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SIMULATION-BASED TEAM TRAINING IN EMERGENCY MEDICINE: A REVIEW OF INNOVATIVE EDUCATIONAL TECHNOLOGIES AND THEIR IMPACT ON CLINICAL PERFORMANCE

Kinga Lubomska *(Corresponding Author, Email: kinga.lubomska@umed.lodz.pl)*
Medical University of Lodz, Lodz, Poland
ORCID ID: 0009-0002-8777-5273

Daria Julia Makowska-Woszczyk
Medical University of Lodz, Lodz, Poland
ORCID ID: 0009-0004-9897-0618

Patrycja Jagura
Medical University of Lodz, Lodz, Poland
ORCID ID: 0009-0008-2394-3673

Julia Groszewska
Medical University of Lodz, Lodz, Poland
ORCID ID: 0009-0002-4637-1264

Michał Romaniuk
Medical University of Lodz, Lodz, Poland
ORCID ID: 0009-0008-6002-000X

Agata Rapior
Medical University of Lodz, Lodz, Poland
ORCID ID: 0009-0002-0300-2303

Jan Romaniuk
Medical University of Lublin, Lublin, Poland
ORCID ID: 0009-0000-3017-3330

Agata Mytych
Wroclaw Medical University, Wroclaw, Poland
ORCID ID: 0009-0004-4575-6327

Marta Dziedziak
Wroclaw Medical University, Wroclaw, Poland
ORCID ID: 0009-0004-3463-2804

Łukasz Nosek
Wroclaw Medical University, Wroclaw, Poland
ORCID ID: 0009-0006-8294-5842

ABSTRACT

Background: Simulation-based team training (SBTT) is increasingly applied in emergency medicine (EM) to enhance interprofessional collaboration and non-technical skills within high-acuity, time-critical scenarios in the emergency department. Effective teamwork—encompassing communication, leadership, situational awareness, and coordination—is critical for patient safety. Evidence on SBTT remains heterogeneous, particularly regarding clinical outcomes and adoption of emerging technologies.
Methods: This narrative review synthesizes literature from PubMed, Scopus, and Google Scholar (1984–2025) on SBTT in EM. Eligible studies included systematic and narrative reviews, randomized and non-randomized studies, and qualitative reports. Data extraction focused on simulation modalities, educational strategies, non-technical skill development, and reported effects on team performance and clinical outcomes.
Results: SBTT has been shown to improve communication, leadership, situational awareness, and coordination across diverse contexts and modalities, including low- and high-fidelity manikins, virtual reality, and augmented reality. Pilot applications of artificial intelligence have shown potential for adaptive scenarios, individualized feedback, and performance analytics, although evidence in EM remains limited. SBTT also supports workflow efficiency, protocol adherence, and simulated clinical performance. However, data linking training to sustained behavioral change and patient-level outcomes remain limited.
Conclusions: SBTT constitutes a valuable educational approach for interprofessional EM teams, fostering non-technical skills and team-based competencies. Its effectiveness relies on structured pedagogy, standardized frameworks, and high-quality debriefing rather than technological fidelity alone. Integration of innovative technologies may enhance scalability and individualized learning. Further longitudinal and multicenter research is required to clarify SBTT's impact on clinical practice, patient outcomes, and sustainable implementation within EM training programs.

KEYWORDS

Simulation-Based Education, Emergency Medicine, Team Training, Innovative Educational Technologies, Non-Technical Skills, Clinical Performance

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Introduction

Emergency medicine (EM) is characterized by time-critical decision-making, high patient acuity, and the need for effective communication and coordinated teamwork among multidisciplinary healthcare teams. Clinical scenarios in the emergency department (ED) often involve dynamic patient conditions, diagnostic uncertainty, and high cognitive workload, requiring clinicians to integrate technical expertise with non-technical competencies such as communication, leadership, coordination, and situational awareness [1, 2, 3, 4]. Deficiencies in teamwork and non-technical performance, including communication breakdowns, have been consistently associated with adverse patient outcomes [2, 3].

Traditional educational approaches including didactic lectures and point-of-care clinical education provide limited opportunities to systematically train healthcare teams in rare, high-risk scenarios, due to ethical, safety, and organizational constraints [5, 6]. Consequently, gaps may persist in both individual and team-based competencies, particularly in interprofessional emergency care settings [7, 8].

Simulation-based education has emerged as an innovative strategy to address these challenges by providing a safe, controlled, and reproducible environment for experiential learning, thereby allowing teams to practice technical procedures and develop non-technical skills without patient risk [9]. Early EM applications demonstrated improvements in team coordination and clinical preparedness during high-stakes scenarios [6, 10].

Increasing attention has been directed toward simulation-based team training (SBTT), particularly in interprofessional settings. Systematic reviews indicate that SBTT enhances communication, role clarity, leadership, and coordination in time-critical events [7]. Pediatric-focused reviews suggest improved adherence to clinical guidelines and team processes measures, though patient-level outcome data remain limited [8]. Similarly, airway management training improves procedural success and teamwork [11].

Despite the growing body of research, evidence on simulation-based team training in EM remains heterogeneous. Studies differ in design, simulation modality, participant composition, and outcome measures, particularly regarding non-technical skills and clinical performance. Many investigations rely on surrogate outcomes, such as self-efficacy or simulated performance, while longitudinal data linking SBTT to sustained behavioral change and patient outcomes are scarce [7, 8, 12].

Rapid technological advances—including high- and low-fidelity manikins, computer-based simulations, virtual reality (VR), and augmented reality (AR)—have expanded training possibilities, enabling immersive, scenario-driven team learning. However, the relationship between specific technologies, training strategies, and educational and clinical performance outcomes has not been comprehensively synthesized [7, 13].

Therefore, the aim of this narrative review is to synthesize and critically appraise current evidence on SBTT in EM, with a particular focus on innovative educational technologies and their effects on team performance, non-technical skills, and clinical outcomes. By integrating systematic reviews, empirical studies, and methodological analyses, this review seeks to clarify the educational value of SBTT and identify directions for future research in EM education.

Methodology

This review is based on a narrative synthesis of scientific literature examining SBTT in EM, integrating educational, technological, and clinical perspectives.

The comprehensive literature search was conducted using major biomedical databases, including PubMed, Scopus, and Google Scholar, covering publications from 1984 to 2025. The search strategy combined the following keywords: “simulation-based education”, “team training”, “emergency medicine”, “non-technical skills”, “interprofessional education”, “clinical performance”, and “educational technology”.

Eligible studies comprised systematic and narrative reviews, randomized controlled trials, cohort studies, cross-sectional surveys, qualitative studies, and case reports investigating SBTT in emergency or acute care settings. Only peer-reviewed articles published in English were included. Additional references were identified through manual searches of bibliographies from key review articles.

Studies were screened for relevance, methodological quality, and alignment with the review objectives. Data extraction focused on simulation modalities, team training strategies, development of non-technical skills, and reported effects on clinical performance and patient safety.

This narrative synthesis integrates empirical and review evidence to examine the effects of SBTT on team performance, non-technical skills, and clinical preparedness in EM.

Results

4.1 Educational Technologies Applied in Simulation-Based Team Training

The reviewed literature indicates that SBTT in EM incorporates a wide spectrum of educational technologies, ranging from traditional low-fidelity task trainers to advanced immersive simulation systems. These interventions can be conducted either in dedicated simulation centers or in situ, within clinical environments such as emergency departments (EDs), intensive care units (ICUs), or prehospital settings. In situ simulations allow healthcare teams to practice in their usual working environment, facilitating contextual learning and identification of system-level challenges, whereas simulation centers offer controlled conditions for focused skill acquisition and standardized scenario repetition [7, 13].

High-fidelity manikins represent the most frequently reported simulation modality, particularly for training scenarios involving cardiac arrest, trauma resuscitation, airway management, and sepsis, where physiological realism and dynamic responsiveness are essential for effective team coordination and clinical decision-making [6, 7, 11]. Contemporary high-fidelity manikins are capable of generating real-time physiological responses, including dynamic alterations in vital signs, heart and lung sounds, pupillary reactivity, verbal outputs, and responses to pharmacological and procedural interventions, thereby closely approximating real clinical conditions [13, 14, 15]. These systems are frequently supplemented with audiovisual recording and structured debriefing frameworks, facilitating reflective learning, performance feedback, and the analysis of team functioning [9, 13].

Low-fidelity simulation modalities, including basic manikins, role-playing exercises, and tabletop simulations, are also widely applied within SBTT programs, providing a flexible, resource-efficient, and easily implementable approach for training non-technical skills [7, 12, 13]. These modalities are primarily used to develop communication strategies, role allocation, procedural sequencing, and situational awareness, particularly during early-stage training or for skills reinforcement [7]. When integrated into well-structured scenarios and accompanied by facilitated debriefing, low-fidelity simulations have been shown to enhance learner confidence in team coordination and structured handovers [16], foster reflection on collaboration, communication, and situational awareness, and in some contexts achieve outcomes comparable to high-fidelity modalities in the acquisition of non-technical skills [7, 17].

Recent studies emphasize the increasing adoption of computer-based simulation, virtual reality (VR), and augmented reality (AR) within SBTT initiatives. VR-based simulation typically involves fully immersive, computer-generated environments in which learners interact with virtual patients, equipment, and team members using head-mounted displays and motion-tracking interfaces. These systems allow precise control of scenario progression, environmental complexity, and task demands, enabling standardized repetition of identical team scenarios across training sessions [7, 18].

In contrast, AR platforms overlay digital information—such as visual cues, physiological data, or procedural guidance—onto the real clinical environment, allowing learners to interact simultaneously with physical surroundings and virtual elements. AR-based simulations are often integrated with real equipment or manikins, supporting hybrid training formats that combine physical task execution with digitally enhanced situational information. Both VR and AR technologies facilitate flexible deployment, including remote or distributed team training, and offer detailed data capture on learner actions, timing, and task sequences [7].

Emerging evidence reports pilot applications of artificial intelligence (AI) in SBTT. AI-driven platforms have been explored for adaptive scenario progression, automated performance analytics, virtual mentoring, and individualized feedback, supporting both technical and non-technical skill assessment [19, 20, 21].

Across the reviewed literature, interventions using high- or low-fidelity manikins remain the most frequently reported, whereas an increasing number of investigations have incorporated VR, AR, or computer-based simulation components. This distribution indicates a gradual trend toward technological diversification in SBTT while preserving manikin-based simulation as the core educational modality [7, 8, 11].

Overall, the integration of manikins with varying levels of fidelity alongside digital and virtual technologies facilitates an integrated simulation model, promoting the simultaneous development of technical competencies and non-technical skills essential for effective team performance in EM.

4.2 Simulation-Based Interprofessional Team Training

Effective emergency care relies on coordinated performance of interprofessional teams, comprising physicians, nurses, paramedics, and other healthcare professionals [7]. SBTT interventions target interprofessional collaboration by replicating complex clinical scenarios and emphasizing communication, leadership, role clarity, and task allocation [7]. Such approaches support identification of system-level challenges and reinforcement of interprofessional protocols, allowing teams to practice workflows in realistic or controlled settings.

Simulation scenarios frequently utilize mixed-fidelity approaches, combining high-fidelity manikins to simulate complex physiology with low-fidelity models for procedural practice, thereby enabling rehearsal of both technical and collaborative skills [7, 18]. VR and AR platforms increasingly facilitate geographically dispersed team participation, role awareness, and situational engagement in rare or high-stakes scenarios, enhancing cognitive load management and decision-making under pressure [7].

Preliminary applications of AI-driven platforms have been explored to support remote or distributed interprofessional team training, providing adaptive scenario progression and individualized guidance to team members [19, 20, 21].

Evidence indicates that interprofessional SBTT improves mutual understanding of roles, situational awareness, and collaborative behaviors, particularly in pediatric and acute care settings where team coordination is critical [8, 23]. These interventions contribute to streamlined task allocation, anticipatory teamwork, and enhanced adherence to emergency protocols.

4.3 Impact of Simulation-Based Team Training on Non-Technical Performance

SBTT has been consistently shown to enhance non-technical performance, encompassing decision-making, situational awareness, adaptive leadership, communication, conflict management, and task prioritization, all of which are crucial for effective team functioning in EM [1, 2].

Empirical studies provide evidence for measurable improvements in these domains. Systematic reviews and clinical simulation research indicate that simulation-based team training is associated with improvements in coordinated team behaviours, team communication, and shared understanding among team members, reflecting enhanced non-technical skills and team cognition in time-critical clinical contexts [7, 22]. Meurling et al. (2013) reported improved collaboration and workflow efficiency in ICU teams following SBTT implementation, demonstrating tangible operational benefits associated with strengthened non-technical skills [23]. Weaver et al. (2010) and Brydges et al. (2014) found that structured SBTT programs improve error detection, adaptive decision-making, and distributed leadership under high cognitive load, suggesting that repeated exposure to realistic scenarios fosters resilience and flexibility in clinical teams [24].

Low-fidelity simulation modalities, such as role-play and tabletop exercises, support deliberate practice of communication strategies, handover procedures, task prioritization, and coordination under pressure, allowing teams to focus cognitive resources on teamwork dynamics rather than technical execution [16]. In pediatric and acute care contexts, where interprofessional collaboration is complex due to diverse roles and dynamic patient needs, these approaches reinforce understanding of cross-disciplinary responsibilities, support anticipatory teamwork, and enhance task management during high-acuity events [8]. By providing opportunities to rehearse workflows in controlled environments, low-fidelity simulations strengthen shared mental models and the application of structured communication and coordination strategies in clinical practice [7, 12, 13].

Emerging VR and AR modalities further support the development of non-technical competencies, providing scalable, repeatable, and resource-efficient training solutions that enable immersive, scenario-driven learning and remote or synchronous distance simulation [7, 18]. Systematic reviews indicate that VR simulations have been increasingly used to train teamwork, communication, and situational awareness, which are core components of non-technical performance [25]. Participant evaluations of virtual simulation report high levels of perceived realism and engagement, with learners identifying improvements in communication, teamwork, decision-making, and critical thinking [26]. Preliminary research on AR applications suggests that multiplayer AR can be a feasible and acceptable approach for teaching communication skills, particularly under crisis conditions, supporting rehearsal of complex team coordination and interprofessional protocols [27].

Pilot studies indicate that AI-based systems can also facilitate objective assessment of non-technical skills, including communication, situational awareness, and decision-making, complementing instructor-led debriefing [19, 20, 21].

Although evidence remains at an early stage and more robust outcome data are needed, these immersive technologies show promise for enhancing experiential learning, scenario retention, and cognitive engagement in non-technical skills development.

4.4 Influence of Simulation-Based Team Training on Clinical Performance and Patient Outcomes

SBTT in EM has been associated with measurable improvements in clinical performance during time-critical scenarios, including enhanced adherence to protocols, accelerated procedural execution, and greater technical accuracy [6, 7, 11]. These improvements are particularly relevant to patient safety, as deficiencies in non-technical skills remain a major contributor to adverse events in emergency care [3, 4].

Empirical studies demonstrate real-world operational benefits of SBTT. Meurling et al. (2013) reported reductions in staff sick leave and increased workflow efficiency in ICU teams following the implementation of structured simulation-training programs [23]. Similarly, in trauma and cardiac arrest contexts, SBTT has been linked to higher survival to discharge and more effective execution of critical interventions [6, 7].

Current evidence directly assessing patient-level outcomes remains limited, with most studies reporting performance metrics, workflow measures, or surrogate outcomes rather than morbidity, mortality, or other clinical endpoints [8, 12].

Discussion

This narrative review synthesizes current literature on SBTT in EM, with a focus on educational technologies, non-technical performance, and clinical outcomes. The body of evidence reviewed reflects sustained interest in SBTT as an educational approach within high-acuity emergency care environments, where effective teamwork and coordination are essential. Across diverse study designs and clinical contexts, the literature consistently emphasizes the central role of non-technical skills—such as communication, leadership, and situational awareness—in shaping team performance and patient safety [1, 2, 3].

At the same time, the reviewed studies demonstrate considerable heterogeneity in training models, technological modalities, and outcome measures. This variability highlights the importance of interpreting SBTT-related findings within broader educational and organizational contexts, particularly when considering transferability, scalability, and system-level impact in emergency medicine settings.

5.1 Educational Effectiveness of Simulation-Based Team Training

The educational effectiveness of simulation-based team training in emergency medicine should be considered within the framework of experiential and competency-based learning. SBTT is not designed solely to improve isolated procedural skills but to support learning processes that integrate individual expertise with collective cognition and coordinated action in complex clinical environments. Prior educational theory emphasizes that learning in high-risk domains is most effective when it involves active participation, contextualized problem-solving, and structured reflection—elements that are intrinsic to well-designed simulation-based training [9, 28].

Across the reviewed literature, SBTT is frequently associated with improvements in learning-related constructs such as shared mental models, anticipatory coordination, and reflective capacity, rather than narrowly defined task performance. This aligns with team cognition theory, which conceptualizes effective team performance as emerging from shared understanding and adaptive coordination rather than individual competence alone [1, 2]. Consequently, educational effectiveness in SBTT is often better captured through changes in team processes than through single-outcome performance metrics.

Nevertheless, interpretation of educational impact is constrained by substantial heterogeneity in study design and outcome measurement. Many studies rely on self-assessment, learner satisfaction, or simulated performance outcomes, which may overestimate educational benefit and provide limited insight into knowledge retention or behavioral transfer [8, 12]. Moreover, variation in debriefing quality and instructional design further complicates attribution of learning effects to simulation modality alone. These limitations underscore the importance of viewing SBTT as one component of a broader educational strategy rather than a self-sufficient intervention.

Importantly, the literature suggests that educational effectiveness is not inherently dependent on high technological fidelity. Low- and mixed-fidelity simulations have been shown to support the acquisition of non-technical competencies when paired with structured facilitation and debriefing [7, 13]. This finding reinforces the central role of pedagogy, feedback, and team composition in shaping learning outcomes and cautions against equating technological sophistication with educational superiority.

5.2 System-Level and Organizational Implications

Beyond its educational role, SBTT has broader implications for system-level functioning and organizational learning in emergency care settings. Several studies conceptualize simulation not only as a training modality but also as a mechanism for identifying latent safety threats, communication breakdowns, and workflow inefficiencies embedded within clinical systems [7, 9]. In this capacity, SBTT operates at the intersection of education, patient safety, and quality improvement.

The extent to which SBTT contributes to sustained system-level change appears to depend largely on organizational integration. In situ simulation, in particular, allows teams to observe actual workflows and environmental interactions, providing actionable insights that can inform process improvements and policy adjustments, including redesign of care pathways, optimization of equipment placement, and refinement of interprofessional protocols [12, 13, 23]. Simulation programs embedded within routine training structures and aligned with institutional policies are more likely to translate these insights into tangible organizational benefits, reinforce shared standards, and support interprofessional collaboration [12, 13]. In contrast, isolated or episodic simulation initiatives may yield short-term educational benefits without measurable impact on workflow or safety culture.

Resource requirements represent significant organizational consideration. Effective SBTT implementation necessitates investment in faculty development, simulation infrastructure, protected training time, and coordination across professional groups [7]. These demands may limit scalability and contribute to the concentration of advanced simulation programs within large academic centers, raising concerns regarding equitable access to high-quality team training across healthcare systems. As a result, the system-level value of SBTT must be evaluated not only in terms of educational outcomes but also in relation to feasibility, sustainability, and institutional capacity.

5.3 Training Models and Implementation Challenges

Despite the demonstrated benefits of SBTT, its implementation faces several challenges. High-fidelity simulation technologies, including advanced manikins and immersive virtual environments, require considerable resources, including financial investment, ongoing maintenance, and dedicated infrastructure [7, 13]. Consequently, the implementation of technologically advanced SBTT is likely more achievable in well-resourced institutions, whereas smaller or resource-limited emergency departments may face practical constraints in adopting such programs.

Another important factor influencing SBTT effectiveness is the quality of debriefing and facilitation. Skilled debriefing has been consistently shown to be central to achieving educational outcomes, including improved team coordination, communication, and clinical decision-making [9, 12]. Although the literature does not provide systematic quantification of facilitator training across institutions, it is plausible that inter-institutional variability in instructor expertise modulates the effectiveness and educational impact of simulation programs.

Hybrid training models that combine low-fidelity simulation with targeted deployment of digital technologies may provide a practical and resource-efficient approach to SBTT implementation. Such strategies can maintain educational effectiveness while reducing financial and logistical burdens, thereby facilitating broader accessibility and scalability of team training across heterogeneous emergency care settings.

5.4 Emerging Technologies and Future Directions

Technological developments continue to broaden the scope of SBTT in emergency medicine. VR and AR platforms enable scenario-based, interactive training and may facilitate remote or distributed participation of interprofessional teams, thereby addressing certain logistical and geographical constraints associated with traditional simulation delivery [7]. These modalities may be further advanced through integration with AI, which has the potential to support more adaptive scenario design, structured performance monitoring, and individualized learner guidance in future SBTT implementations.

Recent studies have explored the use of AI-powered virtual mentoring systems capable of monitoring trainee performance, identifying learning needs, and recommending targeted practice. Preliminary findings suggest that such systems can support both technical and non-technical skill development, including communication, teamwork, and clinical decision-making, within simulated emergency care contexts [19, 20, 21]. Potential applications include real-time performance analytics during simulations, automated support for debriefing through objective assessment of team behaviors, and adaptive learning pathways that adjust scenario complexity in response to trainee performance.

Concurrently, the literature increasingly highlights the need to enhance the efficiency, consistency, and reproducibility of simulation-based healthcare education through the development of standardized training frameworks and evidence-based guidelines. Several authors argue that future progress in SBTT should not rely solely on technological innovation, but also on the establishment of shared standards for scenario design, learning objectives, assessment methodologies, and facilitator competencies. Such standardization may improve comparability across programs, support scalability, and align SBTT more closely with competency-based medical education models [12, 13, 29].

Although empirical evidence specific to emergency medicine remains limited, the combined application of AI-supported tools and standardized SBTT frameworks may contribute to improved scalability, reduced instructor burden, and more efficient delivery of team-based training. Further research is required to determine the effectiveness, feasibility, and optimal integration of these approaches within routine emergency medicine education [8, 29].

5.5 Limitations of the Evidence Base

The current evidence base on SBTT in EM is characterized by substantial heterogeneity in study design, simulation modalities, participant populations, and outcome measures. Many studies rely on surrogate endpoints, such as simulated performance, self-reported confidence, or process measures, rather than direct patient-level outcomes [8, 12]. Longitudinal data examining the sustainability of SBTT effects and their transfer to clinical practice remain limited.

Additionally, much of the available evidence originates from high-resource settings, limiting applicability to smaller emergency departments or low- and middle-income healthcare systems. These limitations highlight the need for standardized outcome frameworks and multicenter studies to strengthen the evidence base.

5.6 Implications for Practice and Research

From a practical perspective, SBTT represents a core component of EM education, particularly for interprofessional teams managing high-risk clinical scenarios. Greater emphasis should be placed on scenario design, team-based learning objectives, and high-quality debriefing rather than exclusive reliance on advanced technology.

Future research should prioritize longitudinal and multicenter studies examining the relationship between SBTT and patient-level outcomes, including morbidity, mortality, and safety metrics. Additional investigation into cost-effectiveness, faculty development models, and the role of AI-supported simulation is warranted. Addressing these gaps will be essential for optimizing the educational and clinical impact of SBTT in emergency medicine.

Conclusions

SBTT represents a well-established component of EM education, addressing the complex demands of high-acuity, time-critical care delivered in the ED. The evidence synthesized in this narrative review indicates that SBTT consistently supports the development of non-technical skills, including communication, leadership, situational awareness, and coordination, which are critical determinants of effective team performance and patient safety in emergency care.

Across diverse clinical contexts and simulation modalities, SBTT has been associated with improvements in team processes, workflow efficiency, and protocol adherence during high-risk scenarios. However, the existing evidence base remains heterogeneous, with substantial variability in study design, educational interventions, and outcome measures. Consequently, evidence linking SBTT to sustained behavioral change and patient-level outcomes in the ED remains limited.

Technological innovations, including VR, AR and emerging applications of AI, offer opportunities to enhance the scalability and analytical capacity of SBTT. Nonetheless, educational effectiveness appears to depend primarily on pedagogical design, structured facilitation, and high-quality debriefing rather than on technological fidelity alone. Future advances in SBTT will require the integration of innovative technologies with standardized training frameworks, clearly defined learning objectives, and robust assessment strategies.

Overall, SBTT constitutes a valuable educational approach for interprofessional teams in EM, with demonstrated benefits for non-technical skill development and simulated clinical performance. Further longitudinal and multicenter studies are required to clarify its impact on clinical practice and patient outcomes and to inform the sustainable implementation of SBTT within EM training programs.

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