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Cost-Benefit Analysis of the Modern Classroom within the Army University Military Learning Environment

William Coletti, Walter Dickson, Mitchell Gutgsell, Markel Johnson, Ashlon Williams, Daniel Finch, and Dr. Ahmed Bahabry

Department of Systems Engineering United States Military Academy West Point, New York 10996

Corresponding author's Email: mitchell.s.gutgsell.mil@army.mil

Author Note: William Coletti, Walter Dickson, Mitchell Gutgsell, Markel Johnson, and Ashlon Willaims are senior Cadets at the United States Military Academy and part of West Point's Department of Systems Engineering. CDT Coletti will be commissioned as an Infantry Officer, CDT Gutgsell will be commissioned as a Field Artillery Officer, CDT Dickson as a Chemical Corps Officer, CDT Johnson as a Transportation Officer and CDT Williams as an Armor Officer. The views expressed herein are those of the authors and do not reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

Abstract: The U.S. Army is working to develop and upgrade classroom learning environments by implementing technologies to further educate current and future Army soldiers. These innovative classroom conditions will integrate learning science with enabling technologies that empower learners through a culture of persistence. The technologies are tailored development tools to optimize student learning, skills, and behaviors to serve as members of highly effective teams. In support of this objective, the project team conducted a cost-benefit analysis and developed a weighted scoring matrix to determine the most cost-efficient course of action (COA) for Army University classroom modernization. This includes a tradespace analysis that depicts the findings of our recommendation to Army University.

Keywords: Cost-Benefit Analysis, Augmented Reality, Artificial Intelligence, Learning Management System, Technology Integration Methodology, Tradespace Analysis

1. Introduction

The United States Army must remain at the forefront of education as multi-domain operations continue to shape the warfighting environment. Modernizing the Army classrooms is essential to creating a more immersive learning experience that leverages advanced technology for future operations. Spearheading this effort is the Army University. The Army University system integrates all Army educational efforts, including Training and Doctrine Command (TRADOC) and the Combined Arms Center (CAC) Centers of Excellence (CoEs), along with the Army War College and the United States Military Academy as independently governed academic institutions. This research continues the effort put forth during Academic Year (AY) 2024, with the objective of assisting Army University in the analysis of educational technology integration. Through logical technology integration methods, Army University aims to incorporate the use of artificial intelligence, learning management systems, and avatar-based collaboration to enhance learning. These advancements are critical in preparing soldiers for the complexities of future warfare. To ensure alignment with Army University's objectives, our project team conducted a cost-benefit analysis on classroom modernization. This included evaluation of Virtual Battle Space 3 (VBS3), ChatGPT, Learning Management Systems (LMS), and avatar augmented/virtual/mixed reality. Utilizing a weighted scoring model, we determined the most effective COA and provided a recommendation for implementing these modernized learning methods. Additionally, we conducted a cost-benefit analysis of this project, providing a recommendation for the most cost-effective approach to classroom modernization.

2. Background

2.1 Technology Integration Methodology

The project examines effective technology integration methods for Army University, aligning with its mission to better prepare leaders to be critical thinkers in an ever-changing environment. Using the Substitution, Augmentation, Modification, and Redefinition (SAMR) model, we explore technology's progression from basic tools to transformative learning. In the substitution phase, traditional tools and methods are substituted with modernized ones. The augmentation phase enhances the new methods and tools and enhances them through understanding and training with the equipment. In the modification stage, task redesign occurs by integration of new organization and functions. In the redefinition phase, new techniques and methods are implemented to enhance student learning (Wahyuni et al., 2020). The following platforms are potential innovations that our client may consider integrating based on SAMR model methodology, including additional technologies researched throughout this project. Research demonstrates simulations, 3D modeling, and microworlds as effective in forming creativity and problem-solving, with applications in logistics and tactical decision-making (Bereczki & Kárpáti, 2021). Platforms like Simio, Virtual Battle Space 3 (VBS3), and Blender provide interactive, realistic training (Zhang et al., 2024; Georgoulas-Sherry, 2022). The SAMR model is a logical and efficient technology integration technique that, if utilized, allows the Army University system to provide enhanced learning, critical thinking, and military training in a scalable, technology-driven setting. Ultimately the modernized learning and training environment will help Army University prepare leaders and soldiers to be more combat effective on the modern battlefield.

2.2 Artificial Intelligence (AI) Self-Assessment

A central requirement of Army University's modernization effort is the integration of artificial intelligence as an educational self-assessment tool. Research determined that ChatGPT is the most cost effective and efficient AI tool currently available for that meets Army University requirements. ChatGPT allows for the generation of practice questions and evaluations, writing assessments, and personalized tutoring. In addition, a custom GPT can be created to tailor Chat GPT to specific courses of instruction (OpenAI, 2024). Beyond technology, this effort aims to enhance instructional methods, accessibility, and the overall learning environment to better support both students and instructors. By balancing technology, collaboration, and strategic design, Army University can streamline education, improve adaptability, and better prepare soldiers for future challenges.

2.3 Cloud Based Learning: Learning Management Systems

Implementing cloud-based learning through learning management systems (LMSs) allows the learning environment to be more effective, efficient, and collaborative. Use and research of LMSs has dramatically increased throughout the last decade. Studies show significant increases in quantitative and qualitative metrics when LMSs are implemented (Nguyen, 2023). This research focused primarily on the LMSs most used in higher education which are Canvas, Blackboard and Moodle. Canvas is very easy for the users to use but can be difficult for instructors or administrators to integrate different platforms directly into the platform. Blackboard is shown to help improve test scores of students but is a very expensive program for large institutions (Alturki & Aldraiweesh, 2023). Moodle is one of the most cost-effective platforms but can lack in its capabilities such as user engagement and usability. Army University is currently using Blackboard; however, research shows Canvas is likely to produce higher effectiveness at a lower cost.

2.4 Avatar-Based Small Group Collaboration

The use of avatar-based small group collaboration with virtual, augmented, and mixed reality would be a positive step to enhancing the Army University classroom. The use of avatar-based collaboration could potentially result in a reduction of temporary duty (TDY) and permanent change of station (PCS) costs due to a decreased requirement for students and teachers to be in the same physical location. For example, avatar learning paired with LMSs would allow a soldier in New York to participate fully in a Captain's Career Course (CCC) class that takes place in Missouri. A cost-benefit analysis will evaluate the hardware, development, and licensing costs for Virtual, Augmented, and Mixed Reality compared to its value. From initial research Augmented Reality (AR) is the most cost-efficient method to implement in the classroom, leveraging existing devices and allowing for seamless technology integration (Shaukat, S.M., 2023). Army University can modernize the classroom by using augmented reality for avatar collaboration while minimizing costs and enhancing the learning experience.

2.5 New Classroom Design

As previously stated, this project is a continuation of a previous capstone effort and as such utilized the Academic Year 2024 (AY24) prototype classroom design as the foundation to map out the costs for this year's modernization project, focusing on cost-benefit analysis. This design served as the baseline for AY25 to encapsulate all costs for the newly designed classroom, as well as additional educational technologies as outlined by stakeholder requirements. Technologies that include smart boards, iPads, magnetic white boards, and ceiling mounted tracks to move screens around the classroom. All technologies were previously researched by the AY24 team.

3. Methodology

3.1 Course of Action Development

The first step within our methodology was to map out different COAs for improving the learning environment. The method we used is Zwicky's Morphology which explores alternative combinations of design parameters. The specific design parameters for this study include LMS, AI, collaborative avatars, ease of technology integration, and varying levels of equipment from the prototype classroom designed by the AY24 project team. In turn, one choice is selected (e.g., selecting Canvas for LMS) from each of the design parameters. Each COA is created with alternate goals to create a wide variety of alternatives for Army University. Three different selections are assembled giving us three differing COAs.

3.2 Alternative Courses of Action

The three COAs analyzed for the final model each offer different potential outcomes for this project. Course of Action 1 involves fully integrating digital platforms with a focus on technological advancements. This approach maximizes knowledge transfer into digital environments by utilizing platforms such as ChatGPT-4, Canvas, avatar mixed reality, and VBS3, while also leveraging the redefinition phase of the SAMR model. For equipment integration, all relevant technologies would be incorporated into the classrooms. Course of Action 2 prioritizes collaboration between students and teachers. The key platforms and technologies supporting this approach include Canvas, augmented reality, and ChatGPT (Business Plan). To facilitate collaboration, all necessary technology would be implemented. Course of Action 3 focuses on budget constraints including Moodle, avatar mixed reality, ChatGPT-4, and the substitution phase of the SAMR model. To minimize costs, the proposed equipment integration includes one iPad per two students, three small TVs, and one large TV. Each piece of technology, including iPads, remains in the classroom not with students. All three COAs were approved by Army University

3.3 Method of Gathering Data

Through extensive research, our team gathered reliable data to support Army University's modernization efforts. We primarily sourced information from Semantic Scholar and the USMA library, ensuring credibility and relevance. A key component of our analysis was the selection criteria for ranking equipment, which focused on ease of use, performance, and cost-effectiveness. This structured approach allowed us to identify the most practical solutions for implementation depending on the cost and needs of Army University. We compiled a comprehensive set of findings, equipping Army University with the necessary insights to make well-informed modernization decisions. All cost data represents the highest possible price point for each design parameter. This is to ensure Army University understands all possible risks, allowing for the most informed decision possible.

3.4 Cost-Benefit Analysis Using Net Present Value

Cost Benefit Analysis (CBA) was completed to assist Army University in their decision-making process for classroom modernization. As requested by the client, this effort serves as the initial analysis of costs associated with integrating new educational technologies for each of the different COAs. To this end, the team utilized Net Present Value (NPV) calculations for costs related to each COA. NPV measures present value, or cost, throughout the project life cycle of 10 years as decided by the client. The NPV calculation discounts annual cash flow back to present dollar values utilizing applicable rates of return and or inflation rates. Through analysis, the team determined the initial investment and annual costs for each COA. Additionally, the average inflation rate of 2.65% was used to account for time value of money over the 10-year project life cycle. This analysis was completed for4,000 classrooms throughout the Army University system. Final NPV calculations are shown in Table 1. The project team used equation 1, seen below, for NPV calculations.

$$NPV \ = \sum_{n=0}^{N} FV(1+i)^n \qquad (1)$$

where

PV= Present Value
FV = Future Value
i = inflation rate
n = period

COA 1	$460,659,170.90
COA 2	$364,589,652.63
COA 3	$109,774,645.31

Table 1. NPV For Each COA

3.5 Weighted Scoring Methodology

A Weighted Scoring Model (WSM) was used to provide an objective approach to the project team's COA recommendations. Through collaboration with the client, three COAs were approved that captured varying levels of technology integration. The client also provided the value criteria and associated objective weighting for each criterion. Given this information, the project team was able to establish raw scores for each value criteria within the context of a specific COA. Raw scores were determined utilizing a value scoring matrix that ultimately assigned scores for each criterion within a COA based on client weighted values. The results of the WSM analysis are shown in Table 2 below.

Weighted Scoring Matrix									
				Raw Score			Weighted Score		
Value Criteria	OBJ	Value	Rel.Wt	COA1	COA2	COA3	COA1	COA2	COA3
Classroom Instruction	Maximize	8	0.186	10	7	4	1.86	1.30	0.74
Student Knowledge Transfer	Maximize	10	0.233	9	9	5	2.09	2.09	1.16
Ease of user/instructor interface	Maximize	7	0.163	4	6	9	0.65	0.98	1.47
Distance Education	Maximize	6	0.140	9	9	6	1.26	1.26	0.84
Disruption to classroom use	Minimize	8	0.186	5	7	9	0.93	1.30	1.67
Ease of integration	Maximize	4	0.093	5	6	8	0.47	0.56	0.74
Total		43	1.000				6.79	6.93	5.88

Table 2. Results of Weighted Scoring Model Analysis

3.6 Tradespace Analysis

Trade space analysis within CBA is used to compare the results of the weighted scoring to the NPV. This allows us to demonstrate to the client visually how each COA ranks in terms of cost versus value. The x-axis consists of total NPV, and the y-axis consists of the weighted value. The dotted blue line represents the efficiency frontier which is the point where the COA has sufficient value for every dollar spent, relative to the alternate COAs. If a COA is on or above the efficiency frontier it is a viable solution option. The red circle around COA1 represents that it is a dominated solution, meaning that the value of COA2 is greater but at a lower cost.

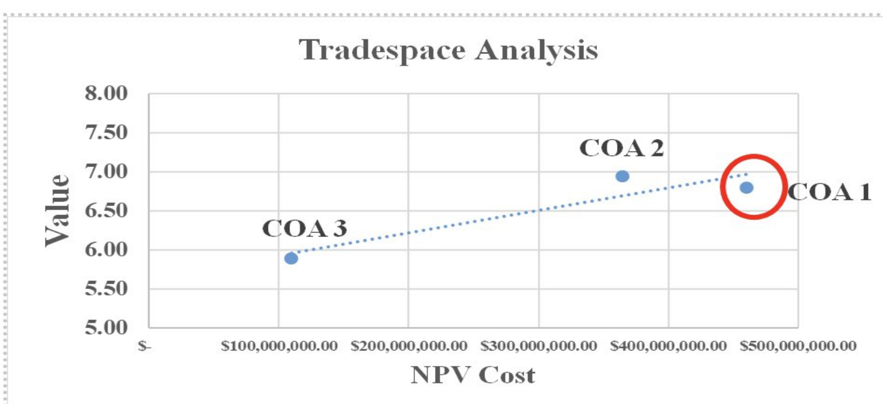

Figure 2. Tradespace Analysis Graph.

4. Analysis

4.1 Model Analysis

The final model is best represented by Figure 2. The trade space analysis shows COA1 is not a feasible solution because there are alternatives that bring more value for less relative cost and is therefore dominated. Both COA2 and COA3 are seen to be feasible solutions because they are above or on the efficiency frontier. Course of Action 3 provides the most value per dollar spent. This ultimately makes sense due to the cost-efficient mindset that COA3 is created with.

4.2 Cost Inefficiency

Through model analysis, cost inefficiency became apparent due to the ceiling mounted track and the amount of screens within the classroom. By reducing the number of iPads from one per student to one per two students, Army University can expect to save around $24,000,000. We also see an increase in value from decreasing the number of iPads because of the subjective increase in the value criteria of student knowledge transfer (i.e. collaboration). The least cost-efficient aspect of the model is the ceiling mounted track for screens. Every 24 feet of straight track costs $47,500,000, not including the necessary curved track. Meanwhile the track does not bring a relevant amount of value for its cost. This is likely why COA3 gains more value per dollar spent as it only requires 24 feet of straight track, whereas COA2 requires 48 feet of straight track and one curved track. This equates to a price difference of $87,500,000 for minimal value gained.

4.3 Error and Uncertainty Analysis

It is important to identify the different points of possible error within the project. Firstly, the project does not consider the costs of labor required to upgrade classrooms. Additionally, it does not consider the maintenance costs that are required when technologies malfunction. To mitigate this risk, we utilized the highest number of each price range. A second point of error could be the effect of inflation. It is almost guaranteed that inflation will remain inconsistent throughout the project life cycle. Finally, the project life cycle itself is uncertain as technology continues to evolve at faster rates. The technology selections we have made may become obsolete, creating uncertainty within the project life cycle. The longer the life cycle, the more uncertainty there is.

5. Conclusion

5.1 Recommendations

Based on overall analysis, the recommended approach is COA2, collaboration-based, while reducing the ceiling track to only 24 feet of straight track per classroom. This change brings the total NPV to $277,089,652.63 without decreasing value. The theme of this selection provides the implementation of online learning and collaboration. Course of Action 2 offers Army University the opportunity to assess the most effective modern tools with a middle ground approach to cost. This will allow decreased uncertainty in the life cycle of the project. By aligning with Army University's priorities, COA2 with our recommended changes, delivers a balanced solution that enhances education while maintaining fiscal responsibility. It allows both faculty and students to experience a modernized learning environment with the ability to collab at the highest level with each other and via online.

5.2 Future Work

First, we recommend the cost-benefit analysis be refined to include the quantifying of potential benefits of classroom modernization. Continued research into classroom technology innovations would assist in the management of life cycle obsolescence. A deeper analysis of these benefits will allow for comparative studies with other institutions or organizations utilizing similar technologies. Additionally, further investigation into multi-avatar proctoring should assess its scalability, effectiveness in overseeing classrooms, and the potential implications for instructors' roles if this technology is widely implemented. For example, further research into technologies such as Ravatar could give Army University the academic edge to make more efficient critical thinkers (Ravatar, 2024).

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