art

The current state of the art in transfer of training is troubled, despite a century of research and 100's of billions of dollars spent per year in the United States alone, most of the research is inconsistent, fails to focus on practical implementation, and has resulted in an ever increasing gap between research and practice.[3], [5]–[7] In a 2011 survey of "... nearly 1,500 senior managers at 50 companies…" found that three-quarters of the respondents "... were dissatisfied with their companies' learning and development function.".[8] The training industry has been facing a multifaceted and extremely complex problem that spans the entire organizational structure.[5], [8] The response from academia has been to conduct research on individual pieces of the problem and present these as parts of the overall solution.[5], [9] Even worse the researchers leave it up to the readers to try to figure out where these bits of information are supposed to be implemented.[5], [9] The area of research that focuses on the effective transfer of training has long been criticized for ignoring the complexity of individuals in their journey to learn from training programs and continues to be an issue even 50 years later.[10], [11] Coupled with the gains seen in the cognitive fields over the last few decades, there are calls for a renewed focus on implementing new schema that pull the all of the sources into a coherent framework.[5], [12], [13] Several of these cognitive theories which focus on improving the amount, accuracy, and length of retention in which data will be transferred into an individual's long-term memory will be explored in more detail in the following chapter to give a basis for our current understanding of the mechanisms involved in memory formation.[12]–[15]

Within the cognitive field, the bulk of the literature focuses on improving the cognitive performance of an individual in discrete trials.[16], [17]

Training programs vary widely in form and purpose, from seminars to academic programs to work-study programs to name a few. Abstracting the typical archetypes, training is done either in-house or through outside agencies, e.g. Community Colleges, Universities, on-line training platforms, or consultants). These players rarely have accountability, such that their revenue is based on the long-term success of students.[18], [19] Instead the focus of these programs is typically to present the information to as many students as possible. Testing may be simplified to the extent that everyone passes and the bare minimum amount of effort is employed in ensuring any information is retained. Furthermore, to the best of our knowledge there is a distinct lack of using advanced mathematical techniques such as Markov Matrices and stochastic analysis to investigate the effect of pass/fail rates, on programs. Furthermore, predicting accurate costs for a given program can be challenging without these tools and removes the possibility of conducting accurate break-even analysis to decide if further investment in the program would be worthwhile. In the case where the program is managed by an outside organization there may even be a financial incentive to use subpar pedagogies to maintain failure rates since students retaking the course or exam could be liable to pay additional fees thus increasing the revenue per student.

Contribution

This paper posits an alternative, data-driven approach that integrates the latest heuristics from research with an iterative approach treating the program as a holistic framework that enables the quantification of the impact of new training techniques. The simulated findings of this thesis demonstrate the following benefits, more accurate budgetary projections, break-even analysis on future investments, asynchronous skill acquisition leading to smoother lateral & vertical moves within the organization, and evaluation of new training techniques and platforms.

2. Literature Review

Universal Design for Learning

This thesis contextualizes the large body of knowledge on the topic of technical training into two primary domains, Transfer of Training, which deals with the effectiveness of a training program to achieve the desired organizational need from their training and Cognitive Science, which focuses on how memory works and what steps can be taken to improve the efficiency of learning. This thesis takes the possibly controversial stance that heuristics of pedagogy are derived directly from the outputs from research in cognitive sciences. Thus, pedagogy fills the tactical role of implementing the strategic findings within cognitive research. Early in the 1990's researchers began to find the standard lecture format of teaching was ineffective for significant populations of their students. Which led to a group of researchers led by Dr. David H. Rose of the Harvard Graduate School of

Education, recognized the need for a framework that put a pedagogical focus on lowering as many barriers to learning as possible and led to the formalization of the Universal Design for Learning (UDL) framework.[20] The UDL framework focuses on encouraging content creators to use multiple: methods to present the content, modes of demonstration of acquired knowledge, activities to increase engagement.[20] The UDL framework has its limitations in that creators of the content for a training program are responsible for ensuring all modalities are represented. To complicate the matter further, the spirit of the UDL framework is based around the recognition that there is not a universal method for presenting content that guarantees the optimal conditions for all students to achieve maximum efficiency in learning. So content creators ultimately rely on a shotgun approach, attempting to use as many modalities as possible to, hopefully, engage with as many students as possible. This clearly represents the addition of a whole new dimension within the content creation process, since not only does the content have to be captured within the curriculum in a way that the lecturer is comfortable presenting it, the creator must also identify multiple modalities and approaches for conveying the same information to fulfill the spirit of UDL. This added burden, however necessary, when coupled with budgetary and time constraints, has a high likelihood of leading to a less rigorous implementation of the framework than needed while still following the spirit of the framework.[21] Looking forward for a moment, UDL could stand to benefit from continued research which attempts to leverage the existing work in the classification of different learning styles and develop a standard set of heuristics that provide a deeper level of guidance for the development of content that successfully targets each subset of learners. Thus allowing for a methodical and iterative approach to developing content that allows creators to support smaller and smaller subsets of student populations. Ultimately, UDL advocates for a redundancy in content but distributed across modalities in an attempt to engage with students via paths that have the potential to activate an intrinsic motivation for learning. Stepping back and looking at the larger picture, UDL provides guidance on how content should be presented and engaged with. The following sections pivot from the tactical pedagogy to delve into the underlying strategies derived by cognitive research which gives insight into how much should be covered at any given time for optimal learning.

Theory of Cognitive Load

In the 1980s John Sweller developed a theory that humans had a limit to the amount of information they could process at any given time.[12] This limited data set is referred to as working memory, which is not to be confused with short-term memory or long-term memory. The key takeaway is that short-term memory is used for holding data for relatively short periods of time, on the order of several seconds to minutes. While in contrast working memory is used for processing data. For example, short-term memory would be used to remember an item from a grocery list while trying to find the item in the aisle at the store. Working memory would be used to identify additional recipes that could be made from the item you are looking for in that aisle and what other additional items would be needed at the grocery store. [22] Trainers and instructors can leverage their understanding of Cognitive Load to approximately know when students have been saturated with information and need a break to free up some of their working memory. The complexity of the content that the student is learning is one factor among many that dictate the cognitive load's bandwidth.[13] Furthermore, complexity plays a role in how long a student will be able to be exposed to active learning before needing a break.[13] The current heuristic for optimal concentration is based off of Ultradian Cycles and the Basic Rest-Activity Cycle, which states typical humans can maintain optimal concentration on an activity for 90 - 120 minutes before needing a break.[23] Obviously, this is not to say that students and individuals can not be productive after 120 minutes of dedicated activity. But there is general agreement with some exceptions, that there will be a reduction in the performance of the student and as such diminishing returns on continued effort without providing sufficient break time for the student to process and digest the information they just received.[24] Intuitively, complex or convoluted topics may require more frequent breaks than the 90 minute average if one wants to keep the students at peak active learning.

The Effect of Temporal Separation of Tasks

In their article within the Journal of Experimental Psychology Dr. Underwood and Dr. Freund, demonstrated that when test subjects were given memorization tasks with confounding content, allowing a temporal separation of three days "markedly" improved the recall.[25] These findings are supported in the work by Cepeda et al 2008, where they were able to corroborate previous findings and demonstrate a relationship between the temporal gap between exposure to content and the length of time that content may be accurately retained.[26] The critical finding was one that has long been suspected, if you want a student to retain course content for a significant period of time, they must have a relatively significant gap in between exposures, e.g. multi-year long retention of information requires gap exposures on the order of several months. The implications of this research can not be understated, to effectively implement this research would require a significant overhaul of existing training program schedules. While enlightening and potentially quite impactful, the current teaching model uses the idea that even though a student will soon forget the specifics of any content they consume, when they need to refresh their understanding of the material in the due course of their job, the effort required to "refresh" to a similar level of mastery as when first exposed is significantly reduced. Said more simply, the second time learning material is much easier than the first time around. The proposed framework within this thesis isn't satisfied with the status quo and demonstrates how the application of Agile Scrum

Methodologies can facilitate an adequate exposure gap. Temporal separation provides insight into the positive effects of a schedule's cadence and directly implies a benefit from the application of an iterative approach where concepts would be touched on at multiple points throughout the training.[27] The proposed framework attempts to further define the multiple touch points as "Yes, and…" opportunities where not only is the information reiterated but expanded upon to give context and constraints, such that the trainee begins to understand not just the core process but gains an holistic understanding of how this specific piece of information fits into the overall job function. By attempting to use the Agile Scrum framework to take advantage of the Effect of Temporal Separation, a training program will be presented with several opportunities to present that information in different modalities thus also satisfying the spirit of the UDL. Research in the underlying theory has provided some additional heuristics which have been applied to the proposed framework in the following sections.

Theory of Multimedia Learning

In 2003 Dr. Richard E. Mayer and Dr. Roxana Moreno published their proposed model for the Cognitive Theory of Multimedia Learning in “Nine Ways to Reduce Cognitive Load in Multimedia Learning”.[15] The model “...relies on three cognitive science principles of learning…”; we learn through the use of our eye and ears to deliver inputs to the brain (dual channel assumption), there is a limited amount of information that can be received via sight or sound for any given period (limited capacity assumption), and that for active learning to happen “...a coordinated set of cognitive processes..” must occur (active processing assumption).[28] Dr. Mayer’s and Dr. Moreno’s seminal work developing this model lends some much needed tactical aspects to the challenge of creating learning content. Not only does the model provide initial guidance on what modalities should be included in presenting the learning content, but it also gives insight into how the content should be organized and limits to how much content should be fed to the students while considering the limits of their cognitive load. As would be expected from a coherent strategic/tactical relationship between cognitive sciences and pedagogy, Multimedia Theory and UDL exemplify this model.

In contrast, one of the most pervasive ideas held by the general public is that they have a specific learning style as described by Flemming and Mills' VARK model.[29] This usually takes the form of self-identification as one of four main types: visual learner, audio learner, reading/writing learner, or tactile learner. The literature in this area of research is surprisingly contentious.[30], [31] What we can say with some measure of certainty is that no one is just a single type of learner, e.g. visual/auditory/reading/writing/tactile. Instead evidence points towards a judicious application of all four modalities considering multimedia theory thereby presenting the highest probability of resonating with the learner as UDL proselytizes.

Future areas of research could include a study that tries to correlate a specific blend of learning modalities to an activity which produces the highest amount of retained information in the student over a period of time. More simply, we would be looking to find out if helicopter instructors should use the exact same composition of modalities as someone teaching

Intro to Excel, or does the nature of the task being learned play a factor in deciding the optimal blend of modalities. At the intersection of content creation and content instruction lies a possible inefficiency in the learning process. The content creator decides on the scope of the content to be covered over a specific period of time. Given the constraints provided by cognitive load, the instructor gets to observe the real-time effects of the content on the students. A common observation is that when too much information is given to a student in too short a time period they can start to show a “glassy-eyed” appearance. Instructors are encouraged to monitor the rate at which students reach this point and are encouraged to investigate if different modalities change that rate.

Physical Indication of Information Overload

There exists a large body of knowledge that gives evidence of a connection between cognitive load and the diameter of the subject’s pupils.[14] In their work researching short term memory, Beatty and Kahneman (1966) were able to show a direct correlation between the amount of memory being used and the diameter of the subject’s pupil to the extent that as the demands on the subject's memory was increased so did their pupil's diameter.[32] Furthermore as the subject removed the need to remember portions of the data, their pupil diameter would decrease roughly proportionally. These findings have provided a basis for measuring cognitive load in a lab setting and while there is an obvious value to leveraging this physiological response, to the best of our knowledge, to date there has been no reliable way to pull this process out of the laboratory reliably. With that in mind, this is an area of research that holds an enormous potential economic value and should be explored in the future.

3. Establishing the State of Practice: Training Programs in Industry and Educational Institutions

Nearly every organization has to implement some form of in-house training to the tune of $160 billion in the United States and $356 billion globally in 2015 alone.[8] Employees come into the organization with various levels of experience and different ways of completing duties. Intuitively, some form of standardization must happen to align everyone's efforts towards industry best practices, regulations, and/or risk mitigation from safety and liability concerns at the least. Typically these types of in-house training programs are classified to be non-revenue generating or “Overhead” activities and in general also carry an opportunity cost in that the employees conducting and overseeing the training could be spending time doing profitable work. These complications are further compounded by a generally perceived lack of positive impact.[8] As a result, from a financial and management perspective, in-house programs will have a financial incentive to be run as cheaply as possible while providing the minimum amount of training required by either internal or external stakeholders.

In-house training programs typically can take one of two forms, a department dedicated to providing training programs for generalized knowledge such as leadership training, supervisor training, or IT security training to name a few. Alternatively, training can be based within a department where the job specific training is given by members of that departmental team to other members of the team. In both cases the organization still has a financial incentive to deliver the most cost effective training possible. Defining cost effectiveness relies on understanding that the cost to the organization is multifaceted and has ripple effects throughout the organization. For instance, the training department's team may have a performance metric that measures the number of people trained and therefore additional time spent on refining the training program is less time spent training individuals and potentially negatively impacts performance numbers. On the other side of the coin, there is an opportunity cost that the trainee's department must pay by having the individual go through the training in the first place since they will be spending time on the training instead of billable work. Ideally the organization's leadership would have performed a cost-benefit analysis to determine whether requiring the training is worth the effort; such as in the case of the cost associated with a potential data breach from a successful phishing campaign versus the cost of training the entire workforce in IT security best practices. Other factors such as contract stipulations or liability insurance may dictate that certain information must be disseminated to the workforce and in such cases would ideally be included into the contract cost or rolled into standard onboarding training. Thus from an organizational lens, there is a demonstrable financial incentive to place the minimum amount of effort, i.e. labor hours, into a training program that delivers the minimum required knowledge to the trainee that satisfies a requirement.

Exploration of In-house Training Programs Formats and the Respective Effectiveness When Viewed Through the Lens of Research Heuristics

Training, at its heart, is a communications challenge. The structure of the communication can take a wide range of forms as seen in UDL and the theory of Multimedia learning. This can be as simple as on the job training or informal coaching where an experienced employee demonstrates an activity while the trainee watches. This is typically followed up by having the trainee run through the activity a couple of times with the trainer looking over their shoulder to make sure they are performing the activity correctly. On the other hand the training can be completely formalized to the point that the trainee works through a fully documented work instruction that takes them step-by-step through a process or procedure. Each form of communication should be chosen to maximize the impact of the training while aiming to reduce the need for retraining or possible mistakes made by the trainee. Furthermore, research has shown that the training doesn't happen in a vacuum, the performance of the training in reaching its organizational goals is heavily influenced by support from the trainee's supervisor, peers, and climate.[33] In practice though, the solution is usually based on convenience rather than efficacy due to a lack of translations between the science-practice gap.[3]

Once the formal training has been completed the all too common scenario of leaving a trainee to figure something out on their own plays out where they can waste hours to days struggling to make progress on a problem that could potentially be solved by a more experienced employee in a relatively short period of time. This can lead to a belief that trainees are wasteful and inefficient, when in reality they are left to struggle with the gaps in the training they received. Within those gaps the trainee loses the structure that gave them confidence that their next action was the correct one. This can lead to the trainee procrastinating to start their next task for fear of making mistakes which in turn can increase anxiety which has been shown to have a strong negative relation with all learning outcomes.[33] These observations are backed up by research conducted by O'Brien (2015) and Postareff, et al… (2008) that demonstrated pedagogical training of the trainers had a beneficial effect.[34], [35] Incorporating student-centered training approaches that recognize and account for training motivation are a critical component to increasing the likelihood of a successful training program.[33] That effort combined with a deeper understanding of the heuristics established in the previous chapter can go a long way towards improving the potential outcomes of a training program.

Exploration of For-Profit Consultants and their Respective Effectiveness When Viewed Through the Lens of Research Heuristics

One of the primary challenges with creating training programs is ensuring that the financial incentives align with the course objectives. This alignment is rarely the case in reality though. Much more common are contracts which stipulate X many hours of training of Y many people covering Z topics. The logical conclusion being an optimization process that focuses on increasing the throughput of people being trained rather than improving the individual outcomes. In part, this makes intuitive sense because for-profit content providers don’t want to assume the risk of their financial security being tied to the performance of individuals whom they have limited influence over. Another complicating aspect is that quantitative analysis of someone’s knowledge retention is difficult and ambiguous, especially given the negative effects associated with anxiety that typically present during examinations.[33] To what degree does someone “know” something; do they need to have perfect recall within a given timeframe, do they only need to remember the major steps, or do they only need to know which reference materials they should consult?

Consider a situation where a customer is trying to decide between two agencies that specialize in providing the training they need. One agency provides guarantees on performance and the other does not. In general, care must be taken by for-profit organizations because failure to properly execute due diligence efforts and fully define the customer’s learning objectives can lead to arbitrarily setting standards. Which if underestimated, can artificially reduce the success rates of the training program and increase costs by having the difficulty exceed the needs of the program’s desired learning outcomes. From the standpoint of a for-profit training agency, lack of control on who is being trained, and to what degree the trainees must retain the material, represent potential risks to meeting the performance expectations laid out in the contract. The effort required to mitigate that risk can be greater than the reward and may result in increased costs to cover those risks. The increased costs creates a pain point for the customer, because price is always one of the driving factors. The customer is then forced to choose between training agencies, one with performance guarantees which includes a price premium to cover the above discussed risk or one without but at a significant price discount. Given the general lack of faith in training programs held by most executives, it shouldn't be a surprise that the cheaper agency would likely win.[3], [8] The organization under current U.S. labor law doesn't need to assume the liability associated with this choice because they are able to pass that responsibility on to the trainee. As a result the trainee is forced to take the risk associated with the training since lack of performance could be cause for termination. The problem with this approach is that it creates a filter with unintended consequences. Those who pass this hypothetical training program have the traits that are optimized for passing the training. Most importantly those who don't have those traits may lose their employment even though the traits they were hired for may have nothing to do with the traits being interrogated by the training. This mismatch in the alignment of training program goals, successful trainees, and the actual duties of the job could account for a waste of potential talent and deserves its own line of inquiry.

Exploration of For-Profit Training Programs Formats and the Respective Effectiveness When Viewed Through the Lens of Research Heuristics

The inadequacies inherent to the generalized for-profit model are systemic and reflected throughout the various specific methods of implementation discussed thus far. Figure 1 presents a model to represent the basic elements of a generalized training program. The purpose of the model is to give insight into the relationships between different facets of a training program without the need of diving into complicated details of a specific program. The training pyramid posits that there are two legs of equal value, coined here as the Content and Presentation legs. The base of the model is the Course Schedule, which is placed on the bottom to represent its purpose as the foundation upon which the other legs are built.

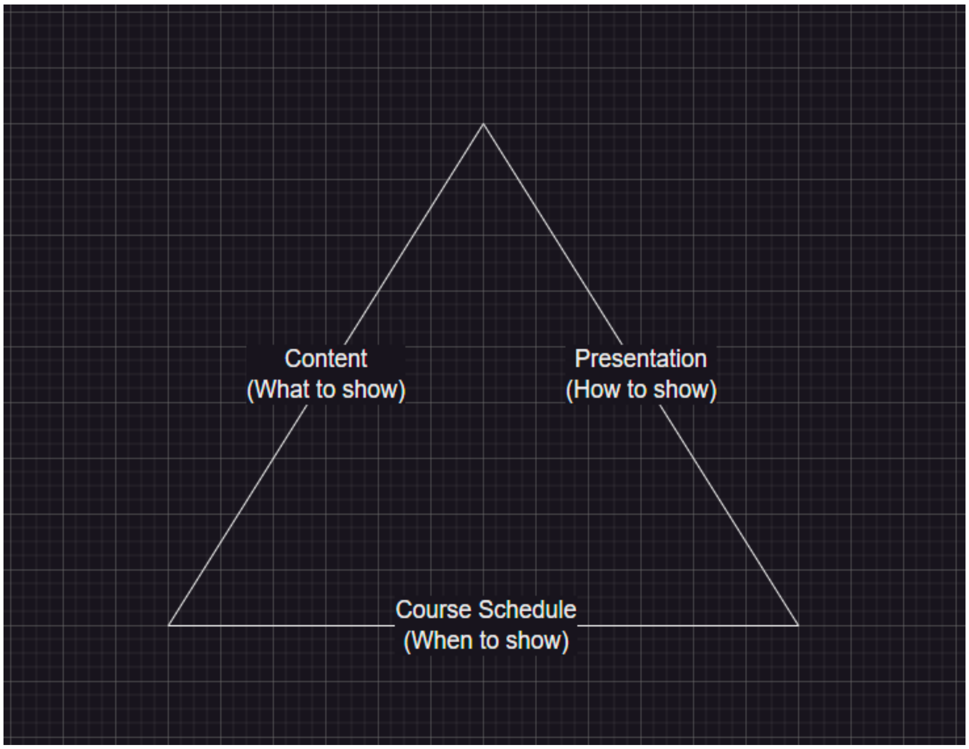

Fig. 1 Training Pyramid

The Content leg of the pyramid simply represents the summary of topics included in the program. While the Presentation leg encompasses the various modalities that will be implemented throughout the duration of the program and take advantage of the latest best practices derived from the cognitive sciences. The Course Schedule encompasses the rate at which Content is covered as well as the order in which topics are covered within the program and solely utilizes heuristics from the Theory of Cognitive Load.

Cognitive Load is affected by both the Course Schedule and Presentation, with the Course Schedule being the driving factor in the relationship. This assertion is based on a simple thought experiment in which one sets either the Presentation or the Course Schedule as the driving factor in a scenario and evaluates the resulting outcome.

Scenario 1: If the Presentation of the Content is poorly executed, a positive outcome can still be achieved by extending the Course Schedule, thereby giving the students enough time to discover examples or material on their own time such that they are able to decipher the intended meaning of the course content. Cognitive Load would spike during the initial training session trying to decipher the poorly executed Presentation but would be reduced during subsequent training sessions due to being given additional time to ask questions, work examples, and fully understand the topic before moving on to the next topic within the Content.

Scenario 2: Where Presentation is the driving factor, the Presentation of the Content is optimized for the audience and teaching environment using the Theory of Multimedia Learning. Though there isn't enough time set aside within the Course Schedule to fully explore the available content or allow the students opportunities to ask clarifying questions. An example of this could be a situation where there is a surplus of resources in several modalities that build upon each other to reinforce each subtopic of the Content. Due to time constraints, multiple topics are superficially covered during each training session leading to poor comprehension during the allotted time and forcing the student to take time from other activities to achieve understanding or risk falling behind and disengaging from the training program.

Within for-profit organizations the conventional method of creating training programs is to focus the bulk of their effort on the Content and Presentation legs of the Training Pyramid. With external financial incentives trying to keep the per hour cost of the training as minimal as possible, there are limited opportunities for trainers to incorporate feedback from trainee cohorts into the program and have the same trainees validate the implementation. As a result, Course Schedules are constantly under pressure to reduce the amount of time and number of exposures to the Content to the absolute minimum as a function of cost. An optimal solution could still be found if it were the case that the Course Schedule was instead optimized to the minimum required to achieve a specific retention window and cost. The reality of the situation is that for-profit training programs typically won't guarantee the performance of trainees through their program because of those pressures and it falls on the student to teach themselves the required Content.

These systemic shortcomings are present in a wide variety of for-profit training program providers because clients go to the providers for the creation of the Content, Presentation modalities, and Course Schedule. The program provider is keenly aware of the sensitivity of the client to price and will make some version of the program that will fit within the established constraints. Below is a non-exhaustive summary of program formats:

- Bespoke training programs
    - Where a program is built from the ground up with input from key stakeholders on the scope of the content.
- A la carte training programs
    - Program providers have an established catalog of topics that clients can choose from to combine together into a single program.

- Seminar Training Programs
    - Where the company has a training program for a specific product or service. Typically presented in a lecture format.
- Online training platforms
    - Where a certificate can be obtained at the end of the program or access to a substantial catalog of topics becomes available.

In fields where the stakes are low-risk or low-complexity, this model may work relatively well. In high reliability organizations where there is significant risk to equipment or personnel, this approach is dangerous and borderline negligent. In such organizations the trainee must be guided through each step in the program so that their lack of experience doesn't color their interpretation of the training content.

4. The Blanton Training Framework

Required Background Information

The concepts and ideas used to create The Blanton Training Framework (BTF) come from a large variety of scientific domains. Cognitive Sciences (Theory of Cognitive Load, Theory of Multimedia Learning, Effect of

Temporal Separation, etc…) provide a strategic foundation for identifying the constraints of the mechanisms controlling memory creation. Implementation of those mechanisms is tactically discussed in Educational Psychology (UDL, Learning Styles) and Industrial & Organizational Psychology (Transfer of Training through the Organizational, Local, and Within Lenses). But as discussed above, those tactical implementations fail to successfully bridge the research-practice gap. By integrating elements of Project Management (Work Breakdown Structures, APM, Break-even analysis, and Return on Investment) and Systems / Operations Engineering (Markov Matrices, Monte Carlo Simulation, Cost Model Optimization, and State Machines) we are able to leverage toolkits from mature tactically focused domains to finally lay the groundwork needed to bridge the research-practice gap. The following sections will provide a primer on those additional topics.

Primer on Agile

Recounted in Martin Fowler and Jim Highsmith's article "The Agile Manifesto" in the August 2001 edition of Software Development Magazine, Agile was created in a snowy lodge in Utah over the weekend of February 11 - 13 2001.[36], [37] At that gathering 17 software developers came together to meet "... talk, ski, relax and try to find some common ground." At the time software development methodologies were in flux. Frustrated with the limitations inherent in the traditional Waterfall development methodology, practitioners began experimenting with integrating elements of lean manufacturing and iterative design with the hopes of discovering a more dependable process for completing software development projects on-time and under budget. The result of that weekend was the birth of a new methodology which was captured symbolically in "a Manifesto for Agile Software Development" which was signed by all who attended.[x]

The Manifesto was short but revolutionary.

"We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:

Individuals and interactions *over processes and tools*

Working software *over comprehensive documentation*

Customer collaboration *over contract negotiation*

Responding to change *over following a plan*

That is, while there is value in the items on the right, we value the items on the left more.”

Over the last two decades Agile Project Management (APM) has grown beyond its origins as a software development tool. As proponents of the methodology gained experience and were able to demonstrate the value of adopting APM, other industries took notice and began implementing elements of the Agile Methodology to see if they too could benefit from this new approach.[2], [38] Companies outside of the traditional use case for APM have begun testing to see if Agile would function in environments outside of software development with generally positive results.[39] Thus leveraging one of the most powerful aspects of agile, its flexibility to be integrated into existing project management structures creating custom implementations that worked specifically for the application at hand.

There are few things all novel projects share, but risk and uncertainty about the details and level of effort required to profitably finish the project are one of them. Because of this, and through trial and error, APM practitioners have been able to leverage Agile's strengths related to rapid iterative development within a project to minimize risks associated with overly constraining an ill-defined system. This thesis posits that the same abstraction and broad implementation of general Agile principles can be applied to training programs.

This assertion is grounded in two points. First is the concept of training as a direct analog to a hypothetical project. Each trainee going through a training program is going to have differing background experiences, education, short-term/working memory capacities, etc… so the path to mastery of the desired learning outcomes will be slightly different for each trainee just as the path to completion of a project will be slightly different each time it is executed. Therefore a system needs to be in place that allows for the integration of feedback on the effectiveness of the training program from not only the perspective of the trainees but from the organization as well. The BTF proposed in this thesis aims to address each of these perspectives and use them as parameters for a stochastic analysis which empowers the program managers to identify and potentially mitigate risks while making informed, data-driven decisions on future investments into the program.

The second point goes, if the training program frames each segment or module of training content as a Minimally Viable Product (MVP) that provides the information required to complete a job function then subsequent iterations can also include the information required to place that content within the larger structure of the overall job. Thus enabling the implementation of best practices derived from research on the effects of temporal separation between exposures to information and the length of time that information is retained. Increasing the frequency of callbacks to previous training content forces the trainee to recall that previous content thus reinforcing those connections in memory and extending the retaining period of that knowledge. As the retention of the information is improved in the trainee, one could expect fewer mistakes on the job along with more trainees successfully completing the training with fewer mistakes on exams, practical demonstrations, etc…

To the best of our knowledge the current state of practice regarding the management of training programs fails to leverage Monte Carlo simulation to aid in the decision making process. Assuming the program is structured such that students have a realistic possibility of failing an exam or practical demonstration and as a result need to review past content or retake the exam results in underestimating the actual costs associated with a training program.

Broadly speaking training can come in two forms. First as an information dump, where the student is presented the training material once with a trainer and is then expected to do whatever they need to do to commit that information to memory. The other way would entail a program that periodically checks on the comprehension of the student via demonstrations of some sort. Intuitively, if there is additional support for the student with knowledge checks designed by those who defined the learning objectives for the training program, students in that program will likely perform better than those who just received the information alone. The risk to the organization is that budgeting for training programs fails to account for the probability that someone will fail. For example, the standard method to calculate the cost of a training program is to find the product of some number of students who will undergo an amount of training for a quantity of money per student, regardless of whether the program uses the info dump style or the supported style.

This presents a problem in the case of the supported style due to the intuitively understood concept of “If a student has the possibility of needing to repeat a course or module then there will be a student that needs to repeat.” This simple aspect has far reaching ramifications on the ability of the program manager being able to accurately predict the actual costs associated with the training program. To address this issue we need to add another tool to our toolbox, broadly known as stochastic analysis or more commonly known for a specific method, Monte Carlo Simulations.

Primer on stochastic analysis

Monte Carlo simulations encompass a family of mathematical operations within the larger topic of stochastic analysis.[40] Starting with an algebraic equation of more than one variable, at least one variable in the equation must be defined as a random variable. Then the equation is solved with each iteration of the solution using a random value plugged into the variable. Each result is plotted and over hundreds to millions of iterations the effect of the random variable on the equation is exposed.[40] In the specific case of this thesis, the random variables are defined as the pass / fail rates of students performing practical demonstrations of the knowledge they just learned from a series of training modules.

On its own, Monte Carlo simulations wouldn’t give much insight into the performance of a training program. The solution was to incorporate elements from Markov Transition Matrices into the algorithm, which was the key to finding useful information.

Primer on Markov Transition Matrices

Andrei Markov (1856-1922) was a giant who stood on the shoulders of geniuses such as Gerolamo Cardano (1501-1575), Jakob Bernoulli (1654-1705), and Pierre de Laplace (1749-1827). Markov furthered our understanding of probabilities and stochastic processes with the discovery of Markov Chains.[41] Markov Chains are a method of representing systems where each state in the system has a probability of transitioning to another state or staying in the current state as seen in Fig. 4

$$P = \begin{bmatrix} P_{1,1} & P_{1,2} & \dots & P_{1,j} & \dots & P_{1,\alpha} \\ P_{2,1} & P_{2,2} & \dots & P_{2,j} & \dots & P_{2,\alpha} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ P_{i,1} & P_{i,2} & \dots & P_{i,j} & \dots & P_{i,\alpha} \\ \vdots & \vdots & \ddots & \vdots & \ddots & \vdots \\ P_{\alpha,1} & P_{\alpha,2} & \dots & P_{\alpha,j} & \dots & P_{\alpha,\alpha} \end{bmatrix}.$$

Since the total of transition probability from a state i to all other states must be 1,

$$\sum_{j=1}^{\alpha} P_{i,j} = 1;$$

Figure 4 Markov Matrix Source: https://en.wikipedia.org/wiki/Stochastic_matrix

One interesting feature of Markov Chains is that they can be used to predict the progression through a system given the probabilities of transition and define the probabilities of transition given an actual progression. Adding Markov Chains to the framework proposed in this thesis adds two critical features.

- Predictive modeling can be accomplished by running Monte Carlo simulations on the training program that is defined by a Markov Transition Matrix.

- Empirical results consisting of the averaged student progression through a training program can be used to quantify the probabilities of transition through a training program.

These features are crucial to increasing the efficiency of any training program. Being able to predictively model costs associated with a training program more complex than an info-dump, X hours of lecture for Y amount of dollars is a key feature missing in training programs on the market today. Furthermore, with the addition of stochastic analysis to a training program, managers now have the ability to perform cost-benefit analysis on marginal tweaks to the program to within a specified probabilistic confidence level. Thus proactive management of the training program becomes an option previously unavailable.

Research Findings - Question #1: Application of WBS model as an Analog to Position Hierarchies

Job Breakdown Structure

In high turn-over environments, defined here as workplaces that lose more than 10% of their staff per year for various reasons, day-to-day operations rely on quickly and effectively training individuals to replace those who left before them. Add in the complication of the workplace being a High Reliability Organization, defined here as an organization in which there is significant risk of damage to employees or equipment in the course of operations.[42] These organizations occur regularly in industry and academia when working with manufacturing equipment. Extensive resources are dedicated to training individuals to operate extremely complex manufacturing equipment as quickly as possible. In such an environment, the battle between undocumented institutional knowledge and what is captured in training modules, work instructions, and standard operating procedures (SOPs) is constant. Therefore to address this issue, a hierarchical job duty framework is proposed to capture not only the discrete elements of a staff position but also how the elements integrate into the overall position. Fig. 5 depicts this proposed framework coined the “Job Breakdown Structure” (JBS).

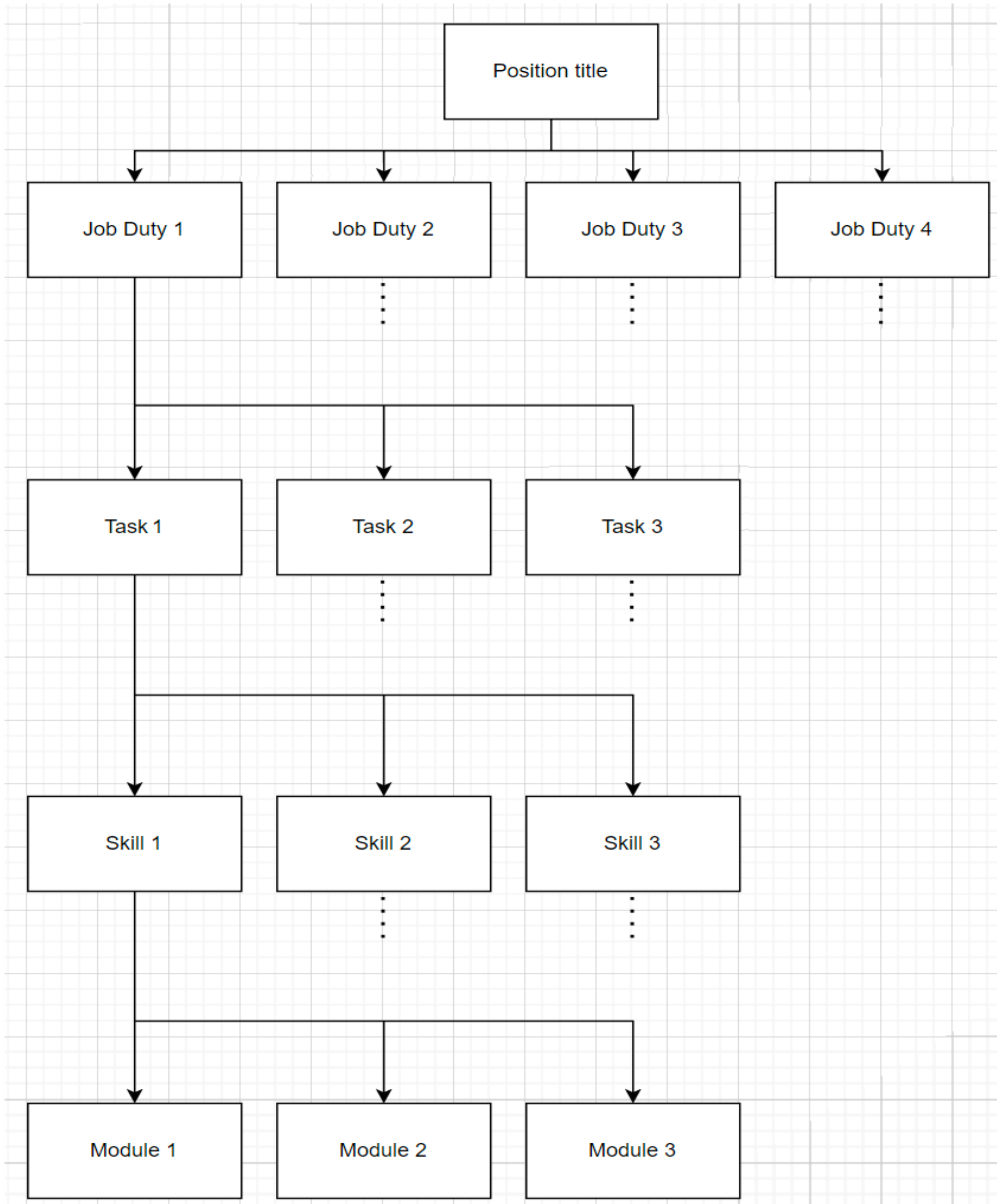

Figure 4 Job Breakdown Structure Framework

The JBS framework is an expansion of the current position listing framework but takes advantage of existing methods of decomposition of a project used by Work Breakdown Structures. Doing this will provide a degree of completeness commonly missing from a standard position listing. But it is critical to the definition of learning outcomes in a training program for the position.

Conventionally, each job listing will typically identify three to five areas of responsibility that cover the primary duties of the position. These are represented in Fig. 5 as the second tier of the hierarchy. Under each of those responsibilities will be a series of tasks that typically define the desired experience for a potential employee, i.e. it’s usually preferable to have someone who already knows how to do those specific tasks and therefore can take on the overall responsibility rather than incurring the cost of teaching them every individual task. These are represented in Fig. 5 as the third tier of the hierarchy. The newly proposed framework expands on this concept to recognize that for each of those tasks individuals will need to have a specific set of competencies or Skills to accomplish them. With the required basic toolset now defined, the next step is to break those skills into modules that adhere to the heuristics alluded to in the previous chapters.

Figure 6 presents a hypothetical example of a Job Breakdown Structure for a computer numerically controlled (CNC) equipment technician. A CNC is any piece of manufacturing equipment that can be programmed to move a tool in coordinate dimensional space to complete a specific manufacturing task. Programmable Mills, programmable drills, programmable lathes, 3D printers, and electronics pick & place machines are all examples of "CNC" type equipment.

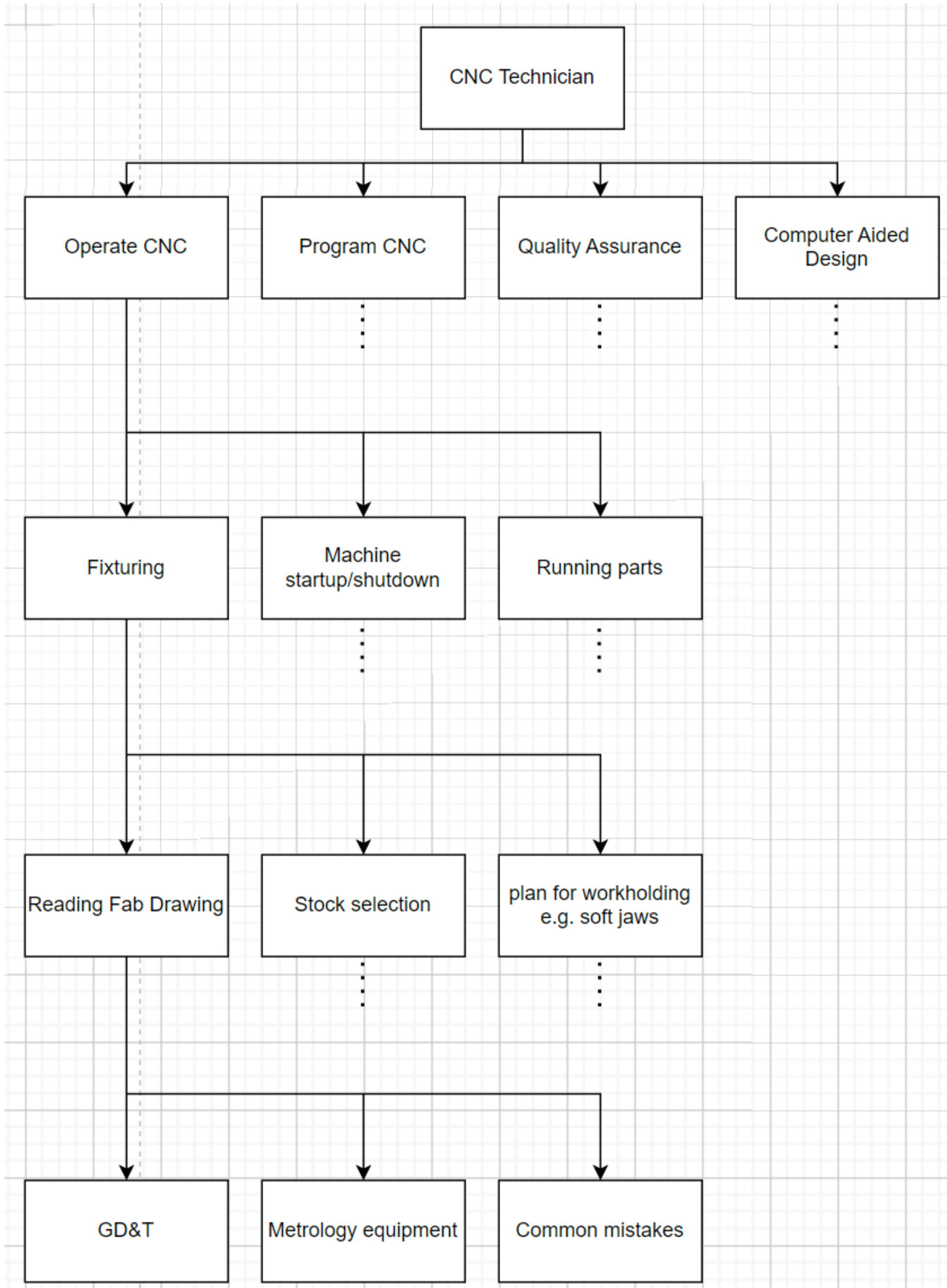

Figure 6. Job Breakdown Structure Example

The example presented in Figure 6 demonstrates how the functions of the position can be structured to derive the topics required for successfully executing the position. As mentioned before, the top line simply lists the position title. The second row is made of the primary responsibilities for the position. For the sake of simplicity a single responsibility “Operate a CNC” is investigated and consists of several Tasks; Fixturing, Machine startup/shutdown, and Running parts to name a few. The Task of Fixturing is further investigated at the Skills level and covers content related to holding the thing that is going to be machined, this topic can include both raw stock materials that are direct from the supplier as well as stock that has already been through some processing steps. For this example we chose Reading Fabrication Drawings to explore at the Skill level which breaks out to several modules that contain the information on sub-skills needed to complete orders that use that Skill. The expansion of the level of detail in a typical job listing presents opportunities for organizations to identify gaps in their training regarding specific duties, responsibilities, skills, or sub-skills. Furthermore this level of detail should increase organizational resiliency when viewed in the context of high-turnover environments (HTEs) while also providing opportunities to identify subsets of critical skills that can be converted into parallel training opportunities.

Application of the JBS Framework requires a cultural embrace of documentation and treating all training content as living documents. Each employee must be vigilant regarding the documentation of tips & tricks, rules of thumb, i.e. institutional knowledge, as they learn it due to the high likelihood of their leaving the organization in the near future. Aside from institutional knowledge being passed by word of mouth, failing to leverage what we know are practices that produce longer terms of retention as detailed by the cognitive sciences, there's also the fact that the dissemination of that knowledge will be limited to the audience that receives it. If the trainer's replacement didn't receive that institutional knowledge from their predecessor then all future generations of trainees also lose out on the knowledge as well. Thus guaranteeing that the organization will have to pay employees to rediscover the same knowledge time and time again. The goal is to break that chain by capturing that institutional knowledge in a format that ensures it will be available to future generations of employees for as long as it is needed.

Another benefit of implementing the JBS framework is that employees will have clear guidance on what is expected of them at their current level, but if they wish to add new skills needed for a position, there won't be any guesswork. Career planning becomes simplified by way of self-identification and the mitigation of uncertainty for the hiring committee. Those who undertake the prerequisite training for specific responsibilities and skills will know they aren't wasting their time and effort on learning skills that won't help them achieve their desired promotion.

Lastly the full implementation also presents opportunities for subsets at the responsibility, task or skill level to be isolated and converted into microcredentials. Individuals that may want to explore options for making moves within an organization could use microcredentials as an opportunity to gain experience in a prospective new position without needing to make the change first. From an resiliency standpoint organizations could incentivize cross-training on subsets of skills or tasks that need additional support and those individuals could be leveraged in times of need.

The integration of the cognitive theories, stochastic analysis techniques, and the JBS framework set the stage for the proposed training framework.

Research Findings - Question #2 Application of Agile as an Analog to Proposed Training Model

Traditional training programs can be modeled ("standard model") as a state machine, presented in Figure 2. The standard model is characterized by discrete modules that must be passed before progressing on to the next module in the course. Each module is intended to be completed in its entirety before moving forward. When viewed through a project management perspective the standard model adopts the characteristics of a Waterfall model with all of its inherent issues and complications as seen in Figure 3. Even though the standard model fails to take advantage of the benefits found in leveraging Cognitive Load Theory, it's still better than an info-dump style program where there are little to no programmatic opportunities for trainees to reflect, assimilate, and extrapolate on the knowledge given to them beyond superficial ones at best.

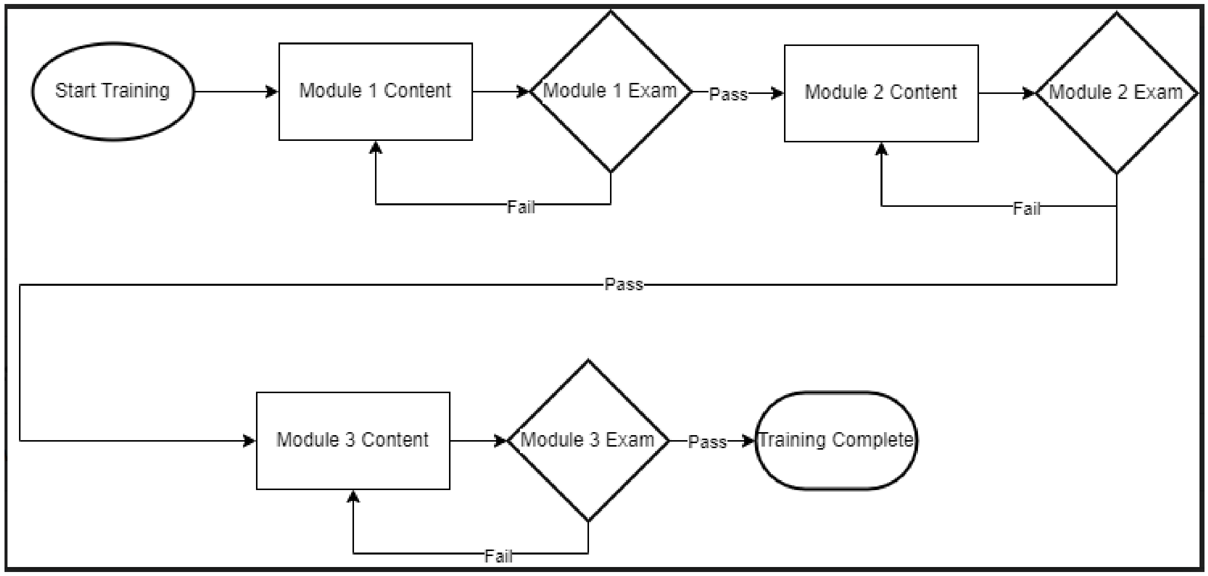

Fig. 2 Standard Training Program Model

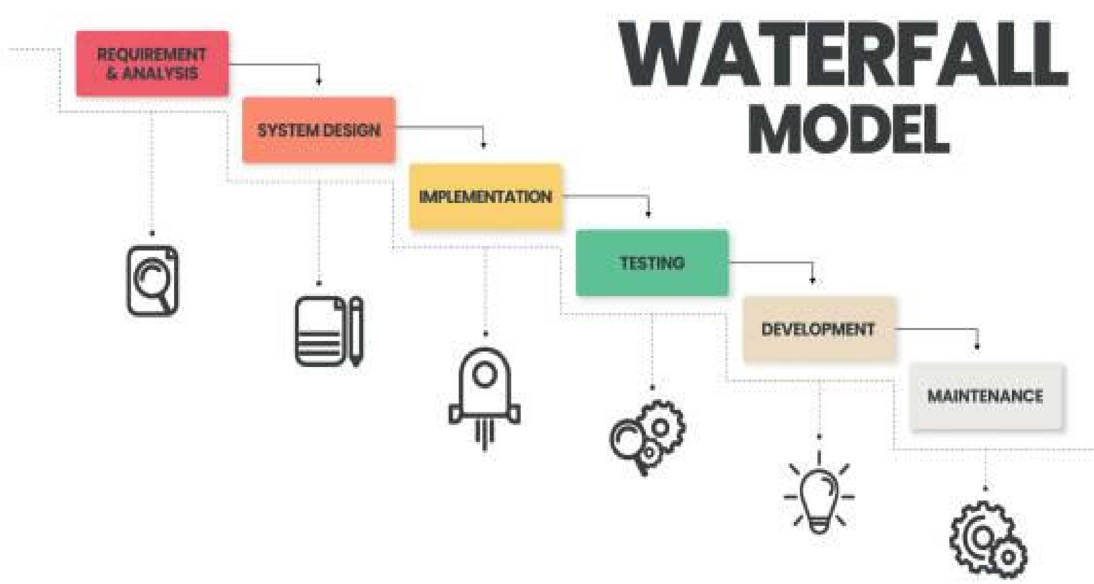

Fig. 3 The Waterfall Model

An underlying issue when dealing with optimization of training programs is the lack of accurate data associated with long-term costs of running the program. Within the standard model a program manager may have data representing the pass/fail rates for specific modules within the program but won't have the ability to see how that plays out to affect the total cost of the program. Thus accurate cost-benefit analysis on changes to the program becomes nearly impossible.

Presentation of the Training Program Toolkit

The Training Program Toolkit (TPT) leverages everything discussed thus far with the aim of providing a toolkit that enables training program managers to perform relatively accurate breakeven analysis on future investment in their training program. To accomplish this a review of a standard training model is required as seen in Figure 2.

The standard training program is defined in this document as any training program that includes some form of practical demonstration of knowledge retention. The standard training model bears a remarkable similarity to the Waterfall Project Management life cycle and includes many of its inherent drawbacks. The completion of one module or “phase” before entering into the next, being one of the largest similarities along with having all of the content in a module be self contained. While there may be times when content is recalled in later modules this typically happens reactively with the content previously covered being used to provide context to the new material, rather than using the original content as a core with the new content being added as a layer with specific content dedicated to the relationship between the topics. For example, using the CNC Operator Job

Breakdown Structure described in Fig. 6, each module; Geometric Dimensioning & Tolerancing, Metrology Equipment, and common mistakes, all could be distinct, divorced topics with only the occasional reference to each other using the standard training model. Whereas in the proposed training model what is taught in the proceeding modules are directly used to provide context to the following modules, iteratively building on the complexity of the topic with each new module until a comprehensive tapestry is created. In this format the progression of the training would more closely resemble the iterative process outlined in Agile Methodologies where a steady cadence of work-in-progress packages are completed with regularly scheduled demonstrations and reflections on progress are conducted. Which also present opportunities for program managers to gather feedback on the effectiveness of content along with demonstrations/exams. Figure 6 shows the proposed training program. There is a specific distinction that needs to be made with respect to the scope of application of the proposed training framework. The proposed training program is not intended for application on any training program or seminar that is essentially a lecture with a trainer simply dumping all of their available information on the students with no concern to how well the information is being retained aka “info-dump”. That is not to say that info-dump style seminars couldn’t benefit from adopting aspects of the proposed framework such as the iterative cycle where concepts and the relationship between concepts are reiterated to take advantage of the increased retention that comes from repeated encounters with a topic.

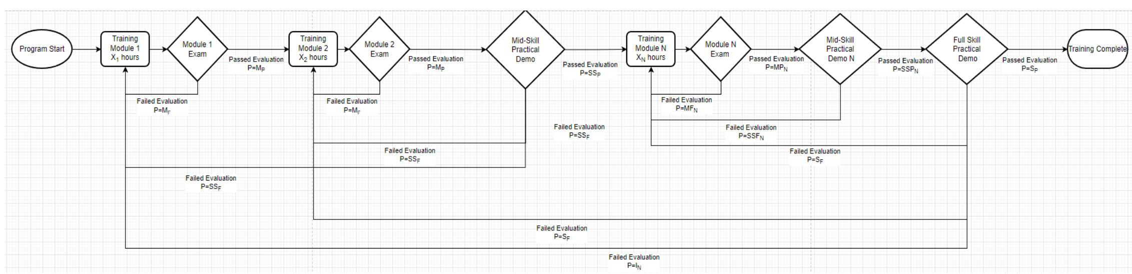

Fig. 7 Training Program Toolkit Model

Fig. 7 presents the workflow through the proposed training program framework. From the starting point of the program, a trainee would start with the Training Module 1 and upon completion take the Module 1 Exam. At this point several important pieces of information are captured.

1. The amount of time required for the trainee to consume Module 1’s content.

2. The amount of time required to complete Module 1's exam.
3. The Pass/Fail rates for Module's exam.

The trainee will proceed through the following modules until they reach an integration point referred to as a Mid-Skill Practical Demonstration (MSPD). The exact number of MSPDs implemented in a program need to be determined by the program management team, carefully taking into account Cognitive Load and natural breakpoints in the topics being covered. The goal of the MSPD is to provide an opportunity to demonstrate how all of the material learned thus far work together to achieve the desired skill. At the same time, providing another touch point on the content and building in time between those contact points, thus taking advantage of the increased retention that occurs with temporal separation. The MSPD also provides an opportunity to gather feedback on the retention of the previous Modules and document any unsatisfactory performance that should be used as an indicator that the trainee must retake that specific module. Once again, the Pass/Fail rates for each MSPD are captured along with the time required to complete the MSPD. The trainee will proceed with stepping through each Module in the Skill progression until they reach a final Full Skill Practical

Demonstration (FSPD). The FSPD is intended to provide an opportunity for the trainee to demonstrate mastery of the Skill in a live environment. This could take the form of simulation, practical demonstration, or probationary period. The duration and complexity of the FSPD must be predetermined by the management team that relies on the output of the Skill. If the trainee fails to perform up to standard, the Module that covers the area of deficiency must be retaken. The final performance of the trainee through each Module, MSPD, and FSPD are recorded for analysis. Presented in this context, the training program continues to become more aligned with the standard Agile workflow as seen in Figure 8.

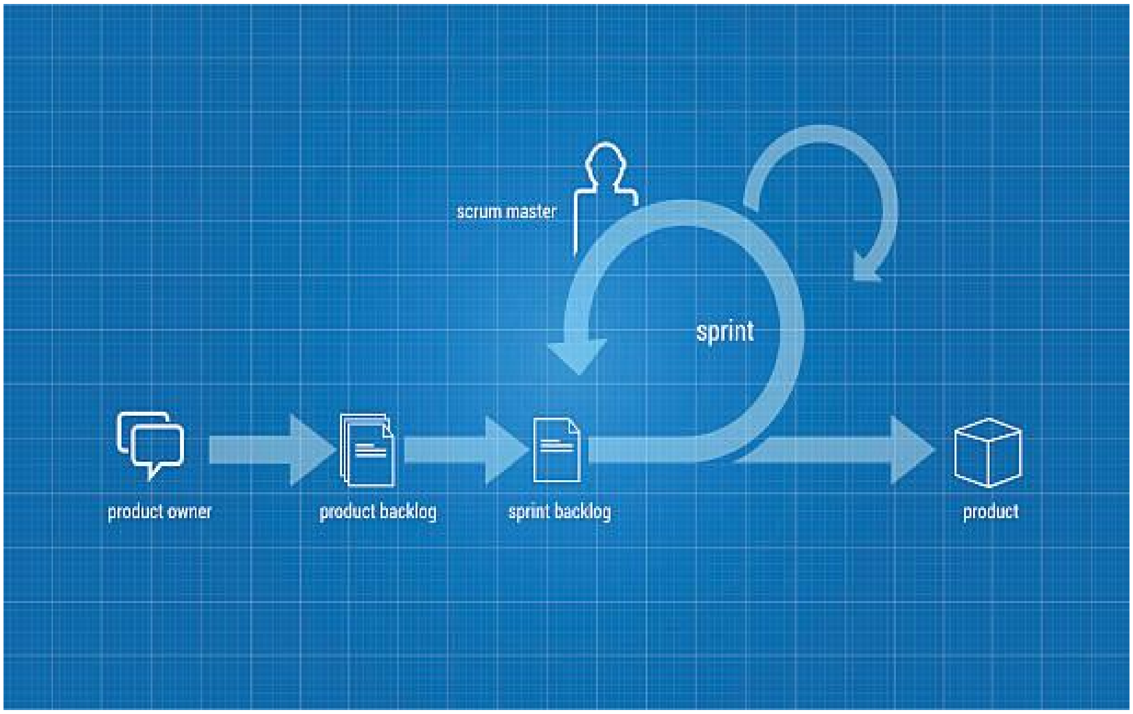

Figure 8 Standard Agile Workflow Source: istockphoto.com

As seen in Fig. 8 the APM model has a Product Owner role, which is filled in the TPT model by the Training Program Management Team. In this role the team focuses on the feedback coming from the Module, MSPD, FSPD, and Trainer/Trainees to determine the rate at which modules are expected to be worked through.

The Product Backlog is renamed the Training Backlog and contains the decomposition of the position listing such that a Job Breakdown Structure is completed. At this point content for each of the modules needs to be created using the heuristics outlined above.

The Sprint Backlog is used to establish a short term prioritization of the training content. This can be adjusted as needed to fit the needs of the organization, with the goal being to target critical microcredentials in each sprint. Furthermore, care must be taken to understand that the number of modules in a sprint is flexible and must be determined by the Training Program Management Team by using the data coming from feedback and past performance, as such the number of modules shown in Fig. 7 is for demonstration purposes only.

The Sprint duration is determined by the Training Program Management Team based program performance data. During the sprint the trainees are able to pull modules from the sprint backlog. Burn-down rates are able to be calculated by reviewing the rate at which an individual is working through the sprint backlog and comparing that rate against the running average for the program. Thus a simple linear extrapolation can be used to relatively accurately predict a completion date.

Mid-Skill Practical Demonstrations fill the role occupied by Sprint Demos in Agile. These are supposed to be quick check-ins that verify the trainee is on track and is able to demonstrate basic module-specific knowledge and/or skills. This should include interrogating the trainee's understanding of how each of the modules completed thus far tie into the larger picture of their overall job duties and those duties priority within the organization.

The Full-skill Practical Demonstration fills the role of the System Demo as seen in Scaled Agile Frameworks (SAFe). Once again this provides an opportunity for the trainee to demonstrate their comprehension of not only the information directly related to the modules covered but also how those modules tie together into larger skills and job duties/responsibilities. Failure to adequately demonstrate that transfer of training results in the repeating of those modules, even if the trainee successfully completed the module and passed the MSPD.

The Scrum Master role is filled by the trainer who oversees the day-to-day progress of the trainees through the program.

By leveraging the iterative nature of the APM methodology, training programs are able to take advantage of the same benefits that everyone else who uses APM does, increased throughput, less wasted effort, and clear expectations on the part of those working through the program. Sprint and system-level reviews must be conducted to analyze the feedback and performance of the program so that potential areas for improvement may be identified. Once those areas have been identified for potential improvement program management can begin to use the rest of the TPT to gain insight into whether investment in the program to address those identified areas of inefficiency is worth it to the organization or not.

Research Findings - Question #3 Improving the Accuracy of Budget Projections

After a statistically significant number of trainees have completed the program, the Pass/Fail results and time required for completion for each Module, MSPD, and FSPD need to be collated and individually averaged. The calculated Pass/Fail rates are then entered into a Markov Transition Matrix which is then able to use those values to generate a Simulated Trainee's Progression (STP) through the training program. Because the average time required to complete each Module, MSPD, and FSPD has been calculated, determining the cost of each STP is simply a matter of assigning a labor rate, multiplying it against each element's average duration and then summing the products.

The next step in the process is to use the Markov Transition Matrix to generate a new STP on each loop of the Monte Carlo simulation while tracking the running average cost of the STP. The output of the Monte Carlo simulation gives two critical insights into the performance of the training program. Program managers will gain insight into:

1. The approximate average cost of the training program at steady-state.
2. How many trainees would need to run through the program before a stable average cost per person could be determined.

The sequence outlined above is illustrated in Fig. 9.

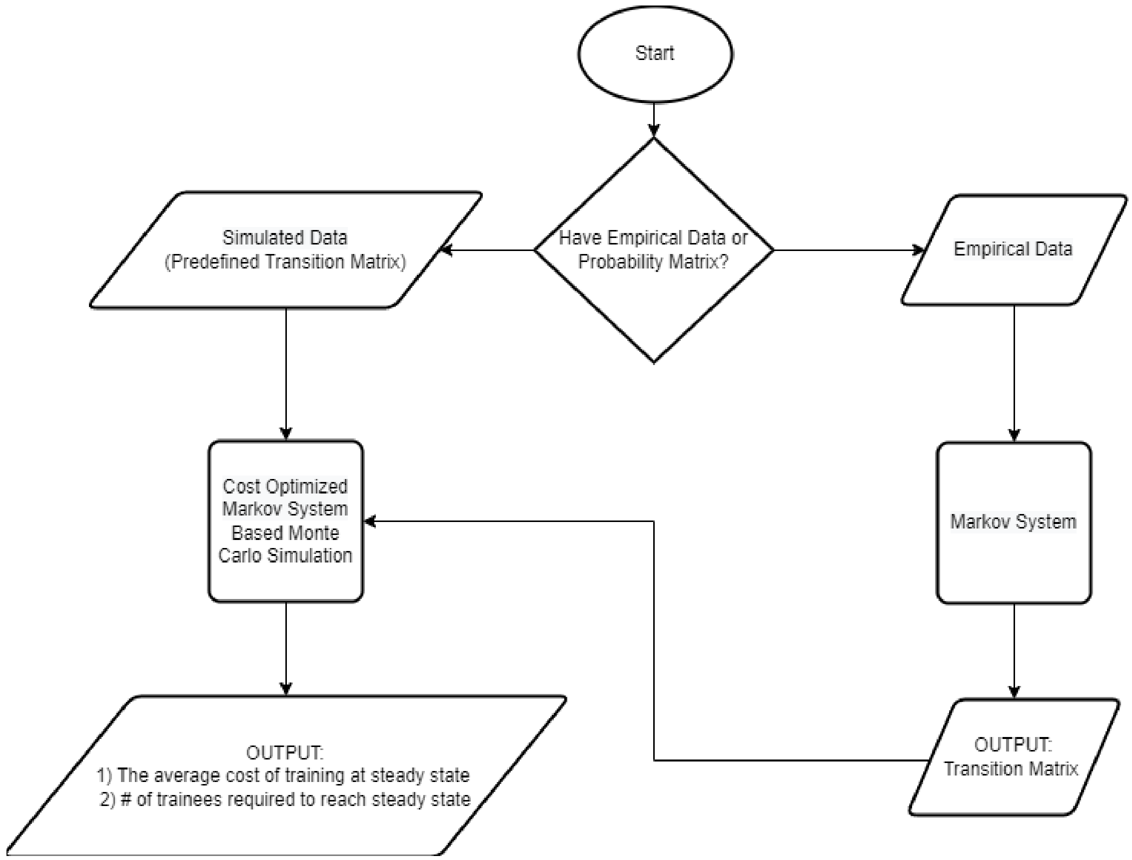

Figure 9 Stochastic Analysis Flow Chart

Comparison between conventional projection methods and the Training Program Toolkit

A hypothetical company has adopted the new TPT, XYZ Corp. is a medium-sized manufacturing company with a staff of 200 CNC Operators and a turnover rate of 20% per year. Their current training program projects

100 hours of training per operator split between 4 training modules. While in training the operators earn $30 per hour.

The conventional training program cost estimate would be calculated using the following formula:

$$Program\ Cost\ =\ \#\ of\ trainees\ *\ \#\ of\ training\ hours\ *\ labor\ rate$$

Table 1 shows these values for XYZ Corp.

Number of trainees (people)	40
Duration of training (hours)	100
Average labor rate	$30
Program cost	$120,000
Average cost per trainee	$3,000

The new model requires program managers to understand their program to a greater depth, such that they know the following information captured in Table 2.

Module 1 Pass Rate:	63%
Module 1 Duration:	22 hours
Module 2 Pass Rate:	82%

Module 2 Duration:	36 hours
Module 3 Pass Rate:	47%
Module 3 Duration:	31 hours
Module 4 Pass Rate:	92%
Module 4 Duration:	11 hours

With this added information we're able to calculate the following results, shown in Table 3:

Steady-State Cost Per Trainee	$4,700
Most Expensive Trainee	$15,750
Least Expensive Trainee	$3,000
# Of Trainees To Reach Steady-State	~700
Program Cost	$188,000

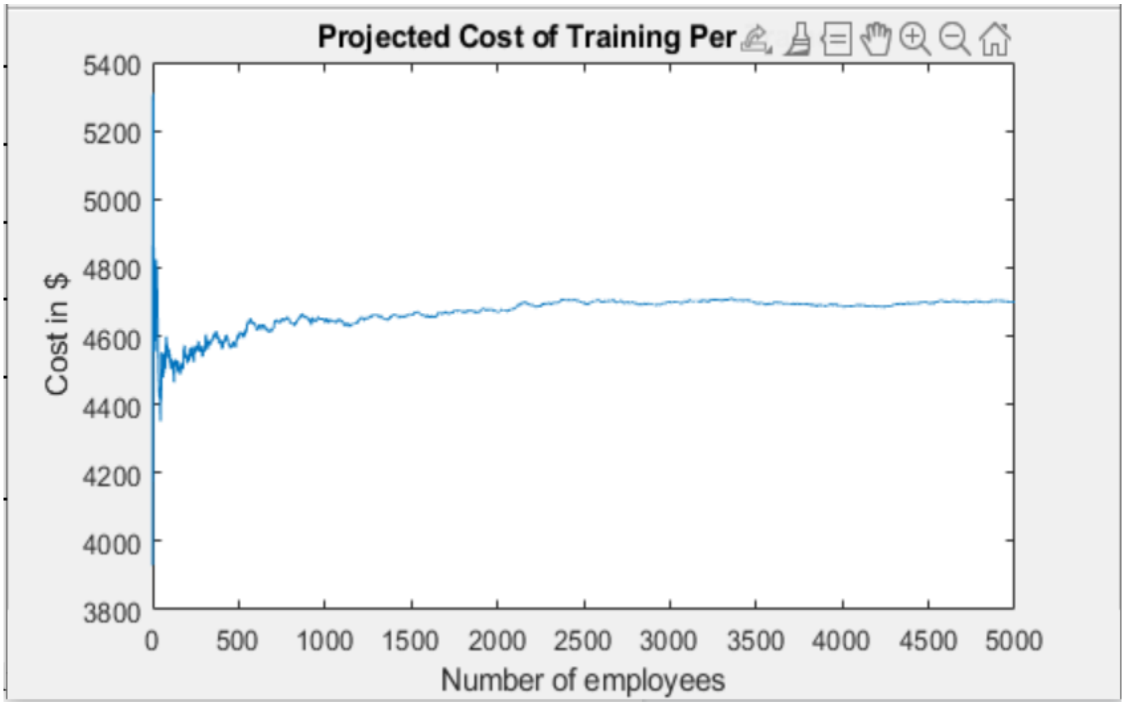

Fig 10 Shows the program projections to reach steady-state

By taking into account the actual pass/fail rates the stochastic analysis projects the steady-state cost of the training program to settle to $4,700 per trainee on average. This represents a nearly 57% deviation from the expected program cost when using the linear method alone. Furthermore, upon closer inspection program managers should be concerned with a single trainee consuming $15,750 worth of resources to pass training. The obvious questions would be, “How did that happen?” and “How can we stop that?”. Reviewing the data gives us insight into the answer. By entertaining the possibility of a student failing a module, management guarantees its occurrence. The original policy didn't stipulate which actions to take when a trainee fails a module, other than to have them repeat it. The lack of any constraints on the number of retakes directly leads to the results seen above. Additionally, if XYZ Corp only trains on the order of ~40 trainees per year, the projected time to reach steady-state would be approximately 17.5 years. This again is a direct result of the lack of constraints associated with the training program and represents a significant risk to the long-term viability of the training program.

To mitigate the effects of this risk, program managers should implement a constraint where a trainee must consult with management if they fail to pass a module after a few attempts. Adding a constraint that limits the number of attempts by taking into account hypothetical preliminary data showing that after intervention by management, the pass rate typically increases by a significant amount. In this case, on the order of 50% after 3 failed attempts. With the new policies in place, the simulation is rerun.

Providing the following results in Table 4.

Steady-State Cost Per Trainee	$4,326
Most Expensive Trainee	$7,530
Least Expensive Trainee	$3,000
# Of Trainees To Reach Steady-State	~130
Program Cost	$173,040

Fig 11 Shows the updated program projections to reach steady-state

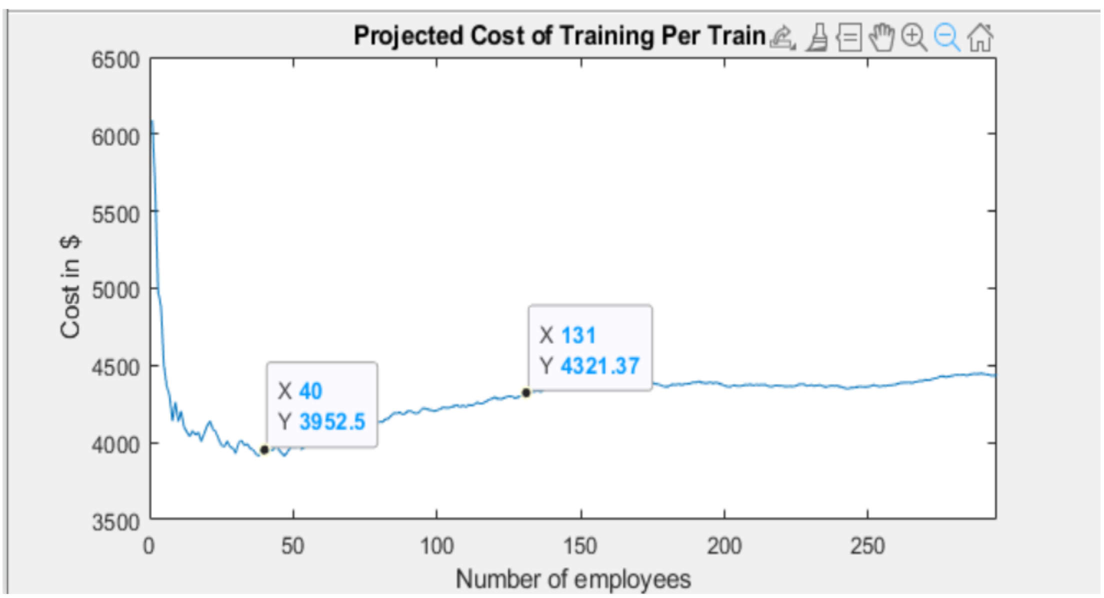

Figure 11 Updated Program Projections

With the new constraints in place the program saw an 8% projected reduction in total cost. Since these values represent increases in efficiency of operations, any gains project would go straight to the organization's profit. Furthermore, by adding the constraints the organization realized an 82% reduction in the time required to reach steady-state. But digging even deeper into the data shown in Fig. 11, it becomes apparent that the projected cost falls within 10% of the steady state cost within 40 trainees, meaning the costs should stabilize to about 90% of their actual costs within a year of implementation. It is our belief that the immediate effect of implementing the proposed framework can provide a significant improvement in the accuracy of training budget projections. The long term effect is the empowerment of program managers to be able to determine the value of future investments in their program which will be demonstrated by continuing to examine XYZ Corp.

Research Findings - Question #4 Break-even analysis and determination of future investments.

The outputs of the stochastic analysis provide two critical pieces of information required to conduct a break-even analysis. In general, break-even analysis is typically used to determine the amount of benefit required to offset the effort, i.e. time, money, resources that are required to generate that benefit. The most basic form of this equation is now presented:

$$\#\ of\ Units\ Sold = \frac{(Startup\ Cost + Marginal\ Production\ Cost)}{Sales\ Price}$$

The formula is used in business to determine the number of units of a product that must be sold to cover the cost of production of the product. That equation has been modified slightly to give insight into the number of trainees required to complete the program after steady-state has been reached before the organization can begin to realize potential benefits from policy or programmatic changes.

$$\#\ of\ Trainees\ in\ steady\ state\ = \frac{Change\ Cost}{Old\ training\ Cost - New\ Training\ Cost}$$

The critical takeaway from this equation is that it informs the program manager on how many trainees are required to go through the training *once the program has reached steady-state* to achieve break-even and negative values mean the program will never break-even. Adding this quantity to the amount of trainees needed to achieve steady state gives the following equation:

$$T_{MIN} = T_{SS} + T_{PSS}$$

Where T_{MIN} is the minimum number of trainees to break-even. T_{SS} is the number of trainees needed while in steady state. T_{PSS} is the number of trainees needed to achieve steady-state.

Program managers will use T_{min} as a threshold for determining whether the investment in the program is worthwhile or not. This determination is based on the following equation:

$$Potential\ Savings\ =\ (T_{PP}\ -\ T_{min})\ *\ (C_O - C_N)$$

Where T_{PP} is the expected number of trainees being trained per time period. C_O is the current steady state cost. C_N is the new projected steady state cost. Note the timeframe variable in the equation allows for the program manager to evaluate short, medium, and long-term outcomes. However, they must remember that T_{MIN} is a fixed number and too short of a timeframe won't allow T_{PP} to reach a point where $T_{PP} > T_{MIN}$, which is a required condition for Potential Savings > $0.00. If there are no other competing opportunities for the investment capital then a simple Go/No-Go threshold can be set:

$$Go\ =\ Potential\ Savings\ >\ \$0.00\ <\ Potential\ Savings\ =\ No\ Go$$

Since the likelihood of no other opportunities existing is pretty low, a more useful formula would be the Return on Investment calculation:

$$ROI = \frac{Potential\ Savings - Cost\ of\ Change}{Cost\ of\ change}$$

With the ROI in hand, executives would be able to make apples to apples comparisons of other potential uses of available capital.

Simulated Walk Through the Training Program Toolkit

The overall process steps for conducting a break-even analysis and optimizing an existing training program using the proposed framework are as follows:

1. Record baseline trainee performance data in each training module for a statistically significant amount of trainees.
2. Populate the Markov transition matrix within the simulation tool with the averaged pass/fail rates for each module.
3. Use the results of the simulation tool to estimate the steady-state cost of each trainee, C_O.
4. Identify low performance modules and prioritize by performing expected value calculations using the duration of the module and its pass/fail rates.

5. Estimate the change cost, C_C, to conduct surveys and feedback sessions to gain insight into potential changes to the module and their implementation to increase the pass rate.
6. Estimate the amount of potential improvement to the module's pass rate as well as recording any estimated changes to the duration of the module.
7. Rerun the simulation based on the estimated improved pass rate and estimated duration.
8. Record the new estimated marginal cost, C_N and the number of trainees needed to get there, T_{PSS}.
9. Use $T_{SS} = \frac{C_C}{C_O - C_N}$ to calculate the number of trainees while in steady-state needed to break-even.
10. Calculate $T_{min} = T_{SS} + T_{PSS}$ to determine the number of trainee required to achieve break-even
11. Decision based on the projected amount of savings / ROI generated from specific actions over a specific amount of time.

5. Conclusion

Current methods for training fail to provide an adequate toolset to training program managers to make informed decisions on potential future investments in their portfolios. The proposed framework presented in this paper demonstrates the potential for not only more accurate budgetary estimates using recognized stochastic analysis but also provides tactical projections that can empower data-driven decision making. Furthermore current training programs heavily focus on what to teach alone, when the how to teach is nearly as important. Developing training program content that leverages the advantages presented in the latest cognitive research while integrating structural elements of Agile Project Management aren't a panacea, but are a large step in the right direction of bridging the research-practice gap.

Areas of consideration for future research include; small-scale testing of the proposed framework in a real-life setting, the integration of machine learning and machine vision to bring the Task-Invoked Pupillary Response out of the lab and into practice.

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