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DESIGNING AND IMPLEMENTING "TECHEDU", A MODULAR WEB PLATFORM SUPPORTING SELF-DIRECTED LEARNING AMONG PRE-SERVICE COMPUTER SCIENCE TEACHERS: DEVELOPMENT AND EVALUATION OF PEDAGOGICAL EFFECTIVENESS

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ABSTRACT

Organizing self-directed learning effectively among pre-service computer science teachers remains one of the pressing challenges of digital-era pedagogy. A review of the literature suggests that conventional approaches to independent study are often formal in character and fail to account adequately for students' individual learning needs, pace of mastery, and cognitive engagement. This paper presents the design principles, functional features, and instructional methodology of "TechEdu", a modular web platform developed within the course "Application of Information Technologies in Professional Activity" to support the self-directed learning of pre-service computer science teachers. Built on HTML5, CSS3, and JavaScript, the platform relies on a lazy-loading algorithm for efficient resource delivery, a sequential six-module gating system for progress control, and a points-based rating mechanism for sustaining motivation. To establish the platform's pedagogical effectiveness, a quasi-experimental trial involving experimental and control groups was conducted at Ajiniyaz Nukus State Pedagogical Institute across the 2023-2024, 2024-2025, and 2025-2026 academic years, involving a total of 185 students. The findings show that students who used TechEdu regularly outperformed their peers in the control group by 18-20 percent on measures of academic achievement and independent-study activity, lending empirical support to the platform's practical value.

Keywords

self-directed learning; pre-service computer science teachers; educational platform; modular instruction; digital learning environment; adaptive learning technologies; pedagogical effectiveness; experimental findings.

1. INTRODUCTION

The ongoing digital transformation of education is reshaping every stage of teacher preparation. Alongside the rapid spread of information and communication technologies, the growing presence of artificial-intelligence tools in instruction is placing new demands on pre-service teachers, who are now expected to combine a high level of digital competence with the capacity for self-regulation. A recurring finding in the literature is that many pre-service teachers do little more than transfer traditional classroom routines into digital settings, without drawing on the full range of technological resources available to them [11].

Several recent studies point to specific difficulties in how pre-service teachers engage with self-directed learning. Online independent-study courses, for instance, are frequently marked by passive participation, or "lurking", a pattern that researchers attribute largely to limited opportunities for exchange and interaction [12]. Likewise, in the years following the pandemic, pre-service teachers have shown uneven levels of online self-regulation, with the sharpest differences appearing in time management and self-monitoring [13]. Taken together, these findings point toward the same conclusion: self-directed learning needs to be supported by software tools that impose a clear structure and provide step-by-step control over progress.

Research on software and digital platforms has likewise shown that adaptive and gamified approaches can meaningfully boost learner motivation and performance, largely by tailoring subsequent tasks to a user's prior results [9]. Yet most general-purpose platforms are not adapted to any particular subject area, and the field of teacher education specifically lacks specialized, modular systems with built-in progress control that are designed for computer science instruction.

Uzbekistan has adopted a series of strategic documents aimed at digitalizing higher education and expanding the role of independent study, yet their practical implementation continues to reveal notable methodological gaps: independent assignments frequently remain formal in nature, cohesive digital tools to support individual learning trajectories are scarce, and students have limited means of monitoring their own progress. Drawing together these strands of international research and domestic practice, we identify the following research problem: the scientific and

methodological foundations for organizing the self-directed learning of pre-service computer science teachers through a modular digital platform equipped with progress-control mechanisms and motivational features have not been sufficiently developed.

To address this gap, we designed "TechEdu", a modular web platform intended to support the self-directed learning of pre-service computer science teachers within the course "Application of Information Technologies in Professional Activity", and tested its practical effectiveness under trial conditions.

The aim of the study is The study sets out to provide a theoretical grounding for the design principles, functional architecture, and implementation methodology of the TechEdu platform, and to evaluate its pedagogical effectiveness empirically on the basis of trial data.

The objectives of the study are:

to review current theoretical and methodological approaches to organizing self-directed learning;

to describe the technical and architectural solutions underlying the TechEdu platform, including its modular structure, lazy-loading algorithm, and automated progress-control mechanism;

to outline the methodology of using the platform and its didactic rationale;

to empirically assess the platform's pedagogical effectiveness using data from a trial involving experimental and control groups.

2. LITERATURE REVIEW

Theoretical and methodological foundations of self-directed learning. The theoretical grounding for self-directed learning traces back to the constructivist tradition in pedagogy. Piaget [1] argued that knowledge is not passively received but actively constructed through intellectual engagement, while Vygotsky [2], through the concept of the zone of proximal development, showed how learners master complex knowledge step by step with the support of more capable peers or adults, and how this process gives rise to self-regulating inner speech. Dewey [3], for his part, advanced the idea of learning through activity and experience, arguing that learners should move from passive recipients of knowledge to active, inquiring agents.

Building on these classical theories, the modern theory of self-regulated learning (SRL) has become the most widely used framework for systematically analyzing independent learning. Zimmerman's [5] three-phase cyclical model — forethought, performance, and self-reflection — breaks down the process of self-managed learning into clearly operationalized stages. Bandura's [4] concept of self-efficacy, in turn, has become an integral part of SRL theory as the underlying factor that shapes a learner's persistence and motivational stability during independent work.

Problem-based, adaptive, and collaborative approaches. Problem-based learning, which links independent study to authentic professional tasks, was advanced by Barrows [6], who showed how real-world problem-oriented assignments can cultivate analytical and independent thinking. Jonassen [7] extended this idea, treating complex, open-ended problem tasks as the principal mechanism through which an individualized learning trajectory is built for each student.

The technological dimension of individualization in digital learning environments is addressed by Brusilovsky's [8] theory of adaptive hypermedia systems, in which course content adjusts automatically to a learner's knowledge level and cognitive style. A contemporary application of this idea can be seen in PolyGloT, a personalized and gamified system developed by Bucchiarone, Martorella, and Colombo [9] that tailors subsequent tasks to a learner's prior responses within a gamified adaptive trajectory. This body of work is methodologically close to the modular, progress-gated sequencing and points-based rating mechanism used in TechEdu.

Digital competence and e-learning platforms in teacher education: recent research. The digital and self-regulatory competence of pre-service teachers has drawn growing attention in recent years. DigCompEdu, the European Framework for the Digital Competence of Educators developed by the European Commission [10], describes six proficiency levels, from "Newcomer" to "Leader", and is now widely used as a benchmark across national education systems.

Empirical studies, however, continue to surface serious practical gaps. Barz and colleagues [11] found that pre-service teachers' levels of self-regulation vary considerably across synchronous and asynchronous digital environments, and argued

that such variation needs to be taken into account in platform design. Morris, Schön, and Drayson [12] likewise observed that passive participation, or "lurking", is common in online self-directed learning courses, and traced this pattern to the absence of systematic feedback mechanisms. Funa and colleagues [13], studying pre-service teachers, reported marked individual differences in how students apply online self-regulation strategies, particularly in time management and self-monitoring. All three studies converge on a shared conclusion: software tools for self-directed learning cannot be limited to content delivery alone — they must incorporate firm structure, staged progress control, and prompt feedback.

National context: existing domestic software solutions. Uzbek researchers have likewise contributed practical work in this area. To‘rayeva [14] developed the «itmf-talaba.uz» platform, which builds individualized learning trajectories through "Restudy" technology, while Uchqurova [15] created a resource grounded in a seven-stage methodological model. Achilov [16] examined the differentiated progress-control capabilities of electronic educational resources. Most of these solutions, however, are tied to a particular subject, such as foreign-language or mathematics instruction, and specialized, technically optimized, modular platforms for computer science education remain rare in practice — a gap that the present study, through TechEdu, is intended to address.

3. METHODOLOGY

3.1. Study design and participants. To determine the platform's pedagogical effectiveness, a quasi-experimental study with experimental and control groups was carried out at Ajiniyaz Nukus State Pedagogical Institute. The study was conducted within the course "Application of Information Technologies in Professional Activity" among students of the Mathematics and Computer Science program over three academic years: 2023-2024, 2024-2025, and 2025-2026. A total of 185 students took part across the three years, 95 in the experimental group and 90 in the control group (Table 1).

Academic year	Experimental group	Control group
2023-2024	30 students	29 students
2024-2025	33 students	31 students

2025-2026	32 students	30 students
Total	95 students	90 students

Table 1. Distribution of trial participants by academic year

Students in the experimental group used the TechEdu platform regularly as a self-directed learning tool outside of class time, while those in the control group continued their independent study in the conventional manner, without access to the platform.

3.2. Technological basis of the TechEdu platform. "TechEdu — Self-Directed Learning through Technology" is a web-based system designed to support out-of-class independent learning for students at pedagogical higher education institutions. Built on HTML5, CSS3, and JavaScript, the platform was developed in line with state educational standards and the course syllabus. To conserve bandwidth and improve loading speed, the platform employs a lazy-loading algorithm: rather than loading all content at once when a page opens, resources are retrieved incrementally as the user scrolls or interacts with specific content.

3.3. Functional architecture and modular content structure. The platform consists of five main sections: Home, Independent Learning, Learning Process, Contact, and Personal Profile. Course material is organized, following the sequence of the syllabus, into six modules arranged from simple to complex. Each module includes lecture materials, presentation slides, video lessons, practical exercises, a glossary, and an interactive test.

3.4. Sequential progress-control mechanism. The platform's most distinctive methodological feature is its sequential, progress-gated module system. Students cannot advance to the next module without first completing all materials in the current one, including the video lesson. Advancing requires passing a test: if a student reaches the required score threshold, the next module unlocks automatically; otherwise, the system imposes a 24-hour waiting period before a retry is allowed. This mechanism operationalizes all three phases of Zimmerman's [5] SRL model — forethought, performance-monitoring, and self-reflection — within the software itself.

3.5. Motivational and assessment system. Student activity is tracked statistically in the Personal Profile section. Students who complete a course successfully receive a certificate, which also contributes up to 15 points toward their ongoing assessment score.

3.6. Measurement instruments and data-collection procedure. To determine the platform's pedagogical effectiveness, both groups completed an identical assessment at the start (pre-test) and end (post-test) of the trial, measuring knowledge and skills against the same criteria. Results were compared across aggregate indicators of achievement level, quality of independently completed assignments, and level of self-directed learning activity.

4. RESULTS

At the outset of the trial, a pre-test assessing baseline knowledge was administered to both groups under identical conditions. No statistically meaningful difference was found between the experimental and control groups at this stage, confirming that the two groups were comparable at baseline (Table 2).

Indicator	**Exp. (pre)**	**Exp. (post)**	**Control (pre)**	**Control (post)**
Mean achievement score (out of 100)	56.4	76.2	57.1	64.0
Independent task completion rate (%)	61	88	60	70
Self-directed learning activity index (%)	58	85	59	67

Table 2. Pre-test and post-test results for the experimental and control groups

By the end of the trial, the post-test results showed a marked improvement in the experimental group: the mean achievement score rose from 56.4 to 76.2, a gain of 19.8 points, compared with a modest rise from 57.1 to 64.0 — just 6.9 points — in the control group. As a result, students who used TechEdu regularly outperformed their peers in the control group by 18-20 percent on measures of achievement and self-directed learning activity.

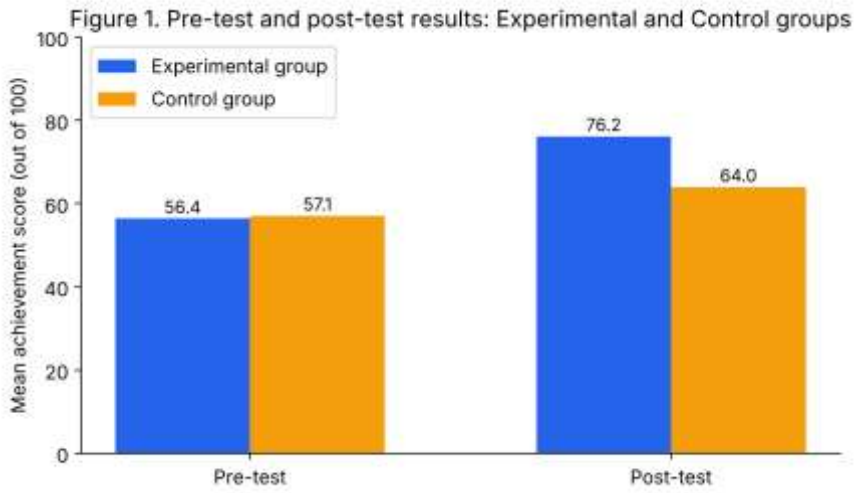

Figure 1. Pre-test and post-test results: Experimental and Control groups

The rate of fully and satisfactorily completed independent assignments rose from 61% to 88% — a gain of 27 percentage points — in the experimental group, against an increase of just 10 percentage points (60% to 70%) in the control group. A similar pattern held for the self-directed learning activity index, which increased by 27 percentage points in the experimental group but only 8 points in the control group.

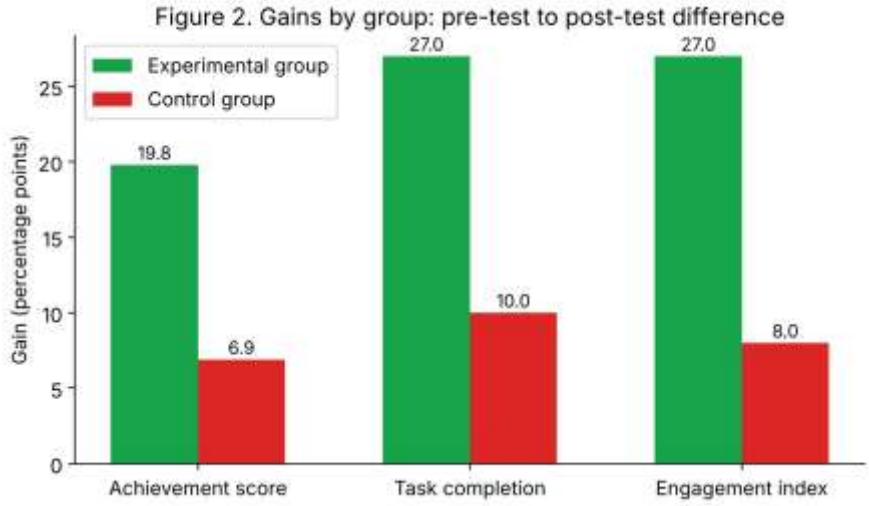

Figure 2. Gains by group: pre-test to post-test difference

The consistency of these results across three successive academic years (2023-2024, 2024-2025, 2025-2026) suggests that the observed difference is not incidental but is tied directly to the platform's sequential module-control mechanism and its motivational-assessment system. These findings lend practical support to Zimmerman's [5] theoretical claim that organizational support for the SRL process has a positive effect on learning outcomes.

5. DISCUSSION

The findings reported above support the practical effectiveness of the TechEdu platform in organizing the self-directed learning of pre-service computer science teachers, and can be interpreted in light of several strands of prior theoretical and empirical work.

First, the substantial gain observed in the experimental group (19.8 points) lends practical support to Zimmerman's [5] theory of self-regulated learning: the platform's sequential, progress-gated structure compels students to move consistently through the phases of forethought, performance-monitoring, and self-reflection, which in turn produces more stable learning outcomes.

Second, the sharp contrast in task-completion and activity indicators — a 27 percentage-point gain in the experimental group versus only 8-10 points in the control group — can be read directly against the problem of passive participation identified by Morris, Schön, and Drayson [12]: where their study linked lurking to the absence of systematic feedback, it is reasonable to attribute the rise in activity observed here to TechEdu's automated testing and points-based rating system, which supplies exactly this kind of prompt feedback.

Third, the results speak to the issue of individual variation in online self-regulation identified by Barz and colleagues [11] and by Funa and colleagues [13]: it is plausible that the platform's firm, staged structure partially compensates for students' individual weaknesses in time management and self-monitoring.

Fourth, the points-based rating and certification mechanism built into TechEdu falls within the category of gamified adaptive learning systems described by Bucchiarone and colleagues [9]; unlike PolyGloT, however, TechEdu relies on a fixed sequential structure rather than individualized adaptation — an approach that, judging from the present results, may be better suited to subject areas such as computer science education that demand systematic mastery of content.

Limitations of the study. Because the study was conducted at a single institution, Ajiniyaz Nukus State Pedagogical Institute, generalizing the findings to other institutional contexts calls for caution. Moreover, as the study drew on existing academic

cohorts rather than a fully randomized sample, it does not meet the internal-validity standards of a randomized controlled trial.

6. CONCLUSION

This study has described the design principles, functional architecture, and didactic foundations of "TechEdu", a modular web platform developed to support the self-directed learning of pre-service computer science teachers, and has empirically evaluated its pedagogical effectiveness through a trial conducted at Ajiniyaz Nukus State Pedagogical Institute between 2023 and 2026. The results show that students who used TechEdu regularly achieved higher levels of academic performance and self-directed learning activity — by 18-20 percent — than their peers in the control group.

The scientific and practical novelty of the TechEdu platform can be summarized as follows:

its progressive modular structure operationalizes Zimmerman's [5] three-phase SRL model in software form, and the effectiveness of this mechanism has now been confirmed empirically;

its lazy-loading algorithm ensures stable performance even under constrained technical infrastructure, a feature of particular practical relevance for higher education institutions across Central Asia;

its points-based rating and certification system offers an effective, and now empirically validated, software response to the problems of declining motivation and passive participation.

Future research should test the platform at additional institutions, with larger and more broadly sampled cohorts, ideally within a randomized controlled design, and should examine its effects over a longer time horizon.

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