Tactical Combat Casualty Care Training: A Blended Approach for Lifelong Learning

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Abstract

The Fiscal Year 2017 National Defense Authorization Act (NDAA 2017), requiring standardized combat casualty care instruction for all members of the Armed Forces, presented a unique opportunity to address foundational training technology challenges and revolutionize the delivery of medical training. These challenges include: delivering tiered training for distinct levels of expertise, ranging from novice to expert, within a standardized framework; developing a range of training support technologies, including apps and content authoring tools; integrating disparate training modalities into a common architecture that supports lifelong learning; and leveraging and expanding the science underlying education and training to ensure better learning outcomes. Specifically, this paper will summarize efforts to develop and deliver a joint Tactical Combat Casualty Care (TCCC) Training capability, as mandated by NDAA 17 and Department of Defense Instruction (DODI) 1322.24. It will show how this capability, with initial delivery planned for Summer 2020, will transform prehospital trauma training from its current state into a lifelong learning health system that trains and prepares more than 1.5 million military and expeditionary civilian personnel to play a critical role in responding to trauma across the spectrum of military operations. In doing so, this paper will focus on key elements underlying development of this capability including: a longitudinal TCCC curriculum based on learner-centric design; a multi-modality approach to delivering training leveraging learning science including micro-learning and deliberate practice; an emphasis on educating and supporting instructors as well as students; and a learning architecture supporting these elements that is sufficiently flexible to integrate future scientific and technical advances in education and training.

ABOUT THE AUTHORS

Matthew Hackett is a science and technology manager for the Combat Capabilities and Development Command Soldier Center. Dr. Hackett had led a variety of medical simulation and training research efforts, including holographic display research, serious gaming, training effectiveness, and simulator hardware. Dr. Hackett holds a PhD in Modeling and Simulation, an MS in Biomedical Engineering, and a BS in Computer Engineering.

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Salma Hernandez earned a Doctor of Nursing Practice (DNP) with a focus on healthcare disparities from the University of Miami (UM). Dr. Hernandez also holds a BSN and an MSN and is a board-certified Acute Care Nurse Practitioner with 15 years of clinical experience in Surgical Critical Care and Trauma. Currently at the William Lehman Injury Research Center within UM, she serves as the Clinical Education Coordinator for the curriculum development and training programs. In this role she has facilitated training and education for US Department of

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Derek Lawrence comes from a broad training background ranging from teaching appointments at Oklahoma City University's Bass school of music and the electrical engineering department at Taiwan's National Changhua Education University. In addition to this experience, he also served as the Training Manager of the National Visa Center from 2015-18, establishing a comprehensive, data-driven training system for visa processing procedures. Joining Allogy as the Program Manager in 2018, Derek Lawrence has been responsible to oversee business operations for development on Deployed Medicine. He holds a Doctorate from the University of Oklahoma and a Master's degree from the University of Wisconsin- Madison.

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INTRODUCTION

Major advancements in U.S. military medicine, in particular changes to prehospital battlefield medicine, have resulted in unprecedented survival and recovery rates for casualties in current conflicts (Dickey, 2015). An analysis of battlefield deaths occurring over ten years of war, from 2001-2011, found that of the roughly 4,000 battlefield deaths, 24% (967 deaths) were potentially preventable had best medical practices been implemented (Eastridge et al., 2012). A deeper analysis of these casualties suggest that a single type of injury, uncontrolled hemorrhage, accounted for over 90% of these potentially survivable injuries. These, and other analyses (Holcomb, 2017), indicate that while our knowledge and technical capabilities have significantly evolved, there remain opportunities for improvement. A great deal of these opportunities present themselves at the point of injury.

Within the US military, the standard of care for the treatment and stabilization of a battlefield casualty at the point of injury is tactical combat casualty care (TCCC, or TC3). TCCC was originally developed to support the United States Special Operations Command (USSOCOM) healthcare community (Butler Jr, Hagmann, & Butler, 1996). Over time, TCCC principles were more broadly adopted, as evidence and guidance was disseminated by the Committee on Tactical Combat Casualty Care (CoTCCC). TCCC is structured in three phases: Care Under Fire, in which the only treatment possible is managing life–threatening hemorrhage; Tactical Field Care, in which care is primarily delivered by non-medical first responders and enlisted medical personnel; and Tactical Evacuation Care, in which the injured warfighter is treated en route to a medical treatment facility. Military units that have fully implemented TCCC have documented the lowest incidence of preventable deaths (Kotwal et al., 2011). This demonstrates that TCCC saves lives when a standardized training program is combined with the necessary healthcare capabilities (Holcomb et al., 2007). While the Services have implemented TCCC in a variety of ways, a push for a unified TCCC educational process came in the form of NDAA 2017 and DoDI 1322.24, "Medical Readiness Training", which mandated all Service-members, including over 1 Million Active Duty personnel, receive TCCC training commensurate with their role.

Fulfilling this guidance requires a TCCC training capability that is: suitable and standardized across the Services; scalable to an enterprise level; adaptable to different levels, or tiers, of required medical knowledge, skills and abilities (KSAs); tailorable to both current and future (next-generation, NextGen) learners; and regularly assessed and validated. Understanding how to effectively develop and deliver TCCC education, in a manner that addresses these requirements, has the potential for driving major breakthroughs not only in battlefield survivability, but also in the education and training of NextGen healthcare providers. NextGen learners have been shown to prefer personalized, flexible and self-directed learning experiences, often using their personal mobile devices (Nicholas, 2008). They also like to learn as they work, share information, and evolve knowledge with peers. In order to tap into these additional learning opportunities for the NextGen audience, future TCCC education and training systems will need to incorporate a broader range of pedagogical approaches and embrace digital platforms as a channel for learning engagement.

As such, the Defense Health Agency (DHA), the Joint Trauma System (JTS), and the Army Futures Command are designing new methods for delivering TCCC education and training to the next generation of uniformed healthcare providers, including enlisted, reserve, and deploying civilian personnel. Specifically, the Learning Strategy, Tactics, and Technology (LSTT) program was initiated to conduct research and development with a focus on rapidly fielding trauma training capabilities. The research program includes two principle efforts: (1) development of Joint, role-based TCCC curriculum and (2) research and development of a mobile application to support TCCC training, known as Deployed Medicine. This paper describes current TCCC training methods, presents an innovative process for improved learning systems, identifies learning barriers, and discusses initial results including technology products and pilot testing of the first new tier of TCCC curriculum. These results have the potential for transforming the Department of Defenses' current approach to trauma training from Service-centric into a standardized, modular, and adaptable enterprise-level trauma training platform, capable of engaging the NextGen workforce in a life-long learning experience that improves performance and helps to reduce preventable deaths.

BACKGROUND

Current TCCC Educational Practice

The scope of TCCC is well-defined, and encompasses the knowledge and skills to care for a patient at the point of injury. The emphasis is on patient assessment, treatment, stabilization and evacuation. In 2015, the DHA reviewed military course catalogues and found 59 courses had some form of TCCC training incorporated into their syllabi, demonstrating the reach of TCCC throughout the military's training system (Barrigan, 2015). This review highlighted the extensive range of TCCC training techniques, from basic to advanced, with variants of TCCC training tailored to non-medical first responders, combat medics/corpsmen, and medical professionals, such as doctors, nurses and physician assistants. At the most basic level, the fundamentals of TCCC, such as bleeding control, are incorporated into self-aid and buddy-aid courses for non-medical first responders. For more advanced providers, including combat lifesavers, combat medics/corpsman, and combat paramedics, more extensive TCCC training is provided. At these levels, initial schoolhouse training includes one or more weeks of didactic instruction and hands-on individual skills training using medical simulators, such as part task trainers or medical mannequins. Trainees also participate in team exercises, including multiple casualty scenarios involving casualty extraction, assessment, treatment, and evacuation. Culmination events, typically in the form of lane training, take place with medical squads treating simulated casualties in a field exercise environment. Lastly, for medical professionals, TCCC concepts are included in trauma management and surgical courses, like the Emergency War Surgery Course. For all these training audiences, the typical TCCC training environment is a classroom setting, augmented with medical simulation and field-based training experiences where available. It can also be offered as "hip-pocket training" at opportune times in any setting, to include deployed environments. After graduation, TCCC refresher training becomes the responsibility of the receiving unit or hospital.

The Next Generation of TCCC Learners

TCCC medical care is routinely delivered to wounded personnel by first responders, including Combat Life Savers, Army Combat Medics, Navy Corpsmen, and Air Force Medical Technicians and Pararescuemen. This cohort of personnel is typically between 21 and 35 years of age. This generation's understanding of the world has evolved in a digitally connected way, and their preferred learning methods differ from traditional educational conventions. This audience relies on digital platforms such as Google and YouTube to search for information, often using their mobile devices. For them, formal learning structure needs to be complemented by informal learning experiences to acquire and assimilate knowledge "just in time"(Nicholas, 2008).

In an attempt to quantify the preferences of the next generation of learners, the DHA conducted a survey in 2015 of 1,356 combat medical personnel exploring current TCCC learning behaviors (Barrigan, 2015). The findings revealed that 34% reviewed TCCC training content less than twice per year, and 17% said they never searched for information outside the 1-2 year refresher training cycle. Over half of those surveyed were not engaged in continuous learning. Importantly, the vast majority, 87%, felt adding mobile learning would enhance their TCCC learning experience, and 82% chose a free mobile app as their preferred learning platform.

More recently, in 2017, 51 Army combat medics at Fort Hood were surveyed to assess their TCCC learning needs and preferences (Barrigan, Hackett, Schulman, & Wakelin, 2017). The overall results suggest some important challenges to how TCCC content is curated, updated and delivered. The surveyed medics indicated that they typically searched for TCCC medical content on non-military internet sites or consulted peers when faced with a medical question or problem. They felt having access to multi-media medical content with more military relevance would be beneficial over current offerings. In general, they were eager to engage in more TCCC learning, and requested exercises that challenged their individual knowledge and skills. The ability to use their mobile devices to view flashcards and participate in ongoing knowledge challenges was a popular request. Learning in collaboration with peers and experts was also seen as very important among participants.

Understanding the perspectives of these military medical providers gives insight into what more can be done to improve learning systems. They are clearly motivated to keep their skills fresh, perform well in their roles, coach others, and be recognized as experts. They also desire improved access to learning content, with an emphasis on content that is current and developed to clear standards with the military end-user in mind. Any new capability should harness and support these motivations. Addressing these findings, our team is creating prototype learning solutions to explore how best to merge the current TCCC educational process with modern learning science and mobile technology to deliver an enhanced learning experience.

METHODOLOGY

As described earlier, TCCC is included in the programs of instruction for providers at a variety of skill levels, and the Medical Readiness Training DoDI mandates a Joint curriculum commensurate with role and skill, accessible by all service-members. As such, our team determined that a single, all-inclusive curriculum and delivery approach would be ill-suited to meeting the diverse needs of these training communities. Instead, we designed a tiered curriculum, where each subsequent tier builds upon content from prior tiers. The new curriculum is organized into four tiers: Tier 1 All Service Members; Tier 2 Combat Lifesaver; Tier 3 Combat Medic / Corpsman; and Tier 4 Combat Paramedic / Provider. To ensure the tiered design created a cohesive TCCC curriculum, we employed a robust research framework for designing a complete training capability (Figure 1). This approach has strong similarities with the ADDIE process (Branch, 2009), or more specifically the Morrison, Ross, and Kemp model (Morrison, Ross, Morrison, & Kalman, 2019). This holistic approach will ensure that the most effective parts of the current TCCC educational process are accentuated, while addressing inefficiencies or gaps in the overall learning experience. This holistic approach will also integrate existing education resources and constructs with the newly developed curriculum and emerging training technologies. Our team also determined that the flexibility of the Morrison, Ross, and Kemp model would be more supportive of the key requirements driving this development effort, compared to the focused rigidity of other models like those proposed by Dick and Carey (Akbulut, 2007; Dick, Carey, & Carey, 2005).

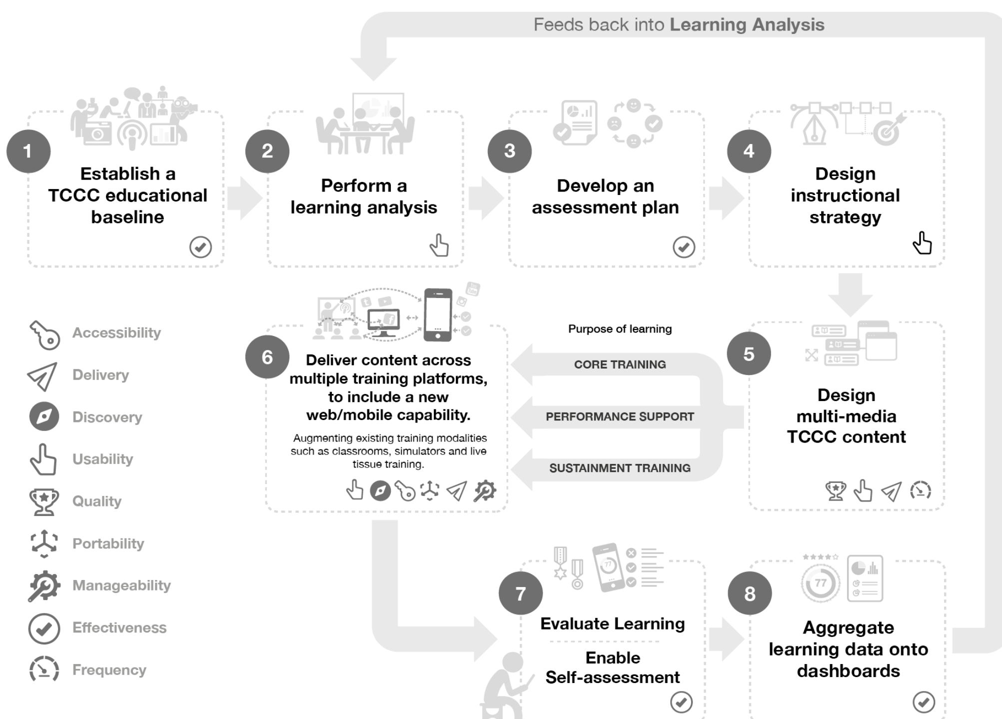

Figure 1: Training Capability Approach

Per the process outlined in the Morrison, Ross, and Kemp model, curriculum development began by establishing an educational baseline for TCCC teaching methods (Figure 1, Step 1). The team collected TCCC educational materials and other information from across the Services to learn how TCCC training is currently structured, delivered, and measured. This included an analysis of programs of instruction, course syllabi, and instructional materials. Researchers also reviewed existing capability gaps outlined in the Combat Casualty Care Training Technologies, Initial Capability Document (Defense, 2016) and policy changes within the 2017 NDAA (Representatives, 2016). In addition, researchers conducted in-person observation of TCCC training events across the Services, using a structured observation form (Given, 2008). The team of observers noted instructional strategies, assessment techniques, and issues or barriers encountered during training. Following the training events, observers conducted informal interviews and focus groups with both TCCC instructors and students.

Following the baseline assessment, we determined the instructional and assessment design to form a learning strategy, and ultimately developed content based on this strategy (Figure 1, Steps 2-5). Initially, a learning analysis identified modern instructional methods which can be mapped into an overall learning strategy. Next, a series of joint TCCC working groups, comprised of Service-designated TCCC experts, developed a set of enabling and terminal learning objectives (ELOs/TLOs). Using these learning objectives, researchers focused on mechanisms for capturing the related learning outcomes. This included the development of measures and assessment tools for individual knowledge and skills proficiency, as well as system-level metrics of programmatic effect. In step 4, the curriculum mapping process began in earnest, determining the appropriate composition of learning activities, such as lecture, demonstration, individual skill stations, and group exercises. After determining the course composition, researchers generated the content of the curricula, including a variety of PowerPoint materials, videos, podcasts, and study guides.

The instructional and assessment design process involved the integration of principles from learning science. We focused on instructional methods to support the learner and instructor, reinforce critical learning, and to improve recall and retention of information (Figure 2). These methods include established concepts such as learner centered design, which focuses on supporting learner needs and motivations (Norman & Spohrer, 1996), and action learning, which focuses on applying learned concepts to realistic, complex problems (McGill & Brockbank, 2003). These concepts led to a heavy emphasis on hands-on skills instruction and minimizing instructor-led lecture. Newer concepts were also employed, such as micro-learning that utilizes short, focused instruction to maximize student engagement (Kovachev, Cao, Klamma, & Jarke, 2011). Finally, Fink's significant learning methodology, which focuses on deciding what can and should be learned in terms of the desired outcomes, was employed in lieu of a strict content-centric approach. This methodology included strategies to encourage students to continually learn and update their knowledge after the course and how to integrate the material with other subjects, such as military tactics (Fink, 2013).

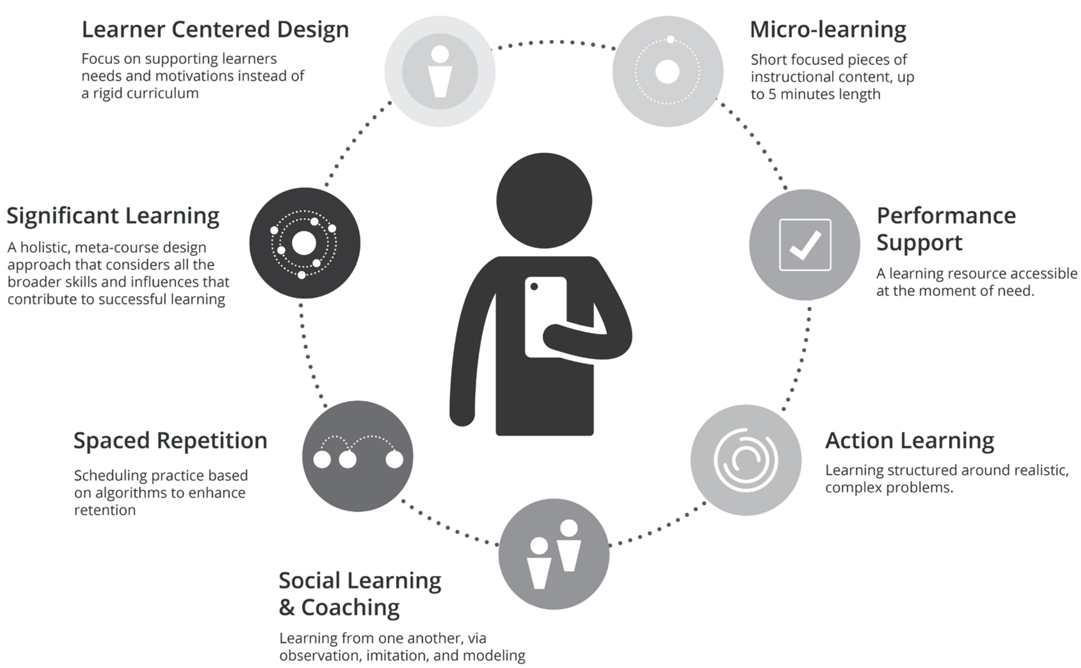

Figure 2: Learning design principles (Kovachev et al., 2011; McGill & Brockbank, 2003; Melton, 1970; Norman & Spohrer, 1996; Rosenthal & Zimmerman, 2014)

With the training content and assessments created and structured into a curriculum, a delivery and implementation capability was needed to fulfill three primary use cases: 1) core training for new recruits at schoolhouses, 2) slower paced sustainment training to maintain proficiency during peacetime, and 3) performance support to assist with pre-deployment and on the job training (Figure 1, Step 6). To achieve this, the team had to overcome one of the biggest gaps in the current military medical training ecosystem - the lack of a medical content delivery capability. The diverse set of use cases would require a flexible and highly accessible delivery platform, leading our team to pursue a hybrid web and mobile technology solution. Furthermore, as discussed earlier, mobile technology is a major driver for NextGen learning, reinforcing the choice to pursue a mobile solution (Nicholas, 2008). The mobile platform, known as Deployed Medicine, will allow instructors and learners to take the classroom with them to field training and deployment sites, extending the training continuum into underutilized learning spaces.

The final stage of this model, evaluation, is necessary to assess the efficacy of the training capability and to determine what modifications, if any, are needed (Figure 1, Step 7). Since the capability being developed was cumulative, with each Tier building upon the previous tiers, the first assessment (which laid the paradigm for all successive assessments) was conducted on Tier 1. Consequently, we report here the methodology for pilot testing of the Tier 1 All-Service Member TCCC curriculum. Subsequent Tiers' evaluation will be conducted in similar fashion as they mature.

For Tier 1, pilot testing of the curriculum was conducted at 6 locations in a variety of delivery formats (Table 1). All instructors attended a train-the-trainer event hosted at Ft. Bullis, TX, in which they were familiarized with the new TCCC content and provided with instruction on administering the various skill stations and assessments associated with the course. During pilot testing, these instructors administered the course to a cohort of military trainees from a variety of medical and non-medical roles. At these pilot events, a team of observers assessed the new materials regarding their efficiency in conveying the key concepts and accomplishing the required learning objectives. Observers also assessed student and instructor perceptions through student and instructor focus groups and written surveys. Lastly, the research team assessed the delivery platform. Rather than using indirect measures of technology acceptance, such as perceived usefulness, perceived ease of use, and intent to use (Venkatesh, Thong, & Xu, 2012), the usage of the platform was directly assessed over the past year. This included a variety of usage metrics including website views, app downloads, and active users. It should be noted that the delivery platform was evaluated beyond the pilot cohorts and the usage data is inclusive of all users.

Table 1: TCCC Pilot Testing Configurations

Location	Service	Sample Size	Curriculum Implementation	Instructors
Joint Base Elmendorf, AK	Air Force	27 Junior Enlisted	Single Day	5 Medical NCOs
Lackland AFB, TX	Air Force	86 Basic Trainees	Split; 3 Days	7 Non-medical NCOs
Afloat Training Group; Norfolk, VA	Navy	34 Junior Enlisted	Split; 3 Days	4 Medical NCOs
Basic School; Quantico, VA	Marines	21 Lieutenant Officers	Single Day	1 non-medical officer; 2 medical NCOs
Fort Bliss, TX	Army	49 National Guard	Single Day	6 Medical NCOs

Finally, in stage 8, the process culminates with the delivery of real-time aggregated analytics of all learners for monitoring of training metrics at the system level. This provides leaders/educators a new lens to analyze training productivity and identify educational techniques that may need further refinement or replacement. As the entire TCCC educational system matures, it could offer deeper analytics about the effectiveness of different training interventions. Stages 2-8 are an iterative process for continuous quality improvement.

RESULTS

Baseline Assessment

Analysis from the structured observations during the baseline assessment revealed that TCCC training faces numerous challenges. To begin, we confirmed that instruction of TCCC lacks standardization across the Services. The Services leverage TCCC guidelines during the creation of training doctrine, but differing implementation strategies and Service-specific needs cause variation between the Services. Furthermore, even within a Service, instruction varies from installation to installation, based on the use of passed-down training materials or instructor drift from guidance. Compounding this issue, when students or instructors search for definitive TCCC content, it has historically been found in a wide variety of locations, including the NAEMT website, Health.mil, or even contractor websites. This scattering of content has led to the proliferation of outdated TCCC content, creating a challenge for the Committee on Tactical Combat Casualty Care (CoTCCC) to ensure everyone has ready access to the most current TCCC guidelines.

Through both observation and interviews, we also uncovered a number of barriers associated with TCCC training, which were categorized into common themes (Figure 3). Barriers of accessibility, delivery, discovery, and portability all related to challenges students or instructors encountered when attempting to find, access, and ultimately consume TCCC content, both during and outside training events. A barrier due to poor usability was uncovered assessing the current state of TCCC training content, which was often in a challenging format for self-study (i.e. 150+ slide PowerPoint decks), had poor graphical resolution, or was poorly suited for mobile delivery. Quality of the content and consistency with official guidelines was a barrier as well, due exclusively to the proliferation of outdated materials as mentioned previously; when current materials were utilized, the quality and accuracy of the content was not an issue. Focusing on the implementation of TCCC training, barriers related to effectiveness and frequency were observed. The lack of consistent assessment measures to determine proficiency led to a barrier in assessing the overall effectiveness of TCCC training across multiple locations or training cohorts. Frequency of TCCC training was highlighted in the earlier survey, and was once again a barrier, resulting from the episodic nature of the training cycle. Finally, manageability of TCCC training content was a barrier related to the dissemination of content updates; as TCCC guidance is updated, training content should incorporate the necessary changes. However, with content posted to multiple locations and controlled by multiple entities, updating the content is a difficult task which leveraged outdated methods such as large email lists, distribution of CDs, and word of mouth.

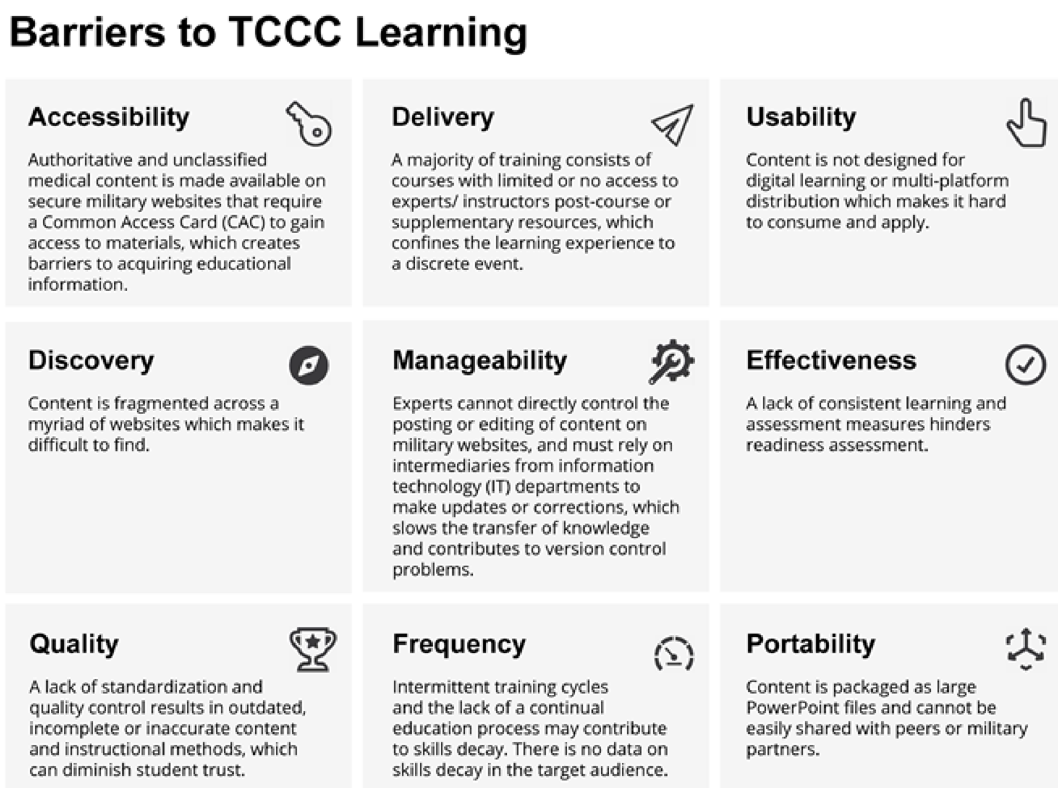

Figure 3: Observed Barriers to Optimal TCCC Learning

Tier 1 All Service Member TCCC Curriculum Pilot Testing

A total of 217 participants began the pilot training; of those, 213 completed the training and surveys and are included in data analysis. The four participants who did not complete left for reasons not associated with the pilot training or its assessment. Results from pilot testing were heavily positive across the Services, regardless of implementation strategy. To begin, both medical and non-medical trainees from all Services were able to demonstrate the necessary knowledge, skills, and abilities associated with the learning objective by the end of the course, suggesting that the curriculum is effective in developing TCCC competency. Further, both medical and non-medical instructors were able to appropriately administer the course, suggesting that the train the trainer course was effective in preparing an instructor to teach Tier 1 TCCC. From a time and resource perspective, observation revealed that the initial time allotted for certain activities, primarily small group and individual skill stations, was underestimated. We modified the curriculum as a result of these observations, shifting additional time from the instructor-led presentation portion and modified the patient assessment skill station.

Based on the survey data, student perceptions were positive across all the pilots (Table 2). The most positive responses were associated with key aspects of the course – understanding how to place a tourniquet and how to apply TCCC concepts to real-world situations. The most negative response was associated with accessing instructional videos after the class, which found that 23% of respondents were unlikely to view videos outside of class, opposed to 77% who responded positively towards self-directed video usage.

Table 2: Student Survey Responses (in percentage; *n* = 213)

Survey Prompt	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
The TCCC-ASM Course met the stated learning objectives.	0.0	0.0	0.9	17.4	81.7
This training motivated me to learn more about TCCC.	0.5	1.4	8.9	18.3	70.9
The course was presented in a way that helped me stay engaged in the learning process.	0.0	0.9	4.2	20.2	74.6
I believe the course was student-focused.	0.0	0.5	5.6	14.6	79.3
The lead instructor was knowledgeable and prepared.	0.0	0.0	2.8	14.6	82.6
I received adequate attention from my skill station instructor.	0.0	0.5	3.8	15.5	80.3
The instructor's explanations helped me understand the concepts and master these skills.	0.0	0.9	4.7	19.7	74.6
The introductory lecture was the right length and provided the right amount of information.	0.0	3.8	8.9	22.1	65.3
The instructional videos helped me learn TCCC concepts and lifesaving skills.	0.0	0.9	7.0	25.4	66.7
The videos enhanced my learning experience.	0.0	0.5	7.5	23.0	69.0
I will use the instructional videos outside the classroom for sustaining my knowledge / skills.	2.3	5.2	16.0	22.5	54.0
Adequate hands-on time was dedicated to practicing the TCCC lifesaving skills.	0.0	1.9	5.2	15.0	77.5
The skills and exercises increased my confidence in delivering lifesaving interventions.	0.5	0.9	4.2	23.0	71.4
I am confident I can properly place a tourniquet on a casualty.	0.5	0.0	1.4	8.5	89.7
I am confident I can pack a wound and apply a pressure bandage to slow/stop massive bleeding.	0.5	0.5	2.3	14.6	82.2
I am confident I can open an airway.	0.5	1.9	5.6	13.1	78.9
I am confident I can assess a casualty	0.5	0.9	3.3	20.2	75.1
I understand how these concepts and skills might apply to real-world situations.	0.0	0.5	1.4	6.1	92.0

While individual responses are useful for overall transparency and specific inquiry, we also grouped and analyzed the questions by themes: curriculum efficacy, instructional quality, instructional materials, and perceived self-confidence (Table 3). Once again, results showed that the curriculum and instructional materials were viewed positively by students. The instructional quality responses suggested that students felt the instructors were well prepared to administer the course, reinforcing the observational finding that the train the trainer course was effective. Lastly, perceived student confidence in skills was very positive with over 95% of students confident in their TCCC skills, highlighting the notion that students believed they were proficient in TCCC following completion of the course. Once again, this aligns with observational findings and suggests that the curriculum was effective in bringing students to a level of proficiency in TCCC.

Table 3: Thematic Analysis of Student Survey Responses (in percentage)

Student Perceptions by Theme	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
Curriculum Efficacy	0.1	0.7	4.9	17.6	76.6
Instructional Quality	0.0	1.3	5.0	18.0	75.7
Instructional Materials	0.6	2.6	9.9	23.2	63.7
Perceived Self-Confidence	0.4	0.8	3.1	14.2	81.5

Technology Development Results

To augment the curriculum and address many of the barriers uncovered in this effort, the team developed the Deployed Medicine technology platform. At present, Deployed Medicine serves as the definitive source for TCCC training content, hosting YouTube-style videos, podcasts, study guides, and other didactic content. Since all content on Deployed Medicine is approved by the JTS, users are assured the TCCC content is the most current and comprehensive available. This addresses the learning barriers associated with quality and discoverability. To improve accessibility, Deployed Medicine is freely available as an iOS app, Android app, and website, allowing access on mobile devices or standard web browsers. The platform also has a robust publishing capability, enabling a non-technical user to directly publish to the platform. This allows for the JTS, CoTCCC, or other military training authority to create and disseminate content immediately, without the need for technical personnel.

While the capability directly addresses learning barriers and accommodates mobile learning preferences, a new technology must be used to be effective. Usage data showed significant use, with over 260,000 website views and over 75,000 app downloads to date. Notably, the platform also has over 21,000 active users, which are users who return multiple times.

DISCUSSION

Curriculum Design

The results of pilot testing indicated that the curriculum was effective in providing students with the necessary KSAs associated with TCCC learning objectives, as evidenced by student proficiency assessments and course passage. This held true across the Services and across the various course delivery formats. The focus on interactive, hands-on skills instruction was appreciated by the students, and was the most common theme of both the focus groups and the free response portion of the surveys. This suggests that the instructional principle of action learning was effective and engaged the students. Students also responded positively to the short videos augmenting the skill stations and interspersed into the lectures, suggesting the micro-learning approach kept student attention while conveying the appropriate skills.

An important facet of the curriculum was providing sufficient flexibility for the Services to accommodate different needs and delivery methods across differing levels of expertise. These varying use cases necessitated that the curriculum be developed in a modular fashion. Modularity as a concept centers on dividing a curriculum into independent units of instruction that are often short in duration (French, 2015). Modularizing curricula is not a new concept, with modularization being pushed to enable greater flexibility for students and institutions as far back as the 1970s (Goldschmid & Goldschmid, 1973; Russell, 1974). The push to modularize curricula is often an organizing method tied to competency-based education. As defined by Frank et al., "competency-based education de-emphasizes time-based training and promises greater accountability, flexibility, and learner-centeredness" (Frank et al., 2010). In this case, the modularization of the TCCC curriculum provides delivery flexibility for both students and the Services, with competency as the ultimate goal rather than simple completion. However, there are arguments against modularizing curriculum, in particular the notion of knowledge fragmentation resulting from discrete, independent units of instruction (Cornford, 1997). To address this concern, researchers ensured that a series of modules at the end of the course were integrative in nature, notably the casualty assessment activities, which requires knowledge of all steps to both assess and treat the injuries of a casualty. The observational data that students demonstrated competency in all the delivery formats suggests that the modularization did not result in knowledge fragmentation in this case.

The TCCC curriculum also adheres to the tenets of deliberate practice. Deliberate practice is the concept that focused training on particular skills results in improved performance when compared to less directed practice of similar duration (Ericsson, Krampe, & Tesch-Römer, 1993). A common example is a person who specifically targets free throw shooting and layups is demonstrating deliberate practice, and would have improved performance compared to a person who is randomly shooting baskets for a similar amount of time. As highlighted by Ericsson et al., deliberate practice typically involves "the provision of immediate feedback, time for problem-solving and evaluation, and opportunities for repeated performance to refine behavior" (Anders Ericsson, 2008). Deliberate practice has been shown to be highly beneficial in numerous subjects, ranging from athletic training (Helsen, Starkes, & Hodges, 1998) to medicine (Ericsson, 2004). In fact, simulation-based medical training using deliberate practice has been shown to be more effective than traditional clinical education (McGaghie, Issenberg, Cohen, Barsuk, & Wayne, 2011). The TCCC curriculum leverages these principles, integrating deliberate practice for foundational TCCC skills, such as tourniquet application, wound packing, and airway management. The course design incorporates multiple skill stations, in which students receive immediate feedback with the opportunity to correct mistakes and improve performance. The survey results related to student confidence in skills combined with the observation-based proficiency assessment suggests that deliberate practice within the skill stations was effective in developing TCCC skills proficiency.

Removing Barriers to Learning

The baseline assessment conducted in our approach to designing a new TCCC training capability revealed numerous learning barriers: accessibility, delivery, discovery, quality, usability, portability, effectiveness, manageability, and frequency. The new curriculum addressed barriers associated with usability, portability, and effectiveness. The instructional materials included new videos and study guides which are easily shareable and consumable, making a much more usable and portable training product for a student, rather than massive PowerPoint decks. The new curriculum also standardized learning objectives and assessments, thereby reducing the effectiveness barrier. With standardized assessment, student data from various cohorts can be aggregated or compared, providing improved readiness measures.

The mobile delivery platform, Deployed Medicine, addresses the other learning barriers. As mentioned in the results, the capability hosts definitive TCCC content in a free, public app, which greatly reduces the barriers of quality, accessibility, discovery, and delivery. The ability of the CoTCCC and the JTS to automatically update the training content alleviates the manageability barrier. The publishing capability is able to remove much of the difficulty of disseminating new content to the training audience, reducing the proliferation of outdated materials.

The final barrier is common in military training, which is frequency. Many military programs utilize periodic training regimes, which creates periods between training events where knowledge and skills decay (Wisher, Sabol, Ellis, & Ellis, 1999). This phenomenon has been studied extensively in military medicine, where providers often have significant periods where trauma related skills are unused (Linde, Caridha, & Kunkler, 2018; Perez et al., 2013). In order to maximize retention, researchers have suggested many remedies, including novel upfront pedagogy, such as the application of virtual reality and adaptive instruction (Siu, Best, Kim, Oleynikov, & Ritter, 2016) or periodic refresh of knowledge in the form of spaced repetition (Kang, 2016). In the case of TCCC, a resource intensive solution such as adaptive virtual reality would be challenging to implement at the enterprise scale. As such, the mobile platform Deployed Medicine was leveraged to allow students to receive instruction at specific intervals via spaced repetition. The reach of a mobile platform combined with the short content of a micro-learning approach holds significant promise of keeping TCCC knowledge fresh. This approach is consistent with research highlighting the potential for mobile micro-learning (Shail, 2019) and data demonstrating retention of IT skills (Kadhem, 2017) and high school knowledge (Nikou & Economides, 2018).

Limitations

There are limitations to the findings of the baseline assessment and pilot studies. To begin, the baseline assessment included subjective observation. To mitigate potential bias, observation was recorded using a standardized form. Further, all observations included multiple personnel who independently evaluated a training event and compared observation data afterward. The principal limitation of the pilot studies is the use of a quasi-experimental study design, as the pilots lacked a control group for comparison. As the principle purpose of the pilots was the validation of the curriculum, researchers felt this was acceptable; however, future studies comparing the relative efficacy between differing delivery formats and across age groups or genders would be beneficial.

Transforming TCCC Training

The broad objective of this research effort is to begin the process of transforming TCCC from a non-standardized program of instruction into a unified training platform that can adapt to provide different tiers of training, tailored to different student audiences, employing modern learning science and measures of efficacy at the individual and enterprise level. By conducting the baseline analysis, we were able to identify, address, and reduce many of the identified barriers to current TCCC learning. In the future, the integration of the Deployed Medicine mobile platform holds significant potential to further progress TCCC education, and more broadly support military medical forces. Similar to how motivational apps help with learning a new skill or starting a new exercise regime (Conroy, Yang, & Maher, 2014), a learning-orientated app can encourage better learning behaviors such as regularly “dipping in” and setting personal goals. This approach builds on the individual motivations of learners to excel, as well as leveraging the best of mobile design practice to encourage more sustained engagement. To foster routine clinical practice, a mobile-app driven capability can facilitate access to on-demand content and aid on-the-job performance (i.e. tourniquet placement). In addition to sustainment training and performance support, the mobile capability can be leveraged as an adjunct to traditional courses, simulation training, or field exercises. In the weeks preceding their arrival at a training event, learners can preview materials on their personal mobile device or online. By leveraging a distributed system to deliver the didactic portions of the curriculum, face time with instructors can be optimized. During the training, content can augment or reinforce classroom activities through the use of mobile checklists and procedural demonstration videos, such as a video to re-familiarize a skill prior to a skills certification. On completion, a series of micro-assessments and surveys, immediately after and further out, would allow instructors to gain a deeper understanding of the effectiveness of the training event, as well as the atrophy rate of the skills.

As the use of the mobile content becomes more embedded, refresher training and simulation centers might eventually adopt an active classroom approach. The active or "flipped" classroom is a mode of instruction where the presentation of didactic instruction and practice are reversed (Bishop & Verleger, 2013). Traditionally, the instructor provides the lecture, and the student practices outside the classroom. But with resource-intensive facilities like simulation centers, classroom time is the most valuable, and didactic instruction could be easily facilitated with mobile learning. This approach could potentially decrease classroom training time, decrease costs, and reduce time away from work. This would place more responsibility on the learner, so the degree to which a flipped classroom is implemented would need to be carefully evaluated for secondary effects.

This initiative combined with the policy changes of DoDI 1322.24 and NDAA 17 provides a significant opportunity to improve skills retention, while broadening the impact of TCCC training through the addition of a continuous learning capability. A standardized Joint TCCC curriculum combined with a mobile delivery capability yield a capability to evaluate and potentially improve the effectiveness of educational interventions across the life-time learning journey of TCCC trainees. These capabilities were designed to help transform the current TCCC educational system into a more engaging learning system tailored to the NextGen workforce. In the future, a life-long learning pathway can emerge that helps learners navigate the existing TCCC training opportunities (courses, simulation centers etc.), while being able to access on-demand and targeted content, learning activities, and support on a continual basis. As the entire TCCC educational system matures, this capability will provide deeper analytics about the effectiveness of different training interventions. Ultimately, this research effort has begun the process to deliver a viable NextGen TCCC Learning System that will ensure the military keeps pace with changes in learning, provide measures of trauma training readiness, and ultimately improve clinical outcomes on the battlefield.

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