Effects of ICT-supported Learning Models and Behavioral Factors on Academic Performance in Professionally Oriented Schooling with Production Tasks: Evidence from a Quasi-experimental Study

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***Abstract*—This study investigates the effects of Information and Communications Technology (ICT)-supported learning models and students' behavioral activity on academic performance in professionally oriented secondary education. Using a quasi-experimental pre-test/post-test design, three instructional models were compared: traditional instruction (Control Group (CG)), blended learning with digital tools Inquiry-Based Learning (IBL), and an ICT-supported production-task–based model Digital Learning Tasks (DLT). The study involved 156 students in grades 9–10 over a 16-week intervention. Academic achievement, critical thinking, and professional self-efficacy served as outcome variables, while online and offline behavioral indicators (learning management system activity, classroom engagement, and production-task reports) were analyzed as explanatory factors. The results show that both ICT-supported models significantly outperformed traditional instruction in academic achievement (Analysis of Variance (ANOVA), $p < 0.001$), critical thinking, and self-efficacy ($p < 0.001$). Regression analyses revealed that classroom engagement and the quality of production-task reports were the strongest predictors of academic performance ($\beta = 0.56–0.71$, $p < 0.01$), while baseline knowledge was significant only in the traditional model. The novelty of this study lies in reconceptualizing professionally oriented schooling as a behaviorally mediated learning process and empirically demonstrating how production-based tasks and behavioral indicators explain the effectiveness of ICT-supported instruction.**

***Keywords*—Information and Communications Technology (ICT)-supported learning, production tasks, academic performance, behavioral indicators, professionally oriented education**

I. Introduction

The rapid digital transformation of education has led to increased interest in learning models that combine Information and Communications Technology (ICT) tools with practice-oriented instructional strategies. Schools are expected not only to deliver theoretical knowledge but also to develop students' readiness for future professional activity through authentic learning experiences. ICT-supported learning models—particularly those integrating production tasks, simulations, and project work—create opportunities to connect curricular content with real-world applications, thereby enhancing students' engagement, problem-solving skills, and cognitive development [1, 2].

Despite the growing use of digital tools in schools, many implementations remain superficial and do not fully integrate ICT into the design of meaningful, production-oriented learning tasks. As a result, students' participation in practical activities is limited, and the pedagogical potential of ICT for developing critical thinking and self-regulation is underutilized. Previous studies have shown that ICT can enhance motivation and conceptual understanding, but there is limited empirical evidence on how different ICT-supported instructional models influence professionally oriented competencies in school settings [3, 4].

This study builds on activity theory and self-regulated learning theory, which emphasize meaningful action, autonomy, and reflection. ICT-supported environments allow students to work with interactive resources, engage in collaborative problem solving, and receive immediate feedback, while production tasks simulate authentic professional processes. Together, these approaches create a dynamic learning environment that integrates theory with practice [5].

A key gap in the literature is the lack of comparative research evaluating distinct ICT-supported models within the same educational context, as well as the limited evidence on how students' behavioral activity—both online and offline—relates to academic outcomes. To address this gap, this study investigates three instructional models: (1) traditional teacher-centered instruction, (2) blended learning using digital platforms, and (3) an ICT-supported model based on production tasks.

Based on this, the study addresses the following research questions:

RQ1: How do ICT-supported learning models influence students' academic achievement, critical thinking, and professional self-efficacy compared to traditional instruction?

RQ2: How do the blended and production-oriented ICT models differ in their impact on students' cognitive and professional development?

RQ3: Which behavioral indicators (digital activity, classroom engagement, production-task performance) are associated with academic outcomes?

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Based on the research questions and theoretical framework, the following hypotheses were formulated:

H1: Students participating in ICT-supported learning models (Inquiry-Based Learning (IBL) and Digital Learning Tasks (DLT)) will demonstrate significantly higher academic achievement, critical thinking, and professional self-efficacy compared to students receiving traditional instruction (Control Group (CG)).

H2: The blended learning model (IBL) will have a stronger effect on the development of critical thinking, whereas the production-oriented model (DLT) will have a stronger effect on professional self-efficacy.

H3: Students' academic achievement in ICT-supported learning environments will be significantly associated with behavioral indicators, including classroom engagement and the quality of production-task performance, rather than with baseline knowledge alone.

In this study, professionally oriented education is understood as school-level instruction that integrates subject learning with applied, practice-based activities designed to simulate elements of real professional or engineering contexts. Although the participants were students in grades 9–10 of general secondary schools, the instructional design emphasized applied problem solving, modelling, project work, and production-like tasks aligned with prospective professional domains such as engineering, computer science, and technical sciences. Unlike traditional subject-centered instruction, professionally oriented education prioritizes not only conceptual understanding but also the application of knowledge in authentic, task-based scenarios reflecting real-world professional practices.

The contribution of this study lies in reconceptualizing professionally oriented school education as a behaviorally mediated learning process within ICT-supported environments. Rather than focusing solely on comparisons between instructional formats, the study emphasizes the role of students' behavioral engagement—manifested through digital interaction, classroom participation, and production-task performance—as a key explanatory mechanism underlying learning effectiveness. By integrating production-based instruction with learning analytics in a quasi-experimental school context, the study provides empirical evidence on how ICT-supported environments translate behavioral engagement into cognitive and professional learning outcomes.

Within this framework, production tasks are understood as structured, multi-stage learning assignments that require students to design, model, simulate, or analyze solutions using digital tools, followed by reflective reporting and evaluation. These tasks serve as a core instructional mechanism linking theoretical content with practical, professionally relevant activity.

This study contributes to the field by systematically evaluating multiple ICT-supported learning models in a professionally oriented school setting and identifying behavioral factors linked to students' academic performance.

Although traditional, blended, and production-oriented learning models have been extensively examined in prior research, existing studies predominantly focus on instructional formats or digital tools in isolation. The conceptual innovation of the present study lies not in proposing new learning models, but in reconceptualizing professionally oriented schooling as a behaviorally mediated learning process, in which academic and professional outcomes emerge through students' active engagement in ICT-supported production tasks.

This study uniquely integrates career-oriented instruction with learning analytics, combining online and offline behavioral indicators to explain learning outcomes in a professionally oriented school context. By shifting the analytical focus from which learning model is more effective to which behavioral mechanisms explain effectiveness within ICT-supported environments, the study provides a theory-driven explanation of how digital engagement, classroom activity, and production-task performance jointly contribute to academic achievement, critical thinking, and professional self-efficacy.

The theoretical foundation of the study draws on activity theory and self-regulated learning theory. Within this framework, academic achievement, critical thinking, and professional self-efficacy are viewed as outcomes emerging from students' purposeful engagement in tool-mediated activities. Behavioral indicators such as classroom participation, task performance, and digital interaction are therefore conceptualized as mediating variables rather than peripheral measures.

II. Literature Review

This section reviews key scientific sources on ICT-supported learning models in professionally oriented school education, with attention to production tasks and learning analytics. Prior research shows that digital tools, blended instruction, and interactive simulations improve academic achievement, motivation, and student engagement; however, many implementations remain fragmented and insufficiently connected to practice-oriented tasks. Studies emphasize that meaningful integration of ICT with authentic, production-based activities strengthens functional literacy and 21st-century competencies [6].

A body of work highlights the value of production-oriented and project-based tasks in supporting critical thinking, collaboration, and independent decision-making. Virtual laboratories, simulators, and digital platforms enhance students' capacity to apply theoretical knowledge to realistic scenarios. Effective implementation requires pedagogical conditions that structure tasks, scaffold collaboration, and provide timely feedback.

Research on Learning Analytics (LA) demonstrates that behavioral indicators—digital engagement, task completion, and interaction patterns—can help explain or predict academic outcomes [7–9]. Classic studies in educational data mining and Problem-Based Learning (PBL) show that multimodal data combined with authentic problem solving deepens cognitive engagement and supports adaptive instruction [10, 11]. These findings form the international foundation for examining ICT-supported models with production tasks.

Despite progress, significant gaps remain. Many studies examine digital tools in isolation rather than as part of a systemic professionally oriented model [12]. Empirical quasi-experimental research comparing distinct ICT-supported models—traditional, blended, and production-task–oriented—remains limited. The influence of online and offline behavioral indicators on learning outcomes is also underexplored, particularly in contexts where production tasks play a central role. While blended and online approaches often produce stronger outcomes than traditional instruction [13, 14], most studies focus on theoretically oriented subjects. Less is known about ICT-supported approaches in disciplines requiring real-world applications, such as computer science, physics, and mathematics.

Student-centered models integrating ICT, simulations, and production tasks have shown consistent benefits for motivation, practical competencies, and creative problem solving [15, 16]. Such environments facilitate autonomy, collaboration, and deeper engagement, aligning with constructivist and self-regulated learning theories. Production-task models, in particular, promote analytical and engineering thinking through activities involving measurement, modelling, prototyping, and evaluation [17, 18].

Learning analytics research further indicates that combining online indicators (platform activity, test performance, digital interactions) with offline indicators (project participation, practical task execution) provides more accurate insights into learning processes than digital data alone [19, 20]. These hybrid datasets support early identification of learning difficulties and contribute to personalized learning pathways. However, their use in professionally oriented schooling remains underdeveloped, especially where production tasks are central components of learning.

To clarify the theoretical distinctions between the three learning models, this study adopts a comparative conceptual framework grounded in contemporary learning theories. Traditional instruction (CG) primarily reflects a transmission-oriented pedagogy, where learning outcomes largely depend on prior knowledge and teacher-directed explanations, often resulting in elevated extraneous cognitive load.

The blended learning model (IBL) aligns with constructivist and self-regulated learning theories by redistributing cognitive load through pre-class digital preparation and in-class collaborative activities. This structure supports deeper cognitive processing, reflection, and analytical reasoning.

The ICT-supported production task–based model (DLT) extends constructivist principles toward an activity-based learning system. In this model, learning occurs through tool-mediated professional action, where students engage in authentic problem solving, modelling, simulation, and reflective reporting. As a result, cognitive development and professional self-efficacy are mediated by meaningful behavioral engagement rather than by instructional format alone. The theoretical distinctions between the traditional, blended, and production task-based learning models are summarized in Table 1, which presents a comparative conceptual framework highlighting differences in learning theory orientation, cognitive load structure, learner agency, and expected educational outcomes.

Although prior research confirms the benefits of ICT-supported and blended learning, most studies examine digital tools or instructional formats in isolation, with limited attention to production-based tasks as central learning mechanisms. Similarly, learning analytics research predominantly focuses on online behavioral traces, often neglecting offline and practice-oriented activities.

As a result, there remains a lack of empirical evidence explaining how online and offline behavioral indicators jointly mediate learning outcomes in professionally oriented school education. This gap underscores the need for comparative studies that integrate production-task–based instruction with learning analytics to identify the behavioral mechanisms underlying academic achievement, critical thinking, and professional self-efficacy—an issue directly addressed in the present study.

Table 1. Comparative conceptual framework of the three learning models

Dimension	Traditional (CG)	Blended (IBL)	Production-based (DLT)
Dominant learning theory	Transmission-oriented	Constructivist/ Self-regulated learning	Activity-based constructivism
Cognitive load profile	High extraneous load	Reduced extraneous load	Productive germane load
Learner agency	Low	Moderate	High
Role of ICT	Supplementary	Organizational and interactive	Tool-mediated professional action
Dominant behaviors	Attendance, prior knowledge	Online tests, class participation	Production reports, problem solving
Expected outcomes	Knowledge reproduction	Analytical understanding	Professional self-efficacy and applied competence

III. Research Methodology

A. Research Design

A quasi-experimental pre-test/post-test design was used with three intact class groups assigned to CG, IBL, and DLT models. This approach preserved ecological validity where randomization was not feasible. Fig. 1 presents the overall design.

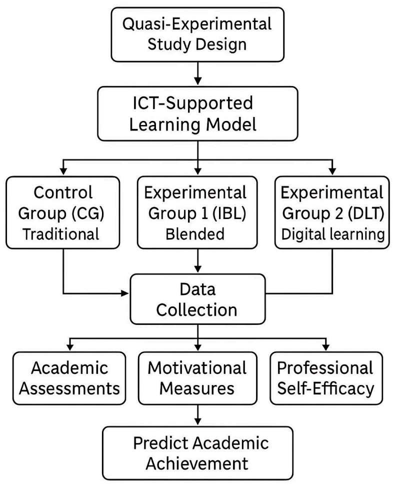

Fig. 1. Quasi-experimental study design.

B. Study Participants

The study involved 156 students (grades 9–10) from three schools. CG (n = 52) followed traditional instruction, IBL (n = 51) used blended learning, and DLT (n = 53) engaged in ICT-supported production tasks. Cluster sampling preserved natural class structure.

C. Learning Implementation

Each model used the same curriculum but different instructional structures (Fig. 2).

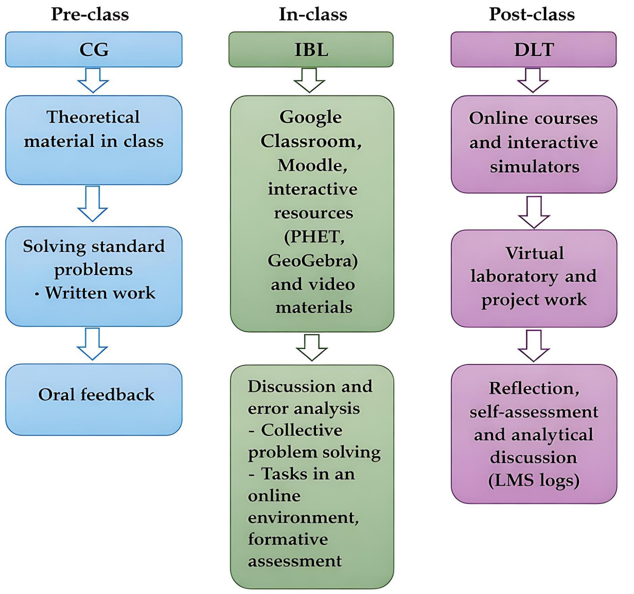

Fig. 2. The differences in the structure of educational processes.

- CG: lecture-based, minimal ICT.
- IBL: flipped format with digital pre-class preparation.
- DLT: ICT-supported production tasks using simulations, modelling, and prototyping tools.

Examples include PhET simulations (physics), regression modelling in GeoGebra (mathematics), and Tinkercad prototyping (computer science). These standardized tasks ensured comparability.

D. Instruments

- Academic Achievement Test—curriculum-based.
- Critical Thinking Disposition Scale (CTDS)—adapted from [21, 22].
- General Self-Efficacy Scale (GSES)—adapted from [23]. Reliability in this study exceeded $\alpha = 0.80$.

E. Behavioral Indicators

Eight indicators were recorded through Learning Management System (LMS) logs and classroom observations (Table 2). All were normalized to [0–1] and used as predictors in RQ3 regression analyses.

Production Task Report (K6) represents students' performance on ICT-supported production tasks and serves as a key behavioral indicator of professionally oriented activity. In this study, production tasks are defined as structured, practice-oriented assignments that require students to design, model, simulate, or analyze solutions resembling real professional or engineering processes. Unlike routine practical exercises, these tasks involve multiple stages, including problem formulation, tool-based implementation, interpretation of results, and reflective reporting.

Each production task was evaluated using a standardized scoring rubric assessing four criteria: (1) accuracy of the solution, (2) methodological correctness, (3) clarity of reasoning and explanation, and (4) completeness of the final report. Each criterion was rated on a proportional scale, and the total score ranged from 0 to 100. This operationalization ensured comparability across subject domains and distinguished production-task performance from general classroom activity.

Table 2. Description of variables in the study of ICT-supported learning with production tasks

Code	Variable	Description	A source	Range
K1	Online tests	Weekly digital tests that assess students' readiness for classes through tasks with choosing an answer and filling in the gaps.	Online	[0–100]
K2	Time to watch educational videos	The total time spent by students watching educational videos on Google Classroom, Moodle, and YouTube platforms.	Online	[0–1]
K3	Number of page clicks (Page Views)	The total number of page views of the digital course and interactive simulations (PhET, GeoGebra).	Online	[0–1]
K4	Initial level of training	Final grade for the previous semester in the relevant subject (computer science, mathematics, physics); used as a base variable (pre-test).	Offline	[0–100]
K5	Activity in the lesson	A score that reflects the student's participation in discussions, demonstrations, and work with digital tools in the classroom.	Offline	[0–1]
K6	Production Task Report	A weekly report that is evaluated according to the criteria of accuracy, clarity, and completeness of the assignment.	Offline	[0–100]
K7	Project and team activity	Assessment of students' work as part of project teams in the implementation of ICT-supported production tasks (according to the assessment of teachers and peers).	Combined	[0–100]
K8	Involvement in problem solving	The level of student participation in the collective analysis and solution of practical cases within the framework of problem-oriented learning (PBL).	Combined	[0–100]

F. Data Analysis

RQ1: Paired t-tests, Welch ANOVA, Tukey post-hoc.

RQ2: Kruskal–Wallis and Mann–Whitney for non-normal gain scores.

RQ3: Pearson correlations and multiple linear regression using standardized predictors K1–K8.

Assumptions (normality, variance, multicollinearity) were tested prior to analysis.

The regression models were used for explanatory purposes to identify behavioral factors associated with academic performance rather than for machine-learning–based prediction. Given the quasi-experimental design and the available sample size, no training-testing split or cross-validation procedures were applied. The reported regression models aim to explain variance in academic outcomes and to identify key behavioral predictors within each instructional condition, rather than to provide generalizable out-of-sample forecasts.

IV. Results

A. The Impact of ICT-Supported Learning Models on Academic Achievement, Critical Thinking, and Self-Efficacy

This subsection provides a detailed analysis of how different approaches based on the integration of ICT into vocational-oriented learning have affected student outcomes across three key indicators: academic achievement, critical thinking, and professional self-efficacy.

B. Impact on Students' Academic Performance

Before conducting a pedagogical experiment using ICT-integrated models, a Welch ANOVA analysis was performed, aimed at identifying the initial differences in the levels of academic training of students. The results showed no statistically significant differences between the three groups—F(2.89.21) = 0.592, p = 0.590, which indicates comparable starting conditions for all learning models. After the experimental conditions are implemented, the results of the t-test for related samples (see Table 3) showed that in all three groups there was a statistically significant improvement in the final indicators. However, the groups trained using the IBL and DLT models showed significantly higher results gains than the Control Group (CG), in which training was conducted according to the traditional scheme without active digital integration.

Table 3. Descriptive statistics and results of the paired t-test before and after the experiment

Group	N	Initial points (M ± SD)	Final scores (M ± SD)	The average varies	t(df)
CG	52	76.91 ± 7.74	81.08 ± 6.94	4.18	3.16(52)**
IBL	51	77.65 ± 7.85	86.67 ± 5.57	9.03	8.76(51)***
DLT	53	75.93 ± 12.19	85.55 ± 6.58	9.62	7.15(53)***

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Fig. 3 shows this dynamics clearly: in both experimental groups, steeper growth trajectories were observed from the pre-test to the post-test.

Shaded areas reflecting 95% confidence intervals show that improvements in ICT-integrated conditions were more pronounced and sustained compared to the control group.

Before comparing the groups, the prerequisites for the normality of the distribution and uniformity of variances were checked, both of which were confirmed ($p > 0.05$).

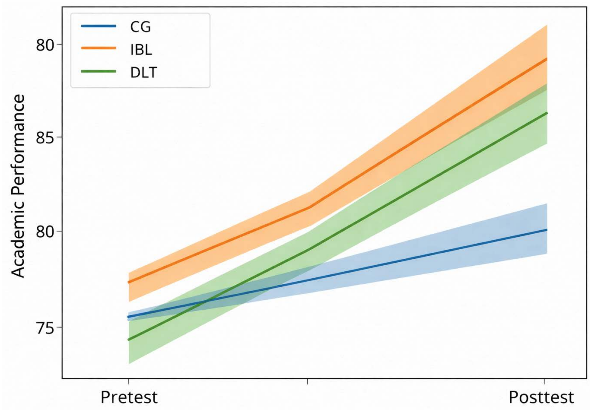

Fig. 3. Dynamics of changes in academic performance depending on the learning model (before and after the experiment).

Then a one-factor Analysis of Variance (ANOVA) was performed to assess the impact of the type of learning model on the final academic performance of students.

The results showed statistically significant differences between the three groups—F(2,167) = 8.89, $p < 0.001$. According to the results of the Tukey post-shock test (see Table 4), students in the IBL ($p < 0.001$) and DLT ($p = 0.003$) groups showed significantly higher results compared to the control group as a group. The differences between the experimental models themselves turned out to be statistically insignificant ($p = 0.539$).

The results convincingly show that the integration of ICT into the learning process significantly enhances students' academic achievements. Both mixed and problem-oriented models have proven effective in developing practice-oriented knowledge, professional orientation, and digital readiness of schoolchildren.

Table 4. The results of Tukey's post-hoc analysis of the final scores between the groups

Comparison	Average difference	95% Dynamics of changes	p-value
IBL vs. CG	5.59	[2.41, 8.77]	0.000
DLT vs. CG	4.46	[1.31, 7.61]	0.003
IBL vs. DLT	1.13	[−1.38, 3.63]	0.539

C. Differences between the Three ICT-Supported Learning Models in the Development of Critical Thinking and Professional Self-Efficacy of Students

This section is devoted to the results answering the question of the RQ2 study and is aimed at analyzing the differences between the three learning models—traditional (CG), mixed (IBL) and practice-oriented with production tasks (DLT)—in the development of critical thinking and professional self-efficacy of schoolchildren. In the framework of this study, self-efficacy is considered as a cognitive construct reflecting students' conscious assessment of their abilities to perform educational and practical tasks using digital tools. Since the distribution of gain scores for critical thinking and self-efficacy did not meet the criterion of normality, the nonparametric Kruskal–Wallis H test was used to test the overall intergroup differences.

Table 5. Comparison of critical thinking and self-efficacy gains between groups

Variable	Group Comparison	The Median (Md)	Z- meaning	Effect size (r)	The level of significance
Critical thinking	DLT vs CG	6.40 vs 2.10	−4.512***	0.471	$p < 0.001$
	IBL vs CG	8.90 vs 2.10	−4.772***	0.498	$p < 0.001$
	DLT vs IBL	6.40 vs 8.90	−0.628	0.056	*n.s.*
Self-efficacy	DLT vs CG	11.80 vs 4.30	−3.952***	0.422	$p < 0.001$
	IBL vs CG	6.10 vs 4.30	−2.381*	0.243	$p < 0.05$
	DLT vs IBL	11.80 vs 6.10	−2.295*	0.214	$p < 0.05$

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

The results showed statistically significant differences between the three learning models in both critical thinking (H = 24.918, $p < 0.001$) and self-efficacy (H = 18.202, $p < 0.001$). This indicates that different ICT-supported learning models had different effects on students' cognitive development. Taking into account the differences obtained, a pairwise analysis was performed using the Mann–Whitney U test to clarify the differences between specific groups. The summary data is shown in Table 5, which shows the median values, Z statistics, and effect sizes (r).

Fig. 4 clearly illustrates the distribution of incremental values in terms of critical thinking and self-efficacy. Visually, it can be seen that the students in the Control Group (CG) had minimal improvements, while the IBL and DLT groups showed significantly higher results. In terms of critical thinking, the IBL and DLT groups showed similar results and both significantly outperformed the control group.

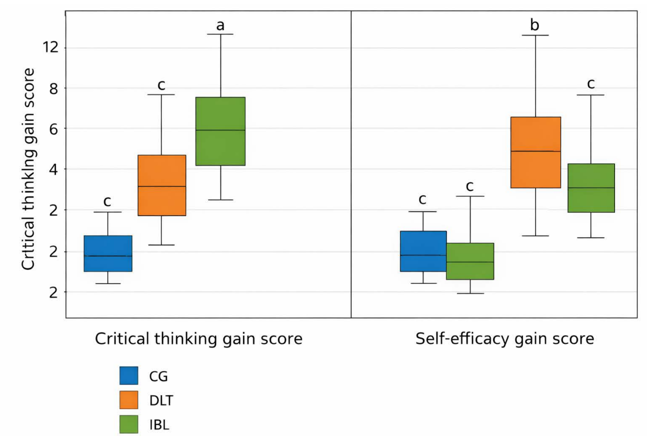

Fig. 4. The influence of learning models on the growth of critical thinking and self-efficacy.

With regard to self-efficacy, there was a clear sequence: DLT > IBL > CG, which indicates a more pronounced influence of the production-based model on the development of confidence and professional self-regulation of students.

In the diagram, the letters (a, b, c) indicate statistical differences:

- identical letters—the differences are insignificant ($p > 0.05$);
- different letters—the differences are significant ($p < 0.05$).

In summary, the results of the analysis showed that:

- Both ICT-supported models (IBL and DLT) significantly outperform traditional training (CG) in developing critical thinking and professional self-efficacy;
- The differences between IBL and DLT in critical thinking have not reached statistical significance, indicating comparable effectiveness in the development of cognitive skills;
- At the same time, the DLT model based on production tasks has demonstrated the greatest effect on students' self-effectiveness, increasing their confidence in completing educational and practical tasks and readiness for professional activity.

D. Online and Offline Student Behavior and Academic Performance under Various ICT-Supported Learning Models

Academic performance is one of the key indicators of the effectiveness of the educational process, and the analysis of the factors influencing it is crucial for improving pedagogical strategies. This study examines how online and offline behavioral indicators of students influence the explanatory analysis of their academic achievements in the context of three ICT-supported learning models: traditional (CG), mixed (IBL) and practice-oriented with production tasks (DLT).

E. Correlation between Learning Behavior and Academic Success

To identify the relationships between students' behavioral variables (K1–K8, see Table 1) and their final academic results, a Pearson correlation analysis was performed for each learning model (CG, IBL, DLT). The data obtained showed marked differences in the structure of correlations between the models (Fig. 5).

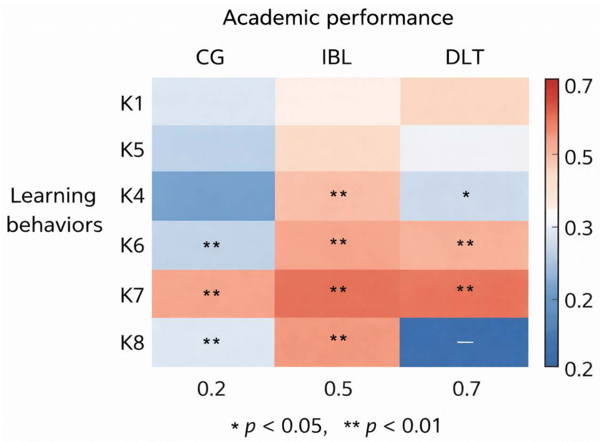

Fig. 5. A diagram of standardized coefficients and confidence intervals (95%) for three learning models.

Fig. 5 presents a heat map of Pearson correlation coefficients illustrating the relationships between behavioral indicators and academic performance, with statistically significant correlations indicated at $p < 0.05$ and $p < 0.01$.

In the IBL group, most behavioral indicators showed moderate to strong positive associations with final academic performance. The correlations between:

- the results of online tests (K1) ($r = 0.412$**),
- the initial level of training (K4) ($r = 0.389$**) were particularly pronounced,
- activity in the lesson (K5) ($r = 0.675$**),
- reports on production tasks (K6) ($r = 0.598$**),
- and project activity (K7) ($r = 0.602$**).

This indicates that in blended learning, the level of participation in digital and collective forms of activity significantly affects academic outcomes.

In the DLT group using production tasks, the greatest correlations were observed between:

- activity in the lesson (K5) ($r = 0.771$**),
- reports on production tasks (K6) ($r = 0.543$**),
- and online tests (K1) ($r = 0.362$**).

At the same time, involvement in solving problematic tasks (K8) showed a weak but positive relationship ($r = 0.119$, $p = 0.112$), which may indicate the influence of external factors—the level of readiness, the quality of facilitation and the complexity of tasks.

There were fewer significant associations in the Control Group (CG). Only the following were statistically significant:

- initial level of preparation (K4) ($r = 0.472$**),
- and activity in the lesson (K5) ($r = 0.459$**).

The task reports (K6) showed a negative correlation ($r = –0.281$), which indicates poor quality of performance and weak student engagement in the traditional form of learning.

F. Multiple Regression Analysis of Factors Associated with Academic Performance

Multiple linear regression analysis was performed to examine the explanatory contribution of behavioral variables within each learning model.

Before the analysis, the Variance Inflation Coefficients (VIF) were checked, which in all cases were below 5, which confirms the absence of multicollinearity.

Table 6 contains standardized regression coefficients (β) and model quality indicators (R^2 and adjusted R^2) for each group, and Fig. 5 visualizes the comparative values of β and confidence intervals (95%).

Table 6. Explanatory contribution of behavioral variables to academic performance

Variables	CG (β)	IBL (β)	DLT (β)
K1 Online tests	0.085	0.192**	0.009
K2 Video viewing time	0.021	–0.048	–0.015
K3 Number of page views	0.168	0.071	–0.082
K4 Initial level of training	0.537**	–0.093	0.131
K5 Activity in the lesson	0.398**	0.563**	0.712**
K6 Production Task Report	–0.295*	0.327**	0.371**
K7 Project activity	——	0.287**	——
K8 Involvement in problem solving	——	——	0.136*
R²	0.559	0.818	0.786
Adjusted R²	0.453	0.801	0.759

In the Control Group (CG), the baseline level of preparation (K4) ($\beta = 0.537$**) and activity in the lesson (K5) ($\beta = 0.398$**) turned out to be significant predictors, while the task report (K6) had a negative impact ($\beta = –0.295$*). The model explained about 45.3% of the variance of the final results (Adjusted $R^2 = 0.453$).

In the mixed group (IBL), activity in the lesson (K5) ($\beta = 0.563$**), task report (K6) (β = 0.327**), online tests (K1) ($\beta = 0.192$**) and project activity (K7) ($\beta = 0.287$**). The regression model showed substantial associations between behavioral indicators and academic performance, indicating that multimodal learning analytics can offer meaningful, though preliminary, explanatory insights (Adjusted $R^2 = 0.801$).

In the practice-oriented group (DLT), activity in the lesson (K5) ($\beta = 0.712$**), a report on production tasks (K6) ($\beta = 0.371$**) and involvement in problem solving (K8) ($\beta = 0.136$*, $p < 0.05$) had the greatest impact. The model explained about 75.9% of the variance of the final results (Adjusted $R^2 = 0.759$).

To illustrate the explanatory consistency of the regression models, graphs were constructed comparing the actual and model-estimated values of academic performance. The proximity of the data points to the diagonal line reflects the extent to which the models explain variance in observed outcomes within each instructional condition (Fig. 6). The dotted diagonal line ($y = x$) indicates an ideal match between model-estimated and observed values: the closer the points are to the line, the higher the accuracy of the model.

The IBL and DLT models demonstrated stronger model fit and higher explained variance compared to the traditional model. The IBL model demonstrated particularly stable results, where deviations are minimal for both low- and high-achieving students. At the same time, the Control Group (CG) was characterized by a wider range of values, especially at the extreme parts of the scale, which indicates a lower explanatory robustness of the model.

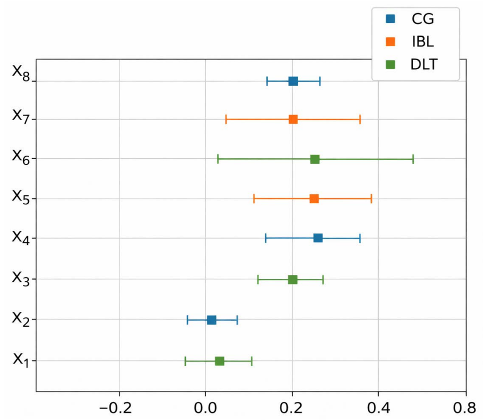

Fig. 6. Comparison of predicted and actual results for three learning models.

The results of the analysis showed that:

- academic performance of schoolchildren is significantly associated with a combination of online and offline behavioral indicators;
- The mixed (IBL) and practice-oriented (DLT) models demonstrate stronger explanatory associations compared to the traditional model;
- Student engagement in the classroom (K5) and the quality of assignment reports (K6) are the strongest in explaining variance in academic achievement outcomes, especially when integrating production tasks and digital tools.

V. Discussion of the Results

Rather than reiterating empirical results, this discussion interprets the findings through the lens of learning theory. The observed differences between the three learning models indicate that learning outcomes are not determined solely by instructional format, but by the behavioral mechanisms activated within each ICT-supported environment. From a theoretical perspective, the effectiveness of the IBL and DLT models can be explained by their alignment with constructivist, self-regulated, and activity-based learning theories.

A. Effectiveness and Comparative Analysis of ICT-Supported Learning Models

In accordance with the RQ1 research questions and the H1 hypothesis, the results confirm that the mixed (IBL) and practice-oriented (DLT) learning models significantly outperform the traditional (CG) in all key indicators—academic achievement, critical thinking and professional self-efficacy of students.

As shown in Tables 2 and 4, as well as in Figs. 3 and 5, students from the IBL and DLT groups demonstrated higher final results with large effect sizes (Cohen's $d = 0.78–0.81$, $p < 0.001$), which was confirmed by the results of the t-test and post-hoc analysis. These data are consistent with the findings of modern meta-studies showing that the use of digital and interactive technologies increases engagement, depth of learning, and motivation.

The IBL model, based on blended learning with inverted classroom elements [24], encourages meaningful learning and active participation through pre-digital preparation and subsequent collective discussion.

The DLT model, in turn, is focused on performing production and design tasks that simulate real professional contexts, which develops independence, research and engineering skills [25].

The results show that the integration of ICT into professionally oriented schooling increases not only academic results, but also students' confidence in applying knowledge in practice.

B. Differentiated Effects of IBL and DLT Models on Critical Thinking and Self-Efficacy

According to RQ2 and H2, both experimental models demonstrated a positive effect on the development of critical thinking and self-efficacy compared to the traditional group. However, their effect varied in focus.:

- The IBL model has proven to be more effective in developing critical thinking,
- and the DLT model is used in the formation of students' professional self-efficacy.

These differences can be explained from the perspective of constructivist learning theory and cognitive load theory [26].

The stronger impact of the IBL model on critical thinking development may be explained by self-regulated learning theory. Pre-class digital preparation reduces extraneous cognitive load and enables students to engage in higher-order analysis during in-class activities, facilitating deeper conceptual understanding. In contrast, the superior effect of the DLT model on professional self-efficacy can be explained through Bandura's self-efficacy theory and activity theory. Engagement in authentic production tasks provides students with mastery experiences, social modeling, and reflective feedback, which collectively strengthen confidence in applying knowledge to professional contexts. The traditional model, by comparison, demonstrates a stronger dependence on prior knowledge, consistent with cognitive load theory. In the absence of structured ICT support and reflective task design, learning outcomes remain constrained by students' initial level of preparation.

The IBL model reduces the external cognitive load by pre-training students, which contributes to deeper information processing and the development of analytical thinking [27, 28].

While the DLT model, which focuses on solving real production tasks, develops internal motivation and self-confidence through practical activities and social interaction [29, 30].

According to Bandura's theory of self-efficacy, practical problem solving and collective discussion increase students' confidence by:

1) Personal experience of success—performing real production tasks contributes to a sense of competence;
2) Social modeling—joint project execution and peer support form positive expectations of success;
3) Reflective assessment of progress—awareness of one's own growth increases intrinsic motivation.

C. Online and Offline Behavior of Students as Explain Variance in Academic Achievement

The results obtained fully confirm RQ3 and H3. Regression analysis has shown (Table 5, Figs. 5 and 6) that the combination of online and offline behavioral indicators of students makes it possible to provide meaningful explanatory insights into the behavioral factors associated with academic performance in the context of ICT-integrated learning.

Importantly, the regression results indicate that academic performance in ICT-supported environments is primarily mediated by behavioral engagement, rather than by baseline knowledge. Classroom activity and the quality of production-task reports emerged as the most consistent explanatory factors across models. These indicators represent cognitively meaningful engagement rather than superficial digital activity, supporting the argument that learning analytics should focus on behaviorally rich indicators when evaluating professionally oriented learning.

The most significant predictors in all models were activity in the lesson (k_5) and the quality of work assignment reports (k_6), which positively correlated with final academic performance in all groups. In the IBL and DLT groups, these indicators had the highest standardized coefficients (β = 0.563–0.712, p < 0.01), which emphasizes the role of active participation, feedback, and project activities in improving learning outcomes.

In the Traditional Group (CG), task reports (k_6) showed a negative impact (β = –0.295*, p < 0.05), which may indicate the formal nature of completing tasks without the inclusion of reflection mechanisms. This discrepancy confirms the provisions of the cognitive load theory, according to which poorly integrated tasks increase the external load and reduce the quality of knowledge acquisition.

Interestingly, the initial level of training (k_4) was a significant predictor only in the CG model (β = 0.537)**, reflecting the dependence of the results on previous knowledge in the traditional environment. On the contrary, in ICT-integrated models, this effect is reduced due to the creation of an inclusive and adaptive educational environment, where academic achievement depends on activity and interaction, and not only on basic training.

Online tests (k_1) proved to be significant only in the IBL model (β = 0.192**, p < 0.01), which confirms their role as a tool for operational control and self-regulation. Other online indicators (pageviews and videos) had no significant impact, which is due to their superficial nature—they reflect access, but not the depth of cognitive interaction.

Engagement in problem solving (k_8) showed a moderate effect only in the DLT model (β = 0.136, p < 0.05)**, confirming that systematic group work on practical cases is a key mechanism for successful learning.

The results of the study demonstrate that:

1) The integration of ICT and production tasks significantly increases the effectiveness of professionally oriented schooling.
2) The DLT model promotes the growth of self-efficacy and professional readiness, while the IBL model develops analytical and critical thinking more effectively.
3) The analysis of online and offline behavior of students makes it possible to predict academic results early and personalize educational trajectories.

These findings confirm that ICT-supported learning models with production tasks create a pedagogical basis for the formation of sustainable motivation, professional identity and cognitive maturity of students—key characteristics of education in the 21st century.

D. Dialogue with Existing Research

The findings of this study are broadly consistent with existing research emphasizing the positive role of ICT integration in enhancing student engagement, learning outcomes, and practical skill development. Previous studies have demonstrated that ICT-supported learning environments, particularly when combined with applied or project-based activities, contribute to improved academic achievement and professional competencies [6, 13, 24]. The present results confirm this conclusion by showing that both blended (IBL) and production-oriented (DLT) models significantly outperform traditional instruction across academic achievement, critical thinking, and self-efficacy.

At the same time, this study extends prior research by identifying behavioral mechanisms through which ICT-supported learning models exert their effects. While earlier studies primarily focused on instructional formats or digital tools themselves, the present findings demonstrate that learning effectiveness is mediated by students' classroom participation and the quality of production-task reports. This contribution complements existing conclusions regarding the effectiveness of ICT-enhanced instruction by providing an explanatory behavioral layer linking instructional design to learning outcomes.

The differentiated effects observed between the IBL and DLT models are also consistent with, yet extend, previous research. Studies on blended learning have reported its positive impact on critical thinking and deep cognitive processing due to pre-class preparation and active in-class engagement [15, 28]. The stronger effect of the IBL model on critical thinking observed in this study aligns with these findings. Conversely, research on practice-oriented and production-based learning has emphasized its role in developing professional skills, motivation, and self-efficacy [24]. The superior effect of the DLT model on professional self-efficacy observed in this study supports these conclusions while further demonstrating that authentic production tasks function as a key mechanism for building confidence in applying knowledge to real-world contexts.

Thus, the present study contributes to the existing literature not by proposing new instructional models, but by clarifying how and why different ICT-supported learning models produce distinct educational outcomes. By integrating learning analytics and behavioral indicators into the analysis, the study advances current research by shifting the focus from instructional formats to behaviorally mediated learning processes, thereby offering a more comprehensive explanation of learning effectiveness in professionally oriented school education.

E. Limitations

This study has several limitations that should be acknowledged.

First, the quasi-experimental design did not allow full randomization of participants, which may limit internal validity. Second, teacher-related factors and instructional style may have influenced student outcomes, despite attempts to standardize procedures. Third, the measures of critical thinking and self-efficacy relied partly on self-report instruments, which may introduce response bias. Fourth, the LMS behavioral data used for learning analytics captured only observable digital actions and may not fully reflect students' cognitive engagement. Finally, the study was conducted in three schools within a specific regional context in Kazakhstan, which may limit generalizability. Future research should consider multi-site randomized studies and additional qualitative measures.

From a policy perspective, the findings suggest that school-level implementation of ICT-supported learning should prioritize structured production tasks and active classroom engagement rather than passive digital content delivery. Educational administrators may use behavioral learning analytics to inform curriculum planning, teacher professional development, and early identification of students requiring pedagogical support.

VI. Conclusion

This quasi-experimental study demonstrates that ICT-supported learning models, particularly those integrating production-based tasks, significantly enhance academic achievement, critical thinking, and professional self-efficacy in professionally oriented secondary education. The findings show that learning effectiveness is primarily mediated by students' behavioral engagement—especially classroom activity and production-task performance—rather than by baseline knowledge alone.

The study contributes by empirically linking production-task–based instruction with learning analytics and demonstrating that behavioral engagement functions as the primary explanatory mechanism of learning effectiveness in ICT-supported school environments. A limitation of the study is its quasi-experimental design and regional sample, which may restrict generalizability. Future research should extend this approach across disciplines and educational contexts using mixed methods and multi-site designs.

From a practical and policy perspective, the findings support the integration of ICT-supported, production-oriented learning models into professionally oriented school curricula. Such models provide a scalable framework for aligning academic learning with labor market–relevant competencies, while enabling data-informed instructional decision-making through the use of learning analytics at both school and system levels.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Gulzhuzim Mendigaliyeva, Tamara Karazhigitova, and Zhupar Bilyalova conducted the literature search, analyzed the data and wrote the paper. Zhanargul Kabylkhamit, Smagulov Yessengali, and Maxot Rakhmetov visualized the data and reviewed the manuscript. All authors have accepted the final version of the manuscript.

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