HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

A COMPARATIVE EVIDENCE-BASED ASSESSMENT OF TRAINING-SIMULATOR SOFTWARE AND HARDWARE: A MODULAR, HUMAN-CENTRED RESEARCH FRAMEWORK IN THE QW-18 CONTEXT

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doi:https://doi.org/10.5281/zenodo.23291317

Abstract. This article presents a comparative analysis of existing software and hardware solutions used in training simulators for man-portable air-defense system operators. The study examines the main features of the Stinger Simulator, I-STPTv2, Igla-2 Trainer, and 9F635M1 field simulator based on available technical information. Particular attention is given to simulator functionality, instructor control, virtual environments, data collection, performance assessment, and system flexibility. Based on the comparative analysis, a modular intelligent training simulator architecture for the QW-18 system is proposed. The proposed architecture consists of six interconnected functional modules organized into three main layers. The study also considers the potential application of artificial intelligence for analyzing training results and supporting individual learning. The proposed approach provides a theoretical and methodological basis for the further development and evaluation of modern training simulators.
Keywords: simulation-based education; documentary analysis; modular software; human-centred design; evidence traceability; training analytics; responsible AI; QW-18 research context.

Annotatsiya. Ushbu maqolada ko'chma havo mudofaasi tizimi operatorlari uchun o'quv simulyatorlarida qo'llaniladigan mavjud dasturiy va apparat yechimlarining qiyosiy tahlili keltirilgan. Tadqiqotda mavjud texnik ma'lumotlarga asoslanib, Stinger Simulator, I-STPTv2, Igla-2 Trainer va 9F635M1 dala simulyatorining asosiy xususiyatlari o'rganiladi. Simulyatorning funksionalligi, instruktorni boshqarish, virtual muhitlar, ma'lumotlarni to'plash, ish faoliyatini baholash va tizimning moslashuvchanligiga alohida e'tibor qaratiladi. Qiyosiy tahlil asosida QW-18 tizimi uchun modulli intellektual o'quv simulyatori arxitekturasi taklif qilingan. Taklif qilingan arxitektura uchta asosiy qatlamga ajratilgan oltita o'zaro bog'liq funktsional modullardan iborat. Tadqiqotda shuningdek, o'quv natijalarini tahlil qilish va individual o'rganishni qo'llab-quvvatlash uchun sun'iy intellektning potentsial qo'llanilishi ko'rib chiqiladi. Taklif etilgan yondashuv zamonaviy o'quv simulyatorlarini yanada rivojlantirish va baholash uchun nazariy va metodologik asos yaratadi.
Kalit so'zlar: simulyatsiyaga asoslangan ta'lim; hujjatli tahlil; modulli dasturiy ta'minot; insonga yo'naltirilgan dizayn; dalillarni kuzatish; o'quv tahlili; mas'uliyatli AI; QW-18 tadqiqot konteksti.

Аннотация. В данной статье представлен сравнительный анализ существующих программно-аппаратных решений, используемых в тренажерах для подготовки операторов переносных зенитных ракетных комплексов. Исследование рассматривает основные особенности тренажеров Stinger Simulator, I-STPTv2, Igla-2 Trainer и полевого тренажера

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9F635M1 на основе имеющейся технической информации. Особое внимание уделяется функциональности тренажера, управлению инструктором, виртуальным средам, сбору данных, оценке производительности и гибкости системы. На основе сравнительного анализа предложена модульная интеллектуальная архитектура тренажера для системы QW-18. Предложенная архитектура состоит из шести взаимосвязанных функциональных модулей, организованных в три основных слоя. В исследовании также рассматривается потенциальное применение искусственного интеллекта для анализа результатов обучения и поддержки индивидуального обучения. Предложенный подход обеспечивает теоретическую и методологическую основу для дальнейшего развития и оценки современных тренажеров.

Ключевые слова: обучение на основе моделирования; анализ документации; модульное программное обеспечение; человекоориентированный дизайн; отслеживаемость доказательств; аналитика обучения; ответственный ИИ; контекст исследования QW-18.

Introduction

Simulation-based education is widely used where real-world instruction is expensive, difficult to repeat or subject to safety constraints. A useful simulator is not merely a visual display: it is a socio-technical system combining educational objectives, instructor oversight, reliable data collection and meaningful feedback. The source study identifies a gap between descriptions of individual training products and a transparent method for translating their reported functions into a coherent research specification [1].

The present paper preserves that comparative research question but narrows its engineering claims to non-operational educational infrastructure. It does not specify weapon handling, target engagement, sensor-emulation fidelity, launch sequencing or tactical optimization. Its contribution is a reproducible way to evaluate what public documents actually establish and to define a testable, human-centred software governance framework.

The objectives are to (i) classify documentary evidence consistently; (ii) compare the disclosed educational and software-support functions of four named systems; (iii) derive traceable, technology-neutral quality requirements; and (iv) define a validation agenda capable of distinguishing conceptual proposals from demonstrated outcomes.

Materials and Methods

1. Study design and evidence boundary

A qualitative comparative document analysis was undertaken using the supplied manuscript as the primary study corpus [1]. The systems included were Stinger Simulator, I-STPTv2, Igla-2 and 9F635M1. The source manuscript attributes product-specific statements to a manufacturer description, a U.S. Army program description, a vendor page and a patent record, respectively [2–5]. These original documents were not independently authenticated in this version; therefore, the comparison is explicitly a secondary synthesis of the supplied manuscript, not an independently verified product audit.

2. Coding protocol

The source manuscript uses three evidence codes: D (directly documented), P (partially or indirectly documented) and U (insufficiently documented in the reviewed public materials). U is an epistemic category, not evidence that a capability is absent. The coding unit is a stated capability,

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rather than an inferred technical implementation. Disagreements in future replications should be resolved by two independent coders with an adjudication record.

3. Evaluation dimensions

To keep the comparison reproducible and education-focused, five non-operational dimensions were extracted: instructor oversight, virtual presentation, records and reporting, post-session review, and portability. These are a subset of the broader ten dimensions in the source study [1]. No weights were assigned because the documents do not establish a common measurement scale or equal evaluation conditions.

4. Conceptual synthesis

Documented capabilities were translated into educational and software-quality requirements using the sequence: source claim → evidence code → stakeholder need → verifiable requirement → proposed validation test. Human-centred design principles and software-quality models informed this synthesis [6,7]. AI-related requirements were limited to accountability, dataset quality, explainability and oversight [8].

Results

Documentary comparison

Table 1 reproduces a carefully selected, non-operational subset of the source article's comparison. The letters summarize what the supplied manuscript reports, not independent bench testing or confirmation of all vendor assertions.

Table 1. Publicly described educational and support capabilities (secondary coding from [1])

Dimension	Stinger Simulator	I-STPTv2	Igla-2	9F635M1
Instructor oversight	D	D	P	D
Virtual/3D presentation	D	D	D	U
Data recording	P	D	D	P
Automated assessment	P	D	D	U
Post-session review	D	D	P	U
Portable use	D	D	P	D

D = directly documented in the source manuscript; P = partial/indirect documentation; U = not adequately documented. Codes do not measure effectiveness, reliability or absence of features.

The matrix indicates heterogeneous public documentation. In particular, the supplied descriptions emphasize instructor and visual functions for the Stinger-related products, record keeping and assessment for Igla-2, and field-oriented use for 9F635M1 [1]. Because evidence provenance and disclosure depth differ, neither counts of D codes nor a simple weighted score can support a defensible "best simulator" conclusion.

Proposed six-domain educational software framework

The conceptual framework has six interoperable domains:

1) learner access and interaction governance;

2) instructor and session administration;

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3) educational content presentation;
4) generic simulation services and quality assurance;
5) secure records and provenance; and
6) transparent learning analytics and feedback.

These domains are proposed research constructs, not verified properties of a QW-18 simulator. Their purpose is to separate responsibilities, improve auditability and support independent software maintenance.

Three overarching layers organize the domains: a user-and-governance layer, an application-services layer and a data-and-assurance layer. Interfaces between layers should be documented, versioned and subjected to change control. This structure is intentionally technology-neutral and does not define operational weapon-specific models.

Requirements traceability

Table 2 converts selected evidence gaps into testable educational-software requirements. The acceptance methods are proposed for future evaluation; they were not executed in the present study.

Table 2. Illustrative evidence-to-requirement traceability matrix

1. **Observed research need**	2. **Proposed requirement**	3. **Future verification**
4. Uneven feature documentation	5. Maintain a source-linked claim register with D/P/U status	6. Independent document audit
7. Instructor accountability	8. Record authorized session configuration changes	9. Role-based usability test
10. Incomplete provenance	11. Time-stamp and version educational records	12. Data integrity and recovery test
13. Assessment transparency	14. Expose scoring criteria and allow human review	15. Expert rubric review
16. Modular maintainability	17. Document versioned software interfaces	18. Compatibility and regression testing
19. Uncertain educational benefit	20. Pre-register learning outcome measures	21. Controlled education study

A staged validation design

Four sequential stages are recommended. First, establish documentary provenance and a frozen comparison protocol. Second, assess usability, accessibility, maintainability and security against predefined acceptance criteria. Third, evaluate educational feedback consistency and instructor agreement using anonymized, consented datasets. Fourth, undertake a controlled educational evaluation with baseline equivalence, transparent exclusions and uncertainty intervals. A pilot should report feasibility rather than infer efficacy from small samples.

Discussion

The central methodological finding is that publicly reported feature availability and independently demonstrated instructional value are different kinds of evidence. Vendor material may identify potential functionality but seldom establishes controlled learning outcomes. The D/P/U method protects against a common error: treating non-disclosure as proof of non-existence. It should

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nevertheless be strengthened by source dates, document versions, direct quotations kept within licensing limits and inter-rater agreement.

A modular research framework is attractive for governance because responsibilities can be inspected independently. However, modularity is not intrinsically superior: interface complexity, latency, cybersecurity exposure and maintenance costs may offset expected benefits. Claims of lower cost, faster training, higher accuracy or improved proficiency require real observations and a specified comparator; none are asserted here.

Human-centred design is particularly relevant to educational feedback. Instructors and learners should participate in requirement definition and usability testing; feedback should be interpretable, contestable and linked to explicit learning objectives [6]. Any future AI-supported analytics should begin with simple, auditable baselines. Dataset representativeness, drift, fairness, privacy, access control and human override must be evaluated before deployment [8].

This study has important limitations. The input is a single supplied manuscript; its cited product descriptions and patent claims have not been independently rechecked. The source comparison has no standardized hardware benchmarks, participant sample, controlled instructional experiment or cost accounting. The proposed framework is consequently a research hypothesis, not a validated product design. Its applicability to the named platform remains untested.

Conclusions and Recommendations

1. Publicly described training systems differ in the functions emphasized by their documentation; those differences do not justify a ranking of operational or educational effectiveness.

2. A documented/partial/undocumented evidence code should be retained, supplemented by source provenance and independent reviewer agreement to prevent unsupported claims.

3. Future educational software research should prioritize instructor accountability, data integrity, usability, transparent feedback and maintainable interfaces within a modular, non-operational framework.

4. AI-based assessment should not be represented as validated until data quality, reproducibility, human oversight and comparison against interpretable baselines have been demonstrated.

5. The next research phase should verify original technical sources and conduct pre-registered usability, software-quality and educational outcome studies before drawing claims about effectiveness or economic benefit.

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10. Research integrity note: This manuscript is a literature-based conceptual study. It reports no new participant data, device testing, empirical model performance or verified implementation. Product claims in [2]–[5] are second-hand descriptions from [1] pending independent verification.