

Article

Managing Educational Innovation and Organizational Transformation in Military Academies: A Socio-Technical Systems Approach

Olga Kapoula *, Konstantinos Panitsidis , Konstantinos Spinthiropoulos , Marina Vezou and Aristeidis Xolopoulos

Department of Management Science and Technology, University of Western Macedonia, 50100 Kozani, Greece; kpanytsidis@uowm.gr (K.P.); kspinthiropoulos@uowm.gr (K.S.); mvezou@uowm.gr (M.V.); mpu00546@uowm.gr (A.X.)

* Correspondence: dmst00032@uowm.gr

Abstract

Military academies operate as tightly coupled socio-technical systems in which pedagogical practice, human agency, technological artefacts, and hierarchical structure are mutually dependent. Drawing on socio-technical systems (STS) theory, this study investigates how the characteristics of instructors condition the management of change and the adoption of educational innovation in such settings, and how the integration of emerging defence-relevant technologies is enacted through—rather than independently of—the organizational structure. Rather than treating technology as an exogenous input, we frame educational innovation as an emergent property of the interaction among four subsystems: the social (instructor attributes), the technical (digital and simulation technologies), the structural (hierarchy, bureaucracy, policy), and the pedagogical (instructional design). A qualitative design was employed, using structured, open-ended interviews with 22 instructors of the Hellenic Army Non-Commissioned Officers' Academy (HNCOA) spanning the military, academic, technical, and physical-training domains. Whereas research on military innovation has concentrated on top-down procurement, macro-level doctrinal change, and officer-commissioning academies, this study contributes empirical evidence from the non-commissioned officer (NCO) tier—the instructional cadre that translates technological mandates into frontline tactical and technical execution—and models innovation as an emergent property of joint optimization across subsystems rather than as an exogenous technological input. Data were analysed through codebook thematic analysis following Braun and Clarke, yielding three thematic axes and four question-aligned code hierarchies. Findings indicate that instructors perceive their technological competence, openness to change, and continuing professional development as the principal levers of change, while hierarchy, bureaucratic approval chains, and the absence of specialization are perceived as the dominant structural constraints. Consistent with STS theory, participants regarded technology alone as insufficient: perceived innovation was reported to emerge only when technical capability was jointly optimized with instructor development, institutional support, and alignment to operational tasks. We deliberately frame these as perceived rather than empirically demonstrated effects and derive a set of propositions and actionable design principles for the joint optimization of the social and technical subsystems in military professional education.



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Keywords: socio-technical systems; educational innovation; change management; organizational transformation; military academies; instructor characteristics; technology adoption; joint optimization

1. Introduction

Armed forces have historically innovated in response to the changing character of conflict. Although readiness has remained the enduring objective, decisive technological developments have repeatedly shaped the outcome of major conflicts, spanning offensive and defensive systems as well as logistics and communications. In most cases these advances were reactions to perceived strategic problems arising from the dynamics of warfare rather than ends in themselves; the internet and artificial intelligence are prominent contemporary examples of military developments later repurposed for civilian, or “dual-use,” application [1].

Military innovation is an increasingly studied domain associated with operational effectiveness, technical advancement, and the improvement of training. It has been defined as a significant change in operational practice that materially improves military performance [2]. Crucially, innovation is not a purely technological phenomenon: it also arises from organizational, doctrinal, and pedagogical transformation [3]. Military innovation therefore encompasses changes in training methods, doctrine, and education alongside the development of new weapon systems, and military educational institutions occupy a pivotal position in preparing personnel to operate, adapt, and innovate within increasingly technology-dense environments [4].

The contemporary educational landscape has been reshaped by the incorporation of advanced technologies—unmanned systems, augmented and virtual reality (AR/VR), and cybersecurity applications—which enhance the fidelity of operational simulation and the cultivation of digital competencies [5,6]. This transition requires that educators strengthen their change-management capacity if adoption is to succeed. Yet it remains insufficiently understood how instructors’ characteristics and pedagogical frameworks shape their capacity to manage change and integrate innovation within military training contexts [7]. The existing literature on military innovation does not offer consistent answers to these questions [8]: theories about the timing and diffusion of military breakthroughs have been repeatedly reclassified according to their (often disputed) catalysts, with comparatively little attention to instructional agency [2]. There is, in particular, a marked scarcity of empirical work on educators’ perceptions of innovation, the influence of their characteristics on change management, and the integration of new defence technologies into teaching [9–11]. Because instructors are the actors who translate institutional change and technological advancement into pedagogical practice, understanding their perspective is essential. Synthesizing this body of work exposes a specific and persistent gap. Military innovation studies conceptualize innovation predominantly as technological breakthrough or doctrinal adaptation, giving comparatively little attention to the micro-level instructional mechanisms through which such change is operationalized [2–4,8]; research on educational technology in military settings, in turn, documents instructor self-efficacy and instructional design without theorizing the organizational conditions in which instructors act [9,10]. What remains unexamined is how the structural rigidity of rank-based academies interacts with instructor competencies when emerging dual-use technologies—drones, simulation, and cybersecurity—are introduced into instruction.

A Socio-Technical Framing and the Problem Addressed

A recurring weakness in this literature is the treatment of technology as an exogenous driver that acts upon education from outside, rather than as one component of a system that must be jointly configured with people, structure, and tasks. We therefore adopt a socio-technical systems (STS) perspective. Originating in the Tavistock studies of work organization, STS theory holds that the performance of any productive system depends on the joint optimization of its social and technical subsystems: optimizing one while ignoring the other degrades overall performance [12]. Framed this way, educational innovation in a military academy is not the installation of AR/VR or drones, but an emergent property of the interaction among instructor attributes (social), digital and simulation tools (technical), hierarchy and bureaucracy (structural), and instructional design (pedagogical). This framing directly motivates the study's focus on the instructor as the locus where the social and technical subsystems meet. The Hellenic Army Non-Commissioned Officers' Academy (HNCOA) constitutes a revelatory case for this question. Non-commissioned officers form the operational backbone of contemporary armed forces, bridging strategic technological mandates and tactical execution, and the HNCOA combines university-level academic instruction, technical engineering, and field tactical training delivered by both permanent military cadre and civilian adjunct faculty. This dual institutional identity renders visible, within a single site, how socio-technical subsystems interact under strict hierarchical conditions.

Accordingly, this study addresses four research questions:

RQ1: How do instructors perceive and experience educational innovation in a military academy?

RQ2: In what ways do instructors perceive their own characteristics as conditioning the management of change in educational practice?

RQ3: How do instructors report enacting the integration of emerging military-relevant technologies in pedagogical methods and curriculum design?

RQ4: What barriers and opportunities do instructors identify in implementing educational innovation, and how are these distributed across the social, technical, and structural subsystems?

The study contributes to the understanding of military innovation by positioning the instructor as the agent through whom the social and technical subsystems are coupled. Its theoretical contribution is to reframe educational innovation in military academies as a problem of joint optimization rather than technology insertion; its practical contribution is a set of design principles for aligning instructor development, institutional support, and technology adoption. The remainder of the article is organized as follows: Section 2 establishes the theoretical framework and derives four study propositions. Section 3 details the qualitative methodology, ethics, and coding procedures. Section 4 reports empirical results. Section 5 critically discusses the findings against the framework. Section 6 addresses study limitations, and Section 7 concludes with actionable design principles.

2. Theoretical Framework

This section builds the theoretical scaffolding of the study. We foreground theory that is directly aligned with the research problem—how instructor characteristics shape changes management and educational innovation—rather than a catalogue of technologies. We first set out socio-technical systems theory as the organizing lens (Section 2.1); we then develop the social subsystem, i.e., instructor characteristics and change management (Section 2.2); the structural subsystem and models of innovation adoption (Section 2.3); and the technical–pedagogical subsystem, i.e., how emerging technologies are enacted in instruction (Section 2.4). A comparative international perspective is provided in Section 2.5,

and the section closes with a set of testable propositions (Section 2.6). Throughout, socio-technical systems theory serves as the primary explanatory framework of the study. Rogers' Diffusion of Innovations and the Unified Theory of Acceptance and Use of Technology (UTAUT) are employed as auxiliary models accounting for structural and command-influence dynamics, while Argyris and Schön's organizational-learning theory and the SECI model are employed as auxiliary models accounting for how instructors convert operational experience into structured pedagogical knowledge.

2.1. Socio-Technical Systems Theory as the Organizing Lens

Socio-technical systems theory conceptualizes an organization as the interaction of a social subsystem (people, their skills, attitudes, relationships, and values) and a technical subsystem (tools, techniques, and the tasks they perform). Its central tenet is joint optimization: sustainable performance is achieved only when the two subsystems are designed together, because a change in one imposes requirements on the other. A complementary formulation is Leavitt's diamond, in which task, people, technology, and structure are interdependent, so that intervention in any one node reverberates through the others [13]. Applied to a military academy, this implies that introducing a simulation or AR system (technical) without correspondingly developing instructor competence (social), adapting approval and scheduling procedures (structural), and redesigning the lesson (pedagogical) will predictably underperform. STS theory thus reframes the research problem: the dependent phenomenon is not technology adoption per se but the degree of alignment among subsystems, and the instructor is the boundary role through which alignment is achieved or lost. It must be emphasized that this framework prescribes no rigid, universal, or closed architecture. Consistent with open socio-technical systems theory [14], the subsystems operate as heuristic lenses whose internal components and boundary interactions configure dynamically according to the institutional environment; the components of a system and their interrelations vary, sometimes substantially, across institutions and cannot be specified in advance as a fixed inventory. Within a military academy, hierarchical and doctrinal specificities produce couplings that differ materially from those observed in civilian higher education, and the framework is therefore applied here as an analytical orientation rather than as a closed model of system components.

This lens carries three analytic commitments that structure the study. First, innovation is treated as emergent from subsystem interaction rather than caused by any single factor. Second, barriers and enablers are read as symptoms of misalignment or alignment between subsystems rather than as isolated obstacles. Third, because interviews capture participants' construals of their system, all claims are framed as perceived relationships—an epistemic stance we maintain throughout the results and discussion. A note on operationalization is required at this point. Although STS theory posits four interrelated subsystems—social, technical, structural, and pedagogical—the empirical design of this study examines them across three integrated analytical axes: (a) the individual/social axis, (b) the structural/organizational axis, and (c) the technical-pedagogical axis. The technical and pedagogical subsystems are analysed jointly because, under the STS commitment stated above, technological artefacts acquire educational meaning only through the pedagogical tasks and curricular contexts in which they are enacted; separating them would presuppose precisely the exogeneity this study rejects. All four subsystems are nevertheless traced individually and consistently from the framework through the results to the discussion.

2.2. The Social Subsystem: Instructor Characteristics and Change Management

Educators are central to the advancement of educational innovation [15]. As lifelong learning becomes a professional necessity, effective teaching extends beyond the classroom

and exerts a durable influence on learners' orientation to further learning [15–17]. Prior learning experiences—shaped heavily by educators' attitudes and instructional methods—condition learners' motivation [18], and instructors who emphasize mere knowledge transmission tend to induce surface learning, whereas those who conceive teaching as facilitating understanding foster deeper strategies [16,19]. Instructor conceptions of teaching therefore substantially shape learning outcomes.

Within the change-management literature, several instructor attributes recur as enablers of innovation: organizational preparedness, instructional clarity, audience engagement, openness to criticism, and technological fluency [20]. Motivation to innovate may be driven by the pursuit of professional recognition, the desire to improve student learning, and the need for equity and esteem [21], and innovation is in turn associated with professional growth and classroom improvement [22]. To sustain innovation, a “rational competency structure” is required, integrating theoretical grounding, critical questioning of the status quo, and practical verification of assumptions through instruction [23]. From an STS standpoint these attributes constitute the **social subsystem's readiness** to be jointly optimized with technology.

Two established organizational-learning theories sharpen this account. Argyris and Schön's distinction between **single-loop and double-loop learning** [24] identifies the instructor's capacity to question underlying assumptions—not merely correct errors—as decisive for genuine reform; the instructor who operates only in single-loop mode reproduces existing practice even when equipped with new tools. Nonaka and Takeuchi's **SECI model** of organizational knowledge creation (socialization, externalization, combination, internalization) frames the instructor as the agent who converts tacit operational experience into explicit, teachable knowledge and back again [25]. Effective change management, on this view, depends on cultivating a culture that promotes learning, knowledge exchange, and stakeholder commitment [26]. In military academies specifically, instructors act as essential agents who translate strategic and technological advances into applicable educational processes, and whose professional experience, leadership, and pedagogical proficiency materially affect the success of reform [3,7]. Managing change here entails a shift from procedural execution to strategic problem-solving—the instructor as a “translator” of strategic problems operating in double-loop mode [1,27].

2.3. The Structural Subsystem: Innovation Adoption in a Hierarchical Organization

The structural subsystem—hierarchy, bureaucracy, resourcing, and policy—determines the conditions under which the social and technical subsystems can be coupled. Two adoption theories are pertinent. Rogers' Diffusion of Innovations [28] identifies the perceived attributes of an innovation (relative advantage, compatibility, complexity, trialability, observability) and the role of organizational context in the rate of adoption; it also cautions that designing for early adopters is insufficient and that the needs of the majority must be addressed. The Technology Acceptance Model (TAM) [29] and its organizational extension UTAUT [30] locate adoption in perceived usefulness and ease of use, moderated by facilitating conditions and social influence—variables that, in a rank-based institution, are strongly shaped by explicit command endorsement. These models explain why, in military settings, model suitability alone is inadequate: successful adoption additionally requires leadership support, strategic implementation planning, and attention to the majority of users rather than only enthusiasts [31].

Effective educational models in military academies should thus be grounded in blended and experiential designs that enhance cognitive autonomy, reflection, and adaptability, and must be structurally integrated with existing practice and aligned to organizational culture [27]. The uncritical insertion of technology without a pedagogical framework

risks the “dehumanization” of education and over-reliance on automation [27]. Instruments such as the Systemic Approach to Training (SAT) institutionalize innovation at the procedural level by providing a structured methodology for designing training activities [32], illustrating how the structural subsystem can be configured to enable rather than obstruct innovation. In STS terms, hierarchy and bureaucracy are **dual-valent**: rigid and unguided, they impede adoption; furnished with clear strategic direction, resources, and support, the same structures stabilize and scale it.

2.4. The Technical–Pedagogical Subsystem: Enacting Emerging Technologies in Instruction

We now turn to the technical subsystem, but treat it strictly as it is enacted pedagogically, consistent with the STS commitment that tools have effects only through the tasks and people that mobilize them. Teaching with emerging technologies can act as a catalyst for professional growth and reflective practice: designing and delivering VR courses has been shown to foster classroom innovation [33], and engaging instructors with varied emerging technologies improves both competence and perceived need for innovative applications [34]. Technological adaptation is argued to be a core performance criterion in military training rather than a superficial intervention [35], and the integration of AR/VR has been associated with perceived improvements in training efficiency and resource use, reported within a single institutional application and presented by its authors as indicative rather than as generalizable effect estimates [35]. These findings suggest a reciprocal relationship in which emerging technologies catalyse educational transformation while pedagogical advances improve the return on defence training.

The alignment between the technologies theorized and those examined is made explicit here. Of the broad technology space discussed in the military-education literature—machine learning, VR/AR, ICT, the Internet of Things and big data, and MOOC (Massive Open Online Course)/SPOC (Small Private Online Course) delivery models [36]—this study foregrounds the subset that (a) recurs across the reviewed literature as pedagogically consequential and (b) is present in the HNCOA operational and curricular context: simulation and VR/AR, drones, AI-assisted adaptive instruction, and cybersecurity training.

The remaining technologies are retained as contextual background (Sections 2.4.1–2.4.4) rather than as objects of the empirical inquiry, and the interview protocol was scoped accordingly. This explicit scoping aligns the theoretical treatment of technology with the empirical design of the study.

2.4.1. Machine Learning

Machine learning (ML) is displacing manual processes with greater efficiency and precision across education, research, healthcare, transport, and defence [37], and is applied in military settings to data exploration, autonomous transport, surveillance, and decision support [38]. Because ML deployment bears directly on national and international security, each application is subject to certification and approval [39]—a structural constraint that shapes how, and how quickly, it can enter the curriculum. ML is treated here as contextual background rather than a primary object of the interviews.

2.4.2. Virtual and Augmented Reality

VR has become a pivotal innovation across sectors, enabling experimental scenarios and equipment that overcome the limitations of conventional tools, sustain engagement, and improve practical comprehension through immersive experience [40,41]. It merges practical application with theoretical instruction and transcends spatial and temporal constraints, materializing operational contexts before the learner [42]. In military academies, VR can strengthen competencies for contemporary operational settings and enrich instruction on new technologies [43]; however, it functions as an economical complement rather

than a substitute, since unforeseen events in real scenarios remain difficult to replicate and integration with live practice is required [44]. VR/AR is, together with simulation, a primary object of the present study.

2.4.3. Information and Communication Technologies

ICTs are increasingly integral to instruction [45]. Design-oriented tools support the creation of infographics, presentations, and interactive materials that enhance teaching and learning efficiency. More broadly, advancing military and academic education requires modern information systems that foster collaboration and innovation, a demand intensified by the diffusion of the IoT and big data [46]. ICT is treated as enabling infrastructure across all examined technologies.

2.4.4. Internet of Things and Big Data

The rapid digitization of information has driven the proliferation of IoT and big data across domains, with an attendant need to transform education using information technology, particularly in military training. ICT provision in military academies can be analysed along platform, architecture and security, and data-application dimensions [47], with the objective of a secure, dependable, and well-governed online learning platform offering high-quality shared resources [27]. Given the disciplinary specialization and stringent operational oversight of the military academy, terminal devices and classification models must satisfy strict security requirements while minimizing cost, as illustrated by SPOC (Small Private Online Course) platforms that integrate instructional systems, resources, and learner support [47]. IoT/big data are retained as contextual background.

2.5. Comparative International Perspective

Situating the HNCOA case within international practice strengthens the external relevance of the findings. Across NATO and partner systems, military academies have pursued convergent but structurally distinct paths to educational innovation. Intent-based leadership models emphasize decentralized initiative as a precondition for pedagogical change [31]; several higher military education systems have formalized the introduction of classroom technologies through structured instructional-design methodologies [32,48]; and technology education at established service academies has long integrated cybersecurity and systems thinking into the core curriculum [45]. Studies of VR-based training across national armies report broadly consistent gains in engagement and skill acquisition while noting persistent limitations in transfer to unpredictable conditions [40–44]. What varies is less the technology than the structural configuration, the degree of curricular autonomy, the length of approval chains, and the institutionalization of instructor development. This cross-national pattern is itself an STS observation: comparable technical subsystems yield divergent innovation outcomes because the social and structural subsystems differ. It also frames the contribution of the present study, which examines a non-commissioned officer academy—an under-represented tier in a literature dominated by officer-commissioning institutions.

2.6. Study Propositions

From the framework we derive four propositions that guide the analysis and are revisited in the discussion. They are stated as perceived relationships, consistent with a qualitative, interview-based design:

1. **P1 (social readiness).** Instructors perceive their own technological competence, openness to change, and continuing professional development as the primary levers enabling educational innovation.

2. **P2 (structural valence).** Instructors perceive hierarchy, bureaucratic approval chains, and lack of specialization as the dominant constraints, but perceive the same structures as enablers when accompanied by explicit direction, resources, and support.
3. **P3 (joint optimization).** Instructors perceive technology alone as insufficient for innovation; perceived benefit arises when technical capability is coupled with instructor development, institutional support, and alignment to operational tasks.
4. **P4 (task alignment).** Instructors perceive technologies as valuable to the extent that they are aligned with authentic military tasks and operational requirements, rather than adopted for their novelty.

Each proposition is anchored to a specific subsystem of the framework, and this mapping is carried forward into the conceptual model (Figure 1) and into the interpretation in Section 5. P1 addresses the social subsystem and concerns instructor readiness; P2 addresses the structural subsystem and concerns the dual valence of hierarchy and bureaucratic approval; P3 addresses the joint optimization of the technical–pedagogical subsystem with the social and structural subsystems; and P4 addresses the alignment of the technical subsystem with authentic operational tasks.

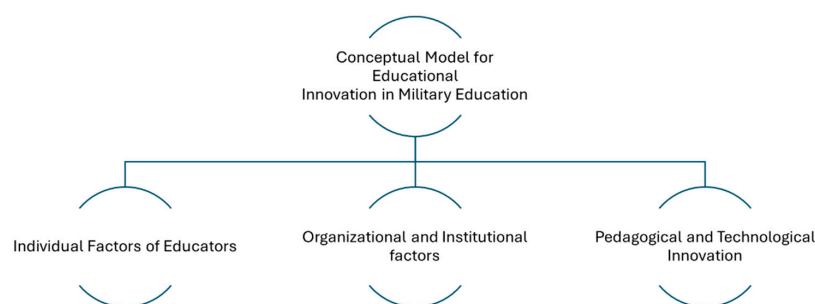


Figure 1. Conceptual model for integrating innovation in military education, structured as three interdependent socio-technical axes.

3. Materials and Methods

3.1. Conceptual Framework/Research Framework

The conceptual model (Figure 1) operationalizes the socio-technical framework of Section 2. It represents educational innovation in military education as emerging from the interaction of three interdependent axes—an arrangement consistent with joint optimization and with Leavitt’s interdependence of people, technology, and structure [13], and consistent with the three-axis operationalization of the four theoretical subsystems set out in Section 2.1. The three axes are:

- (1) Individual factors of educators (the social subsystem)—teaching clarity, pedagogical adaptability, technological proficiency, and openness to change, which condition the capacity to integrate innovative methods and tools;
- (2) Organizational and institutional factors (the structural subsystem)—bureaucratic structure, administrative culture, innovation policy, and leadership support, which act as enablers or impediments to the transfer and implementation of new knowledge;
- (3) Pedagogical and technological innovation (the technical–pedagogical subsystem)—the integration of AR/VR, drones, cybersecurity, and simulators into active, experiential learning. Innovation is modelled not as a technological enhancement but as a transformative process emerging from the alignment of the three axes. The social subsystem is not absent from this arrangement: it is carried by the first axis and remains the locus of instructor agency throughout the analysis, while the technical and pedagogical subsystems are represented jointly in the third axis for the reasons given in Section 2.1.

3.2. Research Design and Methodology

A qualitative design using structured, open-ended interviews was adopted to investigate instructors' perceptions of change management and the enactment of educational innovation at the HNCOA. A qualitative approach was appropriate because the research problem concerns meaning, experience, and perceived relationships within a tightly hierarchical and institutionally regulated setting—phenomena best accessed through participants' own accounts. The design aims to identify the factors that instructors perceive to promote or hinder innovation and the ways they recognize and enact new technologies in teaching. Consistent with the STS lens and with the study's epistemic stance, the design is explicitly interpretive: it captures perceptions and construals, not measured effects on learning outcomes.

Because participants were interviewed within their own hierarchical institution, the risk of social-desirability bias required explicit management. Participation was voluntary and revocable at any point; interviews were conducted in a confidential setting without the presence of supervising officers; transcripts were anonymized before analysis; and no institutional evaluation, reporting, or career consequence was attached to participation. Coding was additionally cross-checked between researchers in order to limit the influence of any single interpretive standpoint. These measures mitigate but do not eliminate the bias, and the findings are accordingly reported as instructors' accounts rather than as verified descriptions of institutional practice.

Reflexivity and positionality. The research team occupies a combined insider–outsider position. One author is affiliated with the military educational system and is familiar with its rank structure, terminology, and instructional routines; the remaining author is located in civilian higher education and held no line-management relationship with any participant. This configuration facilitated access and contextual understanding while introducing the risk that hierarchical authority would shape participants' responses. To mitigate this risk, interviews were conducted by the researcher holding no command authority over the participants, institutional role and rank were not foregrounded during data collection, and analytic memos were maintained throughout in order to surface the team's prior assumptions regarding bureaucracy and instructor agency. Interpretations were deliberately contested between the insider and outsider perspectives before codes were finalized.

Analysis followed Codebook Thematic Analysis, conducted in the six phases specified by Braun and Clarke [49] and summarized in Figure 2: (1) familiarization with the data; (2) generation of initial codes, with semantically related units identified and grouped; (3) searching for themes by collating codes into candidate themes and subthemes; (4) reviewing themes against both the coded extracts and the full dataset to confirm coherence and eliminate redundancy; (5) defining and naming themes, delineating the scope of each and mapping the smaller theme clusters onto three thematic axes aligned to the research questions; and (6) producing the analytic account. Coding was performed manually with constant reference to the primary data. The analytic approach is positioned within the codebook (template) tradition of thematic analysis rather than within fully reflexive thematic analysis [50,51]. This positioning is deliberate and resolves an epistemological tension between the two traditions: because the study applies a structured, theory-informed coding template, reports frequency prominence across participants, and employs collaborative cross-checking, the codebook designation is the methodologically consistent one. To strengthen dependability, both researchers first coded a subset of transcripts independently using the preliminary socio-technical coding template, then compared code assignments, examined semantic discrepancies, and refined code definitions iteratively until consensus was reached. This cross-checking was employed to enrich contextual interpretation and to

limit individual bias, not to generate a quantitative inter-rater statistic, which would be inconsistent with the interpretive aims of the design. The analysis yielded three primary thematic axes and, at the question level, four code hierarchies reported in Section 4.

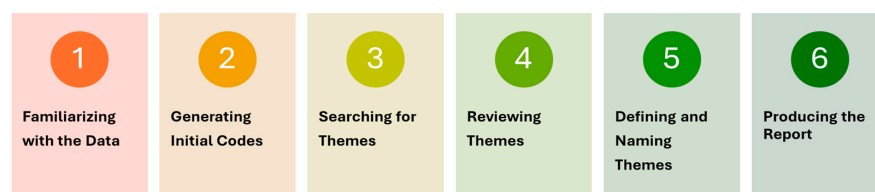


Figure 2. The six phases of Codebook Thematic Analysis (adapted from Braun & Clarke).

3.3. Participants and Sampling

Participants were selected through purposive sampling to cover the four instructional domains of HNCOA education—military, academic, technical, and physical training—and to include both permanent and adjunct (hourly-compensated) staff with varied experience and specialization. The final sample comprised 22 instructors. This heterogeneity supported the collection of diverse perspectives on the acceptance, enactment, and obstruction of educational innovation and improved the credibility of the findings by spanning different backgrounds and levels of technological proficiency. Sampling adequacy was assessed in terms of information power rather than statistical representativeness [52]. The sample carries high informational density because purposive selection spanned all four instructional branches of the HNCOA—military tactics, academic education, technical engineering, and physical training—and included both permanent military cadre and civilian adjunct faculty, thereby covering differing ranks, professional backgrounds, and technological specializations. Thematic saturation was monitored during coding and was reached by the eighteenth interview, after which the remaining transcripts yielded no new codes and no disconfirming categories concerning institutional barriers or technological enactment. The study therefore claims analytical and conceptual generalizability rather than generalization to a population.

Table 1 summarizes the composition of the sample by role, staff type, instructional domain, and years of experience.

Table 1. Demographics.

Participant Code	Institutional Role	Staff Classification	Domain of Instruction	Years of Experience
P1	Instructor	Permanent Military Cadre	Military Tactics/Field Training	14
P2	Instructor	Permanent Military Cadre	Military Tactics/Field Training	18
P3	Instructor	Permanent Military Cadre	Weapon Systems & Ballistics	11
P4	Instructor	Civilian Adjunct Faculty	Academic (Mathematics & Ballistics)	6
P5	Instructor	Civilian Adjunct Faculty	Academic (Informatics & AI)	9
P6	Instructor	Civilian Adjunct Faculty	Technical/Telecommunications	8
P7	Instructor	Civilian Adjunct Faculty	Technical/Electronics Engineering	15

Table 1. Cont.

Participant Code	Institutional Role	Staff Classification	Domain of Instruction	Years of Experience
P8	Instructor	Civilian Adjunct Faculty	Technical/Mechanical Engineering	12
P9	Instructor	Permanent Military Cadre	Physical Training & Obstacle Course	10
P10	Instructor	Permanent Military Cadre	Physical Training & Combat Conditioning	17
P11	Instructor	Civilian Adjunct Faculty	Applied Military Computing & Cyber	7
P12	Instructor	Civilian Adjunct Faculty	International Relations & Military Law	11
P13	Instructor	Permanent Military Cadre	Military Tactics & Field Exercises	13
P14	Instructor	Permanent Military Cadre	Small Unit Operations	16
P15	Instructor	Permanent Military Cadre	Military Topography & GIS	12
P16	Instructor	Civilian Adjunct Faculty	Academic (Applied Physics)	8
P17	Instructor	Civilian Adjunct Faculty	Academic (English for Defense)	5
P18	Instructor	Civilian Adjunct Faculty	Technical/Armament Technology	14
P19	Instructor	Civilian Adjunct Faculty	Technical/Automotive Systems	9
P20	Instructor	Permanent Military Cadre	Physical Training & Survival Skills	15
P21	Instructor	Civilian Adjunct Faculty	Technical/Tactical Cyber Defense	6
P22	Instructor	Permanent Military Cadre	Leadership & Staff Procedures	19

Note: Bold formatting denotes participant identification codes.

3.4. Data Collection

Data were collected through structured interviews during September–October 2025. Each interview lasted 45–60 min and was conducted in person in a prepared, confidential location on the premises of the Academy to assure participants' comfort and candour. Although structured interviews are often used quantitatively, they are equally suited to qualitative inquiry when the questions are open-ended; posing questions in a fixed sequence facilitates comparison across participants within a common frame while still allowing rich, exploratory responses [53]. The protocol comprised 12 open-ended questions organized around five thematic axes:

1. Determinants that obstruct or promote educational innovation;
2. The influence of innovation on the improvement of educational practice;
3. Use of technologies (ICT, AI, VR/AR, simulators)—scoped, as justified in Section 2.4, to the subset present in the HNCOA context;
4. Training requirements and modalities of collaboration;

5. Perspectives on change management and participation in research initiatives.

Due to institutional regulations, national security considerations, and the sensitive military nature of the training context, the exact verbatim phrasing of the 12 interview questions is restricted from public dissemination. A structurally abstracted mapping of the interview protocol framework, describing each inquiry axis and the questions assigned to it, is therefore provided in Appendix A.

All interviews were recorded with participants' informed consent and transcribed verbatim to preserve authenticity and support analytic reliability. Interviews were conducted in Greek, the working language of all participants. Recordings were transcribed verbatim in Greek and coding was performed on the Greek transcripts in order to preserve semantic nuance. The illustrative extracts reported in this article were rendered into English through a forward–backward translation procedure: an initial translation was produced, independently back-translated into Greek by a second researcher, and any discrepancy was reconciled against the original transcript before the extract was finalized.

3.5. Ethical Considerations

Ethical approval was granted by the Research Ethics and Deontology Committee of the University of Western Macedonia (ΕΗΔΕ-ΠΔΜ) under Protocol No. 215, and institutional permission for data collection on the premises was granted by the Hellenic Army NCO Academy. Participants were informed of the study's objectives and methods and provided written consent. Anonymity, confidentiality, and voluntary participation were rigorously maintained, and all identifying information was removed prior to analysis.

4. Results

The analysis produced three thematic axes—institutional constraints, technological factors, and educational practices—which operationalize the four subsystems of the framework: the structural subsystem, the technical and pedagogical subsystems analysed jointly as set out in Section 2.1, and the social subsystem, which is carried by instructors' reported attributes, competencies, and professional development and is reported principally under RQ2 (Figure 3). Across these axes, the interviews yielded four question-aligned code hierarchies: (a) Factors Impeding Enactment (RQ4, RQ2); (b) Perceptions of Educational Innovation and its principal domains of application (RQ1); (c) Emerging Technologies and Pedagogical Enactment (RQ3); and (d) Collaboration and Professional Readiness (RQ2, RQ4). These four hierarchies are reported together in Table 2. Throughout, findings are reported as instructors' perceptions; claims about effects on learning or readiness are attributed to participants rather than asserted as demonstrated outcomes.

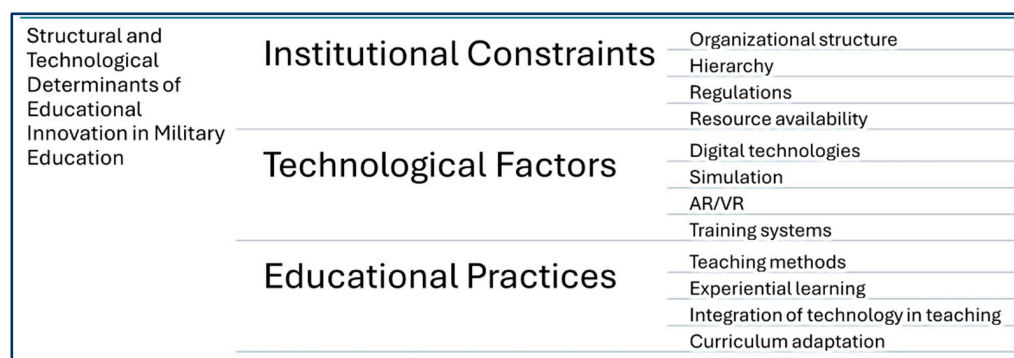


Figure 3. Thematic map of emerging categories across socio-technical subsystems.

Table 2. Code hierarchies and participant frequency distribution (n out of N = 22 participants articulating each code).

Thematic Axis	Question-Aligned Code Hierarchy	Key Nodes/Concepts	Participants Articulating the Code (n out of N = 22)
Institutional Constraints	Factors Impeding Enactment	Lack of specialization among staff	19
		Bureaucratic approval processes	18
		Hierarchical environment	15
Technological Factors	Emerging Technologies & Pedagogical Enactment	Drones in military training	17
		Simulation-based systems	16
		VR/AR training environments	14
Educational Practices	Perceptions of Educational Innovation	Enhanced learning motivation	15
		Technology-based curriculum adaptation	13
		AI-supported adaptive learning	9
Social/Professional Readiness	Collaboration & Professional Readiness	Technological familiarity and adaptability	19
		Continuing professional development	16
		Collaboration with external institutions	15

4.1. RQ1—Instructors' Perceptions and Experiences of Educational Innovation

Instructors construed educational innovation primarily in terms of technological integration and its perceived influence on engagement and training efficacy, most saliently in the military and academic domains. Participants reported that new courses and tools can markedly raise student engagement. One instructor observed, “Students exhibit heightened interest when simulators are employed; they perceive it as a real-life scenario” (P9). Another emphasized adaptivity: “Artificial intelligence enables us to customize courses according to each learner’s pace” (P5). A third linked innovation to employability: “Courses incorporating drones, virtual reality, and cybersecurity equip students with skills that are immediately applicable in the field” (P11). These accounts indicate that instructors perceive innovation as a means to strengthen experiential learning, motivation, and the practical relevance of training. Figure 4 presents the code hierarchy, in which technological integration, student participation, and the modernization of pedagogical practice dominate. The distribution shown in Figure 4 is itself analytically informative. The dominant blocks—the integration of digital tools and the use of simulation technologies—indicate that instructors construe innovation not as an abstract pedagogical doctrine but as concrete, experiential training instrumentation tied to the tasks their students will perform. The smaller peripheral blocks, notably AI-supported adaptive learning and drone and cybersecurity applications, denote emerging and highly specialized domains that participants recognized as consequential but did not describe as embedded in routine curricular practice, and which would therefore require tailored curricular accommodation rather than incremental adoption.

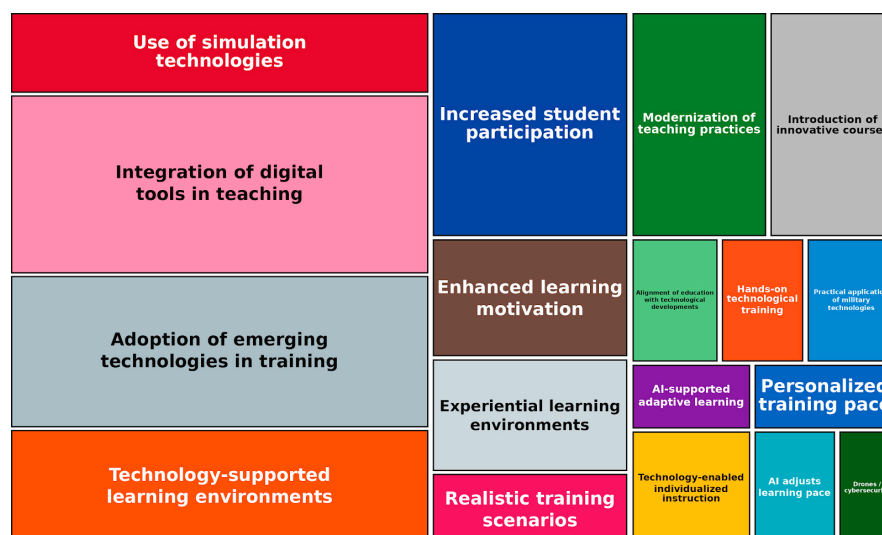


Figure 4. Codes' hierarchy for the 1st research question (RQ1: perceptions of educational innovation). Block area is proportional to the number of participants (n out of $N = 22$) who articulated each code.

4.2. RQ2—How Instructor Characteristics Condition Change Management

Participants identified instructor attributes as decisive for whether innovation is adopted or resisted, with technological competence, openness to change, and continuing professional development named as the critical determinants—directly supporting P1. Dispositions varied: some instructors reported apprehension—“There are educators who fear that technology will outpace them; they require continuous support” (P6)—while others stressed the sufficiency of training—“With adequate training, the majority of educators are favourable towards employing new methods” (P8). Alongside these social factors, participants foregrounded structural constraints consistent with P2: the specificity of the military environment—“the military environment is stringent; innovation occurs only when there is explicit direction; otherwise individuals hesitate” (P4)—and bureaucratic load—“bureaucracy impedes any change; even when we wish to implement something novel, it requires numerous approvals” (P2). Time scarcity for professional development was also noted: “educators do not always have the time to learn new technologies, so they often adhere to more traditional methods” (P7).

Figure 5 orders these codes by prominence. The largest cluster concerns instructors' technological competence—familiarity with tools, capacity to integrate them, and adaptability—perceived as the primary enabler of change. The second concerns continuing professional development, with participants stressing that new methods require structured training and institutional backing to build confidence. A third cluster, openness to innovation, indicates that attitudes materially shape the efficacy of change efforts. The map also surfaces structural impediments—bureaucratic processes, hierarchical frameworks, and the absence of specialization—and smaller but notable codes on technology anxiety and time constraints. Read through the framework, RQ2 shows the social subsystem's readiness and the structural subsystem's constraints being weighed jointly by instructors. The visual weight of the technological-familiarity cluster in Figure 5 is the empirical signature of P1: instructors locate the decisive enabling lever in their own digital competence and in structured professional development rather than in the technology itself. Set against this, the prominence of the structural blocks—bureaucratic procedures and the absence of staff specialization—shows that the same participants who claim agency simultaneously identify the organizational conditions that constrain its exercise, which is the perceptual form of the dual valence developed in Section 5.2.



Figure 5. Codes' hierarchy for the 2nd research question (RQ2: instructor attributes and change management). Block area is proportional to the number of participants (n out of $N = 22$) who articulated each code.

4.3. RQ3—Enactment of Emerging Technologies in Pedagogy and Curriculum

The integration of emerging technologies was recognized as a core component of innovation within the institution. Participants highlighted drones, VR/AR, cybersecurity modules, and AI as increasingly present in the curriculum, deployed principally across three domains: military training, academic education, and technical training (Table 3). Crucially, participants described value as arising from the coupling of these tools with authentic tasks rather than from the tools themselves, supporting P4.

Table 3. Areas of application of innovation in education.

Application Domain	Indicative Technologies	Expected Outcome
Military Training	Drones, simulators, VR/AR	Realistic and safe training environment
Academic Education	AI, e-learning platforms	Personalized learning and increased motivation
Technical Training	Electronic systems, cybersecurity modules	Strengthening technical proficiency

Participants reported that these technologies allow students to experience realistic operational scenarios and acquire directly applicable skills. As Figure 6 shows, drones, simulation systems, and VR/AR environments appear most prominently, reflecting their perceived role in creating realistic training conditions; cybersecurity and electronic-systems training underline the weight given to technical competencies; and AI and digital platforms, though smaller, are associated with personalized and flexible delivery. The distribution mirrors the scoping justified in Section 2.4, closing the theory–design alignment gap.

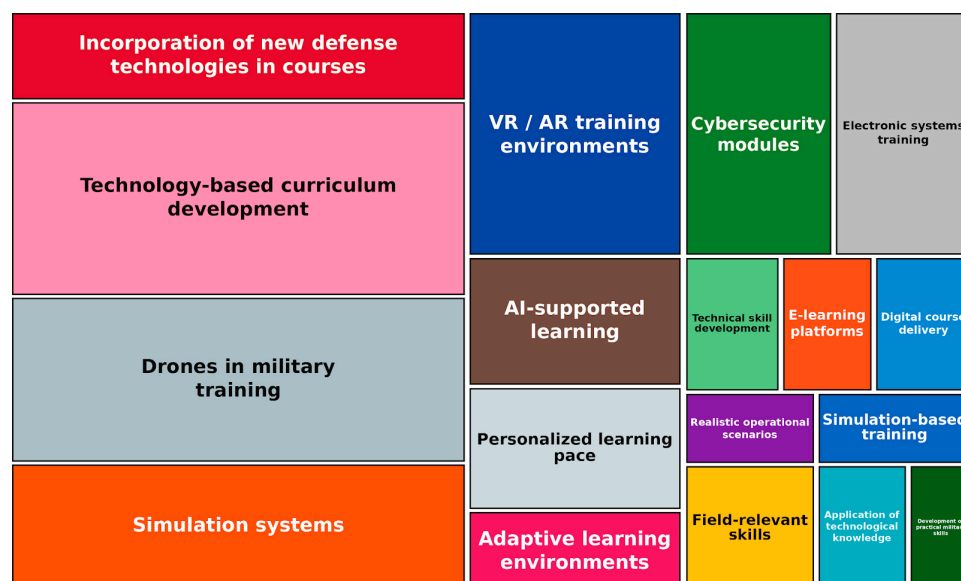


Figure 6. Codes' hierarchy for the 3rd research question (RQ3: technologies enacted in pedagogy and curriculum). Block area is proportional to the number of participants (n out of $N = 22$) who articulated each code.

4.4. RQ4—Barriers and Opportunities Across the Subsystems

Participants identified multiple perceived barriers, dominated by the absence of specialization among instructors, bureaucratic processes, and the particular character of the military context—"The military environment is stringent; innovation occurs only with explicit directives; otherwise individuals hesitate" (P4); "Bureaucracy impedes any change; even when we wish to implement something novel, it necessitates numerous approvals" (P2); "Educators frequently lack the time to acquire new technologies, resulting in a reliance on more conventional methods" (P7). Opportunities were located chiefly in external collaboration and institutional support. Cooperation with foreign polytechnics, universities, and military institutions was valued for the exchange of expertise. Collaboration with universities provides us access to technologies unavailable at the Academy" (P3). Staff dispositions again varied between apprehension (P6) and conditional readiness given adequate training (P8).

Figure 7 orders these codes. The largest blocks represent structural impediments—lack of specialization, limited technological competence, and bureaucratic processes—identified as the principal barriers, followed by rigid organizational culture, hierarchy, and restricted development time. Opportunities cluster around external engagement, institutional support systems, and continuous instructor training. When RQ4 is read against the framework, barriers concentrate in the structural subsystem while enablers require deliberate coupling across subsystems—the empirical signature of P2 and P3.

To provide a transparent overview of the analytical depth, Table 2 synchronizes the extracted thematic axes, their respective code hierarchies, and the number of individual participants (n out of $N = 22$) who articulated semantic units corresponding to each thematic code. The reported values are participant counts, not raw counts of coded text fragments: a code mentioned repeatedly by a single participant contributes one count. The same metric governs the block areas of the treemaps in Figures 4–7.

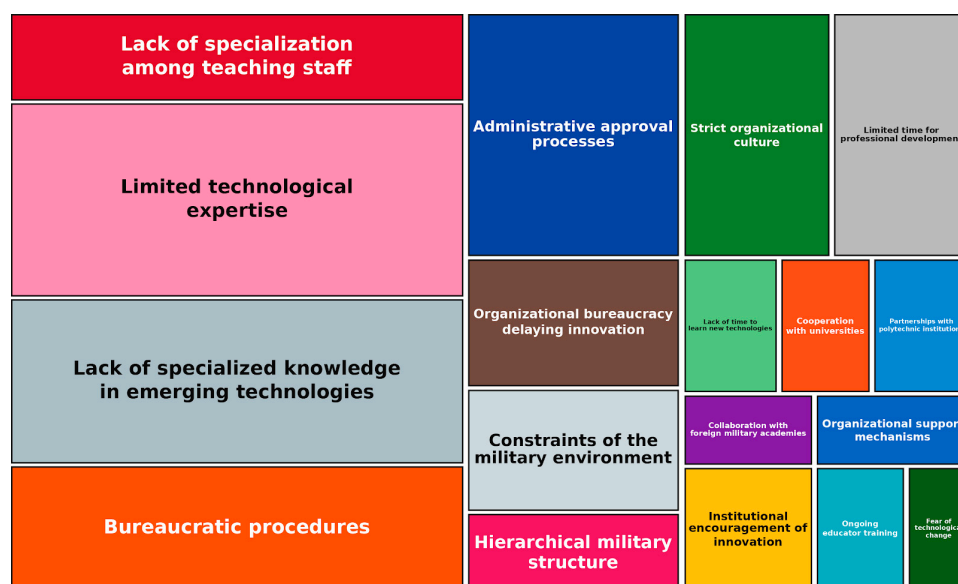


Figure 7. Codes' hierarchy for the 4th research question (RQ4: barriers and opportunities, mapped to subsystems). Block area is proportional to the number of participants (n out of $N = 22$) who articulated each code.

4.5. Cross-Question Synthesis

Integrating the four hierarchies produces a coherent socio-technical account. The social subsystem (RQ2) supplies the primary levers—competence, openness, and development—while the structural subsystem (RQ4) supplies the dominant constraints—hierarchy, bureaucracy, and non-specialization. The technical–pedagogical subsystem (RQ1, RQ3) is perceived to deliver benefit only when its tools are coupled with instructor development and authentic tasks. Two participant statements crystallize the pattern: “technology alone does not affect change; it necessitates a culture of collaboration and managerial support” (P12), and “when we connect technologies to actual military needs, then innovation is justified” (P10). These directly instantiate P3 and P4 and frame the discussion that follows.

5. Discussion

The findings are interpreted here through the socio-technical framework and its four propositions. We stress that they represent instructors' perceptions; the study does not measure innovation's effect on learning outcomes, operational readiness, or training quality, and the discussion is calibrated accordingly. The discussion is organized around the four propositions but is not confined to confirming them: each subsection also identifies the points at which the findings qualify, bound, or extend the theories mobilized.

5.1. Social Readiness as the Primary Lever (P1)

Instructors consistently located the primary capacity for change in their own attributes—technological competence, openness, and continuing development—corroborating the change-management literature on organizational readiness and pedagogical effectiveness [54] and the view that the quality of reform is contingent on the composition and competencies of the teaching staff [23]. The absolute prominence of continuing professional development highlights the role of the military instructor as a core agent of change. Viewed through the organizational learning lens of Argyris and Schön [24], the instructors' emphasis on challenging traditional administrative approval workflows signals a transition from single-loop correction (doing the same things better within established rules) to double-loop transformation, wherein the foundational assumptions governing military instruction are fundamentally questioned and renegotiated.

Furthermore, this dynamic heavily instantiates the SECI model of Nonaka and Takeuchi [25]. In highly institutionalized academies like the HNCOA, vital operational knowledge often resides as tacit—embedded in the practical field experience and leadership instincts of seasoned permanent staff. Educational innovation becomes a systemic spiral: through socialization (co-working and mentoring) and externalization (translating tactical maneuvers into instructional design), instructors convert this tacit military capability into explicit, codified teaching modules (such as simulation scenarios or drone handling manuals). Instructors further described the combination of this codified material with modern ICT infrastructures. The final internalization stage, which concerns students' acquisition of tacit competence, was not observed in this study, since students were not part of the empirical sample; it is reported here only as the outcome that instructors anticipate. The instructor, therefore, operates as the structural bridge of knowledge conversion, supporting proposition P1 by indicating that instructors perceive their own cognitive agility as a necessary and co-dependent component of systemic readiness rather than as its sole determinant, since the structural and technological conditions documented under RQ4 bound what that agility can achieve.

5.2. *The Dual Valence of Structure (P2)*

Consistent with adoption theory [55] and with participants' accounts, hierarchy and bureaucracy were perceived as the dominant barriers, yet the same structures were seen as enablers when accompanied by explicit direction, resourcing, and support. This dual valence is the STS claim that structure must be jointly configured with people and technology rather than removed; instruments such as SAT show how procedural structure can institutionalize innovation [32]. The perceived need for command endorsement aligns closely with the social-influence and facilitating-conditions constructs of UTAUT (Unified Theory of Acceptance and Use of Technology), which are amplified in rank-based organizations. Proposition P2 is supported, but the finding simultaneously qualifies the theory it invokes. In UTAUT, social influence and voluntariness of use are modelled as attributes of an individual's decision environment; in a rank-based academy these constructs acquire an authoritative rather than a discretionary character, since adoption may be mandated through the chain of command irrespective of an instructor's perceived usefulness or ease of use. In this setting the explanatory work is therefore performed less by individual acceptance than by the institutional legitimacy conferred on a technology, which suggests that acceptance models require an explicit command-legitimacy construct when they are transferred to hierarchical public organizations.

5.3. *Joint Optimization and Task Alignment (P3, P4)*

The most theoretically significant result is that instructors perceived technology as insufficient in itself: benefit was reported to emerge only when technical capability was coupled with instructor development, institutional support, and authentic tasks—"technology alone does not affect change" (P12); "when we connect technologies to actual military needs, then innovation is justified" (P10). This is a direct, if perceptual, endorsement of joint optimization (P3) and task alignment (P4). It aligns with evidence that teaching emerging technologies catalyses professional growth [33,56], that technological adaptation is a core performance criterion rather than a superficial intervention [34], and that AR/VR can support measurable gains when embedded in realistic tasks [35], while also cohering with the caution that technology without a pedagogical framework risks surface learning and dehumanization [27]. The comparative perspective (Section 2.5) reinforces the point: similar technical subsystems yield divergent outcomes across national systems precisely because their social and structural subsystems differ. These results also mark a boundary

condition for classical socio-technical systems theory. The tradition's formative studies were conducted in industrial and civilian work settings in which semi-autonomous groups could redesign their own tasks, so that joint optimization was something participants could themselves enact. In a military academy, curricular authority, procurement, and scheduling are reserved to the command structure, with the consequence that instructors can identify misalignment but cannot resolve it. Joint optimization here is therefore not a self-organizing property of the work system but a decision that must be taken at a higher structural level and delegated downward—an extension of STS to hierarchically closed organizations that the original formulation does not address. The same boundary constrains organizational learning: participants described questioning established assumptions, yet the regulations governing syllabus approval confine most of that questioning to single-loop optimization unless a formal mechanism grants pedagogical discretion. Double-loop learning in this setting appears to depend less on individual reflective capacity than on whether the structure supplies a sanctioned route through which assumptions may be revised.

5.4. Theoretical and Practical Contribution

Theoretically, the study reframes educational innovation in military academies from a technology-insertion problem to a problem of joint optimization and extends the empirical base to the under-represented non-commissioned officer tier. Practically, the framework yields design principles for the joint optimization of the social and technical subsystems: (i) pair every technology introduction with a structured instructor-development pathway; (ii) shorten and clarify approval chains and provide explicit command endorsement as facilitating conditions; (iii) design for the majority of users, not only early adopters; (iv) anchor technology choices to authentic operational tasks; and (v) institutionalize collaboration with external academic and military partners as a channel for knowledge transfer. These principles are offered as theory-grounded, perception-informed recommendations rather than as validated interventions.

6. Limitations and Future Research

Several limitations bound the claims of this study and define a clear agenda for future work. First, the evidence base is instructors' perceptions; interviews are well suited to surfacing perceptions, barriers, and readiness, but do not establish the actual impact of innovation on learning outcomes, operational readiness, or training quality. Accordingly, all outcome-related statements are framed as perceived rather than demonstrated. Second, the design draws on a single institution and 22 participants; while purposive sampling captured the four instructional domains, the findings are analytically rather than statistically generalizable. Third, the perspective is limited to instructors; students, curriculum artefacts, and institutional leaders were not sampled. Fourth, the study could not triangulate self-reports against direct operational evidence: access to classified syllabus annexes, tactical field assessment metrics, and operational performance evaluations is restricted under military information-security protocols, so the analysis rests on participants' accounts by institutional necessity as well as by design. Multi-institutional and survey-based studies are accordingly required in order to establish whether the patterns reported here extend beyond a single national academy.

Future research should therefore pursue **triangulation and stronger evidence**: (i) incorporate students' perspectives and measured learning results; (ii) add classroom observation and curriculum analysis to compare espoused with enacted practice; (iii) obtain expert evaluation of technology-embedded lessons; and (iv) employ longitudinal or quasi-experimental designs to test the perceived effects reported here—particularly the joint-optimization proposition (P3)—against outcome data. Comparative, multi-institution

studies across national systems would further test whether the structural configurations identified in Section 2.5 account for divergent innovation outcomes. Such designs would convert the perceptual relationships documented here into causal, cross-validated evidence.

7. Conclusions

This study examined how instructor characteristics condition the management of change and the adoption of educational innovation in a military academy, using a socio-technical systems lens. The evidence—drawn from 22 instructor interviews and analysed through codebook thematic analysis—indicates that instructors perceive educational innovation not as the installation of technology but as an emergent property of the alignment among the social, technical, structural, and pedagogical subsystems. Instructors' technological competence, openness to change, and continuing professional development were perceived as the primary levers of change (P1); hierarchy, bureaucracy, and lack of specialization were perceived as the dominant constraints, yet as potential enablers under explicit direction and support (P2); and technology was perceived as beneficial only when jointly optimized with instructor development and anchored to authentic operational tasks (P3, P4).

Three institutional measures follow directly from these findings. First, accredited and continuing faculty-development pathways in emerging defence technologies should be established for permanent and adjunct staff alike, so that the introduction of a technology is never decoupled from the development of the capability required to teach with it. Second, streamlined administrative review procedures—a dedicated board operating within a bounded decision window for educational software, simulator updates, and curricular adjustments—would reduce the approval delays that participants identified as the dominant structural barrier. Third, formalized partnerships with civilian polytechnics and universities would give the academy access to specialized infrastructure, such as virtual-reality facilities and cybersecurity testbeds, that it cannot sustain internally, while establishing a standing channel for instructor knowledge exchange.

The contribution is therefore twofold. Theoretically, the study reframes educational innovation in military academies as a problem of joint optimization and extends the empirical literature to the non-commissioned officer tier. Practically, it offers a compact set of design principles for aligning instructor development, institutional support, and technology adoption. Because the findings rest on perceptions, they are best read as hypotheses about system behaviour that future, triangulated and longitudinal designs can test against outcome data. Understood in this way, the instructor emerges as the boundary agent through whom the social and technical subsystems of military professional education are coupled—and on whose joint optimization the sustainable transformation of that education depends.

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Abbreviations

The following abbreviations are used in this manuscript:

STS	Socio-Technical Systems
HNCOA	Hellenic Army Non-Commissioned Officers' Academy
EI	Educational Innovation
ICT	Information and Communication Technologies
AI	Artificial Intelligence
VR	Virtual Reality
AR	Augmented Reality
ML	Machine Learning
IoT	Internet of Things
SAT	Systemic Approach to Training
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology

Appendix A. Interview Protocol Structural Framework

In alignment with military confidentiality agreements and defense-sector information security protocols, the specific 12 open-ended questions are categorized here by their broader structural inquiry paths:

- **Axis 1:** Driving and Restraining Factors (Questions 1–3): Evaluated participants' conceptual baseline regarding educational innovation, framing institutional facilitators alongside felt structural barriers.
- **Axis 2:** Pedagogical Evolution (Questions 4–5): Focused on how individual instructor attributes and technical familiarity actively condition shift-management in daily instructional delivery.
- **Axis 3:** Technology Enactment (Questions 6–8): Sampled experiences with specific contextualized assets (simulators, VR/AR, drones) and the structural adaptation of syllabus designs.
- **Axis 4:** Training and Peer Dynamics (Questions 9–10): Assessed requirements for permanent and adjunct continuous training and modes of intra-institutional collaboration.
- **Axis 5:** Change Management & Organizational Horizon (Questions 11–12): Explored readiness toward double-loop learning adjustments and long-term organizational transformation.

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