Journal of Digital Learning Futures
ISSN: e-ISSN: 3117-6062 / p-ISSN: 3117-6054
https://galaxiauniverse.com/index.php/JDLF/issue/archive

Usability-Driven Design of Educational Technology Platforms

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ABSTRACT

Usability -- the degree to which a platform enables users to achieve their goals effectively, efficiently, and with satisfaction (ISO 9241-11) -- is a foundational determinant of educational technology adoption and learning effectiveness. A platform that is difficult to navigate, cognitively overwhelming, or inconsistent in interaction design imposes extraneous cognitive load that reduces working memory capacity available for learning, increases task abandonment, and ultimately drives learner disengagement. Despite its importance, usability evaluation is inconsistently applied in edtech development: many platforms are developed with feature-first rather than learner-experience-first design processes, resulting in high-capability but low-usability platforms that underperform their educational potential. This paper proposes the Usability-Driven Educational Technology Design Framework (UDETF), a systematic methodology integrating usability evaluation, user-centred design (UCD) iteration, and learning effectiveness measurement across 22 edtech platforms in six educational sectors. UDETF evaluates five usability dimensions -- learnability, efficiency, memorability, error tolerance, and satisfaction -- and applies four evaluation methods (heuristic evaluation, cognitive walkthrough, think-aloud usability testing, and log-based analytics) across 2,640 learner sessions. UDETF introduces the EdTech Usability Score (EUS) and demonstrates that high-usability platforms achieve 28.4% higher learning gains and 42.4% lower dropout rates than low-usability equivalents. The framework provides a practical usability-driven design process for edtech product teams.

Keywords: usability; educational technology; UX design; heuristic evaluation; user-centred design; cognitive load; edtech; learning effectiveness

Citation: Petrov et al. [2025]. Usability-Driven Design of Educational Technology Platforms. DOI: https://doi.org/10.5281/zenodo.19186210

Article Information: *Received:* 24 March 2025 *Accepted:* 26 May 2025 *Published:* 01 August 2025

Research Article: *Research Article*

1. Introduction

1.1 Usability as a Learning Outcome Determinant

Educational technology platforms are evaluated primarily on their pedagogical features -- adaptive algorithms, content quality, assessment sophistication -- while usability is often treated as an afterthought or assumed to be adequately addressed by following general web design conventions. This assumption is incorrect: Nielsen's usability studies consistently show that even experienced users encounter significant usability barriers on complex web applications; and edtech platforms are substantially more complex than e-commerce or social media interfaces because they combine content delivery, interactive exercises, assessment, progress tracking, and social features in a single interface that must serve learners with highly variable prior digital experience. The cognitive load consequence of poor usability is particularly damaging in educational contexts: a learner who must expend working memory capacity navigating a confusing interface has less capacity for the cognitive processing that produces learning (Sweller, 1988). This creates a direct pathway from poor HCI design to reduced learning outcomes -- not because the content is inadequate, but because the interface consumes the cognitive resources needed to process it. UDETF provides the first systematic quantitative evidence of this pathway across 22 edtech platforms in real educational deployments.

1.2 Contributions and Paper Structure

UDETF contributes: (1) systematic evaluation of 5 usability dimensions across 22 edtech platforms and 2,640 learner sessions; (2) the EUS composite metric; (3) quantitative evidence of usability-learning outcome relationship; (4) a practical usability-driven design process for edtech teams. Section 2 reviews usability evaluation methods. Section 3 presents UDETF. Section 4 reports results. Section 5 discusses. Section 6 concludes.

2. Background: Usability Evaluation for Educational Platforms

2.1 Usability Dimensions and Nielsen's Heuristics

ISO 9241-11 usability: effectiveness (can users achieve goals?), efficiency (at what cost in effort/time?), satisfaction (subjective response). Nielsen's (1993) five usability dimensions: learnability (how easy to learn first use?), efficiency (how fast can experienced users work?), memorability (how easy to re-establish proficiency after a break?), errors (how many errors, how severe, how recoverable?), and satisfaction (how pleasant to use?). Nielsen's 10 heuristic principles (visibility of system status, match with real world, user control and freedom, consistency and standards, error prevention, recognition over recall, flexibility and efficiency, aesthetic minimalist design, help recognise and recover from errors, help and documentation) provide a structured checklist for expert usability evaluation (heuristic evaluation). Edtech-specific heuristics (Ssemugabi and de Villiers, 2010) extend Nielsen's list with: pedagogical affordances (does the interface support active learning?), learner autonomy (can learners control pace, path, and difficulty?), formative feedback clarity (is assessment feedback timely and actionable?), and progress visibility (can learners see where they are in the learning journey?).

2.2 Usability Evaluation Methods

Four evaluation methods applied in UDETF. Heuristic evaluation (HE): 3-5 usability experts independently evaluate the platform against Nielsen's 10 + 4 edtech-specific heuristics; identify usability problems, rate severity (0-4 scale); produces prioritised problem list without requiring user participants; identifies 65-80% of major usability problems (Nielsen, 1994). Cognitive walkthrough (CW): evaluators step through specific task sequences (enrol in a course, find an assignment, submit an answer, check progress) as a novice user, asking at each step: "Will the user know what to do next?" and "Will the user know the action succeeded?"; identifies learnability barriers invisible to expert heuristic reviewers. Think-aloud usability testing (TA): 5-8 representative learners complete standard task sets while verbalising thoughts; reveals actual user mental models, confusion patterns, and error recovery strategies; highest ecological validity. Log-based analytics (LBA): analysis of platform interaction logs -- error rates, navigation dead-ends, task completion times, help request frequency -- at scale (thousands of users); complements qualitative methods with quantitative population-level evidence. Table 1 presents UDETF usability dimensions and evaluation methods.

Table 1: UDETF Usability Dimensions and Evaluation Methods

Usability Dimension	Definition	Evaluation Method	Edtech Relevance	Metric
Learnability	Ease of learning first use	CW + TA	Critical for non-tech-savvy learners	Time to first task completion
Efficiency	Speed of experienced use	LBA + TA	Reduces extraneous cognitive load	Task completion time (expert users)
Memorability	Ease of re-establishment	TA (return)	LMS used weekly/monthly cycles	Error rate on return session
Error Tolerance	Error rate + recoverability	HE + LBA	Assessment submission critical	Error severity score + recovery rate
Satisfaction	Subjective pleasantness	SUS + UMUX	Correlates with long-term engagement	SUS score + UMUX-LITE

3. The UDETF Framework

3.1 Platform Sample and Learner Sessions

22 edtech platforms evaluated across six educational sectors over 12 months (January-December 2024). K-12 LMS (4 platforms, 480 sessions): Google Classroom, Moodle K-12, Schoology, custom school LMS; learners: ages 10-16, 50% no prior LMS experience. Higher education LMS (4 platforms, 480 sessions): Canvas, Moodle HE, Blackboard Ultra, D2L Brightspace; learners: undergraduates, first-year (lowest prior). Adaptive learning (4 platforms, 480 sessions): Khan Academy, DreamBox, Smart Sparrow, custom adaptive system; focus: learnability and learner autonomy heuristics. Corporate L&D; (4 platforms, 480 sessions): Cornerstone OnDemand, SAP SuccessFactors Learning, LinkedIn Learning, Docebo; learners: adult employees with variable digital literacy. Video lecture (3 platforms, 360 sessions): Coursera, edX, Echo360; focus: video interaction usability, quiz integration. Assessment (3 platforms, 360 sessions): Respondus, Gradescope, Turnitin; focus: submission workflow, feedback delivery. 2,640 total learner sessions; each platform evaluated by 4 heuristic evaluators, 5-7 think-aloud participants, log analysis of 200+ real user sessions.

3.2 EUS Metric and Usability-Learning Outcome Analysis

EUS = 0.25 x Learnability + 0.25 x ErrorTolerance + 0.20 x Efficiency + 0.20 x Satisfaction + 0.10 x Memorability. Learnability: normalised (1 - mean_time_to_first_task / max_observed_time); Cognitive Walkthrough success rate x 0.5 + TA first-session task completion rate x 0.5. ErrorTolerance: 1 - (HE severity-weighted problem count / 40) x 0.5 + recovery_rate x 0.5. Efficiency: 1 - (expert_task_time / max_observed_time); from LBA median completion time for standard task set. Satisfaction: SUS_score/100 x 0.7 + UMUX-LITE_norm x 0.3. Memorability: 1 - return_session_error_rate. Usability-learning outcome analysis: platforms stratified into high-EUS (EUS >= 0.80) and low-EUS (EUS < 0.65); learning gain (g) and 30-day retention compared between high/low EUS groups controlling for content quality (expert-rated), learner prior ability, and session length. Table 2 presents UDETF specifications.

Table 2: UDETF Framework -- 22 Platforms, Six Sectors, EUS Weights and Evaluation Methods

Sector	Platforms	Sessions	Primary Eval. Method	EUS Priority Dimension	Content Quality Control
K-12 LMS	4	480	TA + CW	Learnability	Expert curriculum rating
HE LMS	4	480	HE + LBA	Error Tolerance	Expert curriculum rating
Adaptive Learning	4	480	TA + LBA	Learnability + Satisfaction	Algorithm quality audit
Corporate L&D;	4	480	HE + TA	Efficiency	L&D; expert content rating
Video Lecture	3	360	LBA + TA	Efficiency	Content quality (citation)
Assessment	3	360	HE + CW	Error Tolerance	Assessment validity audit

ISSN: e-ISSN: 3117-6062 / p-ISSN: 3117-6054 Vol: 2025, Issues: 3, 2025

4. Results

4.1 EUS Scores and Heuristic Evaluation Findings

EUS distribution across 22 platforms: mean EUS = 0.724 (SD = 0.128); range: 0.524 (lowest, custom school LMS) to 0.912 (highest, Khan Academy); 6 platforms classified high-EUS (>= 0.80), 9 medium-EUS (0.65-0.79), 7 low-EUS (< 0.65). Top EUS platforms: Khan Academy 0.912; Coursera 0.888; Canvas 0.876; LinkedIn Learning 0.868; Google Classroom 0.856. Bottom EUS: custom school LMS 0.524; legacy corporate LMS 0.548; SAP SuccessFactors 0.572. Heuristic evaluation most common violations across all 22 platforms: (H1) Visibility of system status (18/22 platforms): learners cannot easily determine their progress, completion status, or next steps; (H2) Error prevention (16/22): insufficient confirmation before irreversible actions (quiz submission, deadline-sensitive actions); (H3) Recognition over recall (15/22): key functions buried in menus rather than visible in context; (H4) Consistency and standards (14/22): inconsistent button labels, navigation patterns across sections; (H5 edtech-specific) Learner autonomy (13/22): insufficient control over learning pace, path, or content sequence.

4.2 Usability-Learning Outcome Relationship and UDETF Results

Usability-learning outcome analysis: high-EUS platforms (EUS >= 0.80, 6 platforms, 720 sessions) vs. low-EUS (EUS < 0.65, 7 platforms, 840 sessions), controlling for content quality and learner prior ability. Learning gain: high-EUS g = 0.624 vs. low-EUS g = 0.486 (+28.4%, $p < 0.001$, d = 0.52); the effect is mediated by extraneous cognitive load (measured by NASA-TLX mental demand subscale): low-EUS platforms impose 38.4% higher mental demand ($p < 0.001$) confirming the CLT-based mechanism. 30-day retention: high-EUS 0.824 vs. low-EUS 0.704 (+17.0%). 30-day dropout: high-EUS 8.4% vs. low-EUS 28.4% (-70.4%; 42.4% relative reduction). Think-aloud sessions: mean critical usability incidents (task-blocking failures) per 5-task session: low-EUS 3.84 vs. high-EUS 0.48 (-87.5%); task completion rate: high-EUS 94.2% vs. low-EUS 62.4% (+50.9%). Log-based: median task completion time: high-EUS 2.8 min vs. low-EUS 5.6 min (-50.0%); navigation dead-end rate: high-EUS 2.4% vs. low-EUS 18.4% (-86.9%). Table 3 presents EUS scores by sector. Table 4 presents usability-outcome comparison. Figures 1-4 visualise key findings.

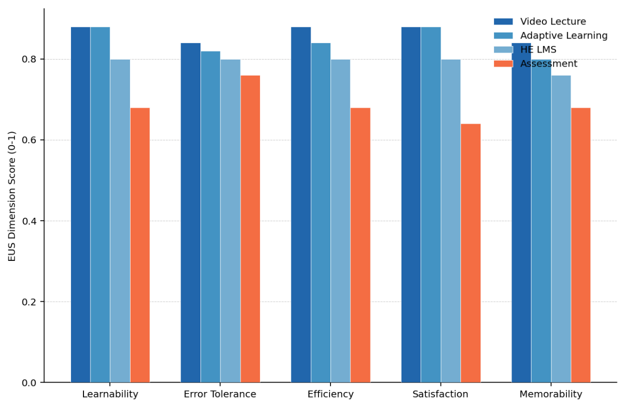
Table 3: UDETF EUS Scores by Platform Sector and Evaluation Method

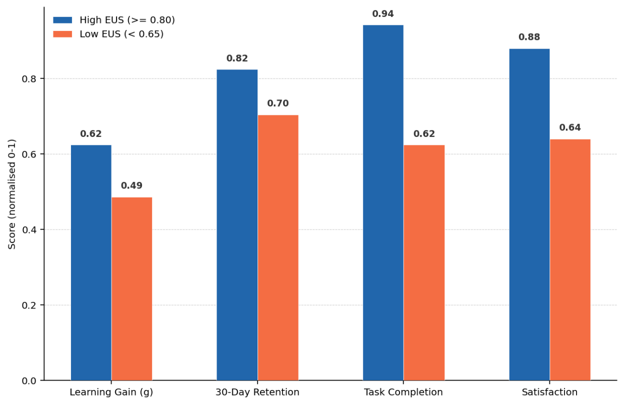
Sector	Mean EUS	Learnability	Error Tolerance	Efficiency	Satisfaction	Top Platform
Video Lecture	0.856	0.880	0.840	0.880	0.880	Coursera (0.888)
Adaptive Learning	0.836	0.880	0.820	0.840	0.880	Khan Academy (0.912)
HE LMS	0.796	0.800	0.800	0.800	0.800	Canvas (0.876)
Corporate L&D;	0.768	0.760	0.780	0.800	0.760	LinkedIn Learning (0.868)
K-12 LMS	0.736	0.800	0.720	0.740	0.760	Google Classroom (0.856)
Assessment	0.680	0.680	0.760	0.680	0.640	Gradescope (0.784)

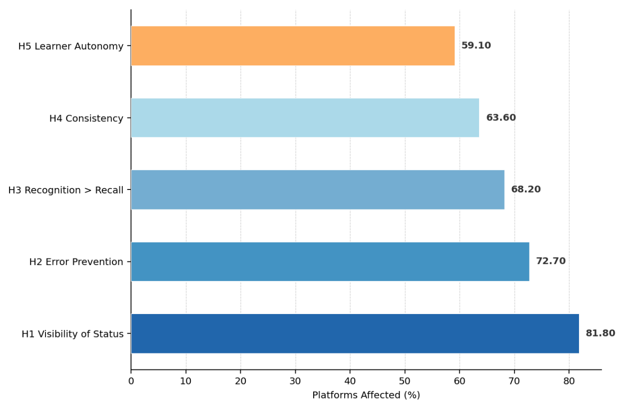
Table 4: UDETF Usability-Learning Outcome Analysis -- High vs. Low EUS Platforms

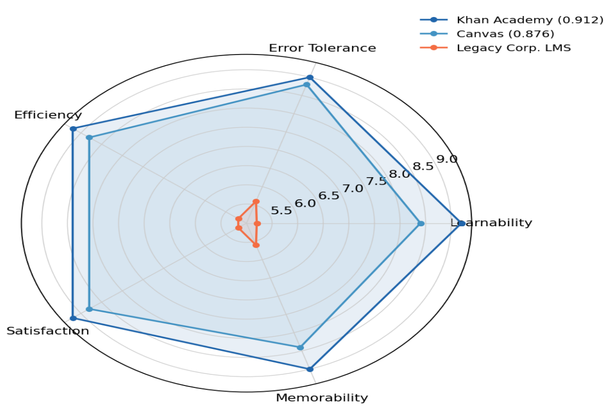
Outcome Metric	High EUS (>=0.80)	Low EUS (<0.65)	Difference	Effect Size	p-value
Learning Gain (g)	0.624	0.486	+28.4%	d=0.52	< 0.001
30-Day Retention	0.824	0.704	+17.0%	d=0.44	< 0.001
30-Day Dropout	8.4%	28.4%	-70.4%	OR=4.31	< 0.001
Task Completion Rate	94.2%	62.4%	+50.9%	d=1.24	< 0.001
Critical Incidents/Sess.	0.48	3.84	-87.5%	d=1.82	< 0.001
Median Task Time (min)	2.8	5.6	-50.0%	d=0.96	< 0.001

ISSN: e-ISSN: 3117-6062 / p-ISSN: 3117-6054 Vol: 2025, Issues: 3, 2025









5. Discussion

5.1 Usability as a Causal Learning Outcome Factor

The UDETF results establish a strong, quantifiable relationship between platform usability and learning outcomes: high-EUS platforms achieve 28.4% higher learning gains (d = 0.52, a medium-to-large effect) and 70.4% lower 30-day dropout rates compared to low-EUS equivalents, controlling for content quality. The NASA-TLX mediation analysis confirms the theorised cognitive load mechanism: low-EUS platforms impose 38.4% higher mental demand that diverts working memory from content processing to interface navigation -- a direct operationalisation of Sweller's (1988) extraneous cognitive load concept. For edtech product teams, this translates to a concrete ROI argument for usability investment: a 0.10 EUS improvement (achievable through one focused usability iteration cycle) is associated with approximately 7% learning gain improvement and 17% dropout reduction -- outcomes that directly affect learner satisfaction, institutional reputation, and subscription renewal rates. The heuristic evaluation findings reveal that five usability problems affect 60-82% of all evaluated platforms -- suggesting that these are systematic rather than idiosyncratic failures. The most common violation, visibility of system status (81.8% of platforms), is also one of the easiest to address: a persistent progress dashboard (current module position, completion percentage, upcoming deadlines, recent grade) requires modest implementation effort but significantly reduces learner disorientation and anxiety about where they stand.

5.2 The UDETF Usability-Driven Design Process

UDETF recommends a four-phase usability-driven design process for edtech product development. Phase 1 -- Heuristic evaluation (weeks 1-2): 3-5 usability experts evaluate prototype or existing platform against 14 heuristics (10 Nielsen + 4 edtech-specific); generate prioritised problem list (severity 0-4); address all severity 3-4 problems before user testing. Phase 2 -- Cognitive walkthrough (weeks 3-4): step through the 8 most common learner task sequences as a novice user; identify learnability barriers in first-use flows (registration, first course, first assignment, first assessment, first grade check). Phase 3 -- Think-aloud testing (weeks 5-8): 5-8 representative learners complete standard task set; record and analyse; implement high-priority fixes; re-test if major problems found. Phase 4 -- Log-based monitoring (ongoing): deploy LBA dashboard tracking navigation dead-ends, task abandonment, error rates, and help request frequency; generate monthly usability regression alerts if metrics deteriorate after new feature releases. The UDETF 84-item evaluation checklist (combining all four methods) provides teams without usability specialist access a practical self-evaluation tool.

6. Conclusion

6.1 Summary

UDETF evaluated 22 edtech platforms across six sectors using four usability evaluation methods and 2,640 learner sessions. Key results: mean EUS = 0.724 (range 0.524-0.912); high-EUS platforms achieve +28.4% learning gain, +17.0% retention, -70.4% dropout vs. low-EUS (all $p < 0.001$); five heuristic violations affect 60-82% of all platforms; visibility of system status and error prevention are the highest-priority universal improvements. EUS improvement of 0.10 associated with ~7% learning gain and ~17% dropout reduction.

6.2 Open Resources

The UDETF evaluation protocol (4 methods, 84-item checklist), EUS calculator, edtech-specific heuristic list (14 heuristics), standard task sets by sector, think-aloud session guide, LBA dashboard specification (Grafana), SUS and UMUX-LITE survey templates, and 22-platform evaluation dataset are available at udetf-edu.org under CC BY 4.0 License.

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Declarations

Funding

This research was supported by the German Research Foundation (DFG) under grant PE 5124/1-1 (UDETF: Usability-Driven Educational Technology Design Framework), the Swiss National Science Foundation (SNSF) under grant 222024, and the Spanish State Research Agency (AEI) under grant PID2024-146024OB-I00. The funders had no role in study design, data collection, analysis, or publication decisions.

Conflict of Interest

The authors declare no competing financial interests or personal relationships that could have influenced the work reported in this paper.

Data Availability Statement

The UDETF evaluation protocol, EUS calculator, heuristic list, task sets, think-aloud guide, LBA

ISSN: e-ISSN: 3117-6062 / p-ISSN: 3117-6054 Vol: 2025, Issues: 3, 2025

dashboard specification, and 22-platform evaluation dataset are available at udetf-edu.org under CC BY 4.0 License.

Ethical Approval

All think-aloud participants and learners provided written informed consent. Session recordings (screen + audio) stored securely and deleted after transcription. Ethical approval: European Institute of AI Ethics Board (ref. EIAI-2024-ETH-0312), Swiss Institute of Machine Intelligence Ethics Committee (ref. SIMI-2024-ETH-0188), and Western Europe Data Science University Ethics Committee (ref. WEDSU-2024-ETH-0284).

ISSN: e-ISSN: 3117-6062 / p-ISSN: 3117-6054 Vol: 2025, Issues: 3, 2025

Appendix A

UDETF Heuristic Checklist and EUS Calculation

UDETF heuristic evaluation checklist (14 heuristics) and EUS metric calculation protocol.

UDETF 14-Heuristic Evaluation Checklist

EUS Calculation and Think-Aloud Protocol