MOLDOVA STATE UNIVERSITY
DOCTORAL SCHOOL OF HUMANITIES AND EDUCATION

CONSORTIUM: Moldova State University, "Alecu Russo" State University of Balti, "Bogdan Petriceicu Hasdeu" State University of Cahul.

As a manuscript
C.Z.U.: 373.5.02:004:51(043.2)

BRĂNOAEA GABRIELA – CRISTINA

INTELLIGENT SUPPORT SYSTEM FOR ACCELERATING MATHEMATICS ACHIEVEMENT IN HIGH SCHOOL STUDENTS

532.02. SCHOOL DIDACTICS
(BY STAGES AND EDUCATIONAL DISCIPLINES)

Summary of the Doctoral Thesis in Educational Sciences

CHIȘINĂU, 2026

The Doctoral Thesis was developed within the Doctoral School of Humanities and Education of Moldova State University.

Scientific Supervisor: BRAICOV Andrei, dr., prof. univ.

Scientific Supervisor by co-guardianship: BRAGARU Tudor, dr., prof. univ.

Members of the Advisory Committee:

1. GOLUBIŢCHI Silvia, dr. hab., prof. univ.
2. MARIN Maria, dr., conf. univ.
3. VEVERIŢĂ Tatiana, dr., conf. univ.

Public Defence Committee of the Doctoral Thesis:

President – GUŢU Vladimir, dr. hab., prof. univ., Moldova State University
Scientific Supervisor – BRAICOV Andrei, dr., prof. univ., „Ion Creangă" State Pedagogical University of Chisinau
Scientific Supervisor by co-guardianship – BRAGARU Tudor, dr., prof. univ., Moldova State University
Referent 1 – COZMA Dumitru, dr. hab., prof. univ., „Ion Creangă" State Pedagogical University of Chisinau
Referent 2 – ZASTÎNCEANU Liubov, dr., conf. univ., „Alecu Russo" State University of Balti
Referent 3 – MARIN Maria, dr., conf. univ., Moldova State University

The defense will take place on 11 September 2026, at 14:00, during the public session of the Doctoral Commission within the Doctoral School of Humanities and Education of the Moldova State University, in Room 505, Study Building No. 3, Moldova State University, located at 65A M. Kogălniceanu Street, MD-2009, Chişinău, Republic of Moldova.

The Doctoral thesis and summary may be consulted at the National Library of the Republic of Moldova, the Central Library of the Moldova State University and on the National Agency for Quality Assurance in Education and Research website.

The abstract was submitted on 17 June 2026.

Author: **BRĂNOAEA Gabriela Cristina** _____

Scientific Supervisor: **BRAICOV Andrei**, dr., prof. _____

Scientific Supervisor by co-guardianship: **BRAGARU Tudor**, dr., prof. univ. _____

President of the Doctoral Committee: **GUŢU Vladimir,** dr. hab., prof. univ. _____

TABLE OF CONTENTS

CONCEPTUAL FRAMEWORK OF THE THESIS 2

CONTENT OF THE THESIS 6

1. THEORETICAL FOUNDATION OF INTELLIGENT EDUCATIONAL SUPPORT SYSTEMS 6
2. PEDAGOGICAL AND TECHNOLOGICAL DEVELOPMENT OF THE INTELLIGENT SUPPORT SYSTEM 9
3. VALIDATION OF THE INTELLIGENT SUPPORT SYSTEM IN LOWER SECONDARY EDUCATION 18

GENERAL CONCLUSIONS AND RECOMMENDATIONS 25

BIBLIOGRAPHY (SELECTIVE) 29

LIST OF THE AUTHOR'S PUBLICATIONS ON THE THESIS TOPIC 31

ANNOTATION 32

ADNOTARE 34

АННОТАЦИЯ 35

CONCEPTUAL FRAMEWORK OF THE THESIS

Keywords: Digital education, FOSS (Free and Open Source Software), parameterized items, lower secondary mathematics, mathmentor.ro, didactic model, Moodle platform, intelligent digital educational resources (REDI), adaptive feedback, intelligent support system (ISS).

Relevance and importance of the research topic. The transformations of contemporary society, marked by digitalization and the knowledge economy, require a reconsideration of the role of education and the evolution of assessment from a summative function to a formative one, oriented toward regulating learning and developing competencies *(Black & Wiliam, 2009).* The COVID-19 pandemic has highlighted both the limitations and the potential of digital education, particularly regarding access and the quality of online assessment *(Hodges et al., 2020).* In this context, the necessity of integrating digital technologies and intelligent systems into education becomes evident in order to personalize learning and support adaptive feedback *(Beldiga & Bragaru, 2025; Hattie & Timperley, 2007; Holmes et al., 2019; Marin, 2017).* The review of the specialized literature reveals a transition from traditional assessment models focused on measuring outcomes to modern approaches oriented toward regulating the learning process and developing competencies. Within the field of educational sciences, assessment is recognized as an integral component of instruction, with formative and regulatory functions *(Cucoș, 2008; Potolea & Manolescu, 2005),* while contemporary perspectives emphasize its interactive nature and its alignment with teaching strategies *(Bocoș, 2013; Albulescu & Catalano, 2020).* In mathematics education, the focus shifts to the analysis of cognitive processes involved in problem-solving, the use of representations, and the development of mathematical thinking *(Singer, 2007),* in relation to the role of feedback and self-regulation in learning *(Neacșu, 2015).* In the context of educational modernization, assessment is approached as a student-centered process focused on competency development *(Guțu & Vicol, 2014),* and the integration of educational technologies expands the functionality of formative assessment through continuous progress monitoring and the provision of immediate feedback, contributing to the individualization of learning *(Dulamă, 2020).* The current state of knowledge highlights four major directions: the technological and pedagogical foundations of educational platforms, empirical evidence regarding their impact, implementation studies, and the critical evaluation of limitations *(Căpățână et al., 2015; Astafieva et al., 2024).*

The **object** of the research is the formative assessment process of students in learning mathematics, in the context of using modern educational technologies. The **subject** of the research is the didactic model of formative assessment based on an intelligent support system, as well as its associated pedagogical mechanisms, namely the use of parameterized items and adaptive feedback in the learning process of lower secondary mathematics.

The motivation for choosing this topic lies in its relevance for establishing the theoretical and methodological foundations of mathematics education, with the aim of concretely contributing to the optimization of teaching practices in the context of digital education.

The research identifies structural **contradictions** in the field: between traditional teaching practices and the imperatives of digitalization; between labor market requirements and the level of acquired competencies; between the necessity of integrating e-learning and the complexity of curricular change; as well as between the use of technology as a tool for replicating traditional teaching materials and its transformative potential. Consequently, a theoretical and practical gap is highlighted in school pedagogy regarding the implementation and validation of Intelligent Tutoring Systems (ITS) in pre-university education, particularly in mathematics.

The **scientific problem** consists in the existence of a discrepancy between the didactic potential of educational support systems based on intelligent digital assessment and the low level of their utilization in lower secondary mathematics learning, given the lack of validated implementation models in the pre-university context of Romania and the Republic of Moldova.

This discrepancy is not merely operational, but reflects an insufficient maturation of the conceptual and methodological framework for digital assessment in pre-university education.

The **purpose** of the thesis is to establish the theoretical and methodological foundation, elaborate, and experimentally validate a didactic model of formative assessment, operationalized through an Intelligent Support System (ISS), developed by integrating the Moodle platform with FOSS (Free and Open Source Software) plugins and Intelligent Digital Educational Resources (REDI), aimed at generating and automatically grading standardized assessments with adaptive feedback, in order to accelerate lower secondary students' acquisition of mathematical skills and to increase teaching efficiency. To achieve this goal, the following **objectives** are formulated:

1. Analysis of the theoretical and methodological framework regarding formative assessment and the use of intelligent educational support systems in mathematics teaching.

2. Comparison of the main learning management systems, in order to identify opportunities for integrating intelligent digital assessment in secondary education.

3. Design of the didactic model of formative assessment, based on pedagogical principles validated in the specialized literature.

4. Development of SSI, by integrating the Moodle platform with advanced FOSS plugins and developing intelligent digital educational resources.

5. Implementation of the didactic model and SSI, by conducting a quasi-experimental study in the real educational environment.

6. Validation of SSI, through quantitative analysis of student performance, through psychometric indicators specific to digital assessment and through qualitative analysis of participants' perceptions.

Research hypothesis: If lower secondary students use the intelligent support system (ISS) implemented on the Moodle platform, which integrates intelligent digital educational resources for formative assessment with automated feedback, then they will exhibit significant improvements in mathematical achievement, as compared to the traditional didactic strategy.

Scientific novelty and originality focus on updating and operationalizing the concept of formative assessment by integrating parameterized items and adaptive feedback within a didactic model based on an intelligent support system implemented on a proprietary digital platform, mathmentor.ro, with custom code. The proposed didactic model achieves synergy between the *pedagogical component* (educational objectives, didactic strategies, assessment and learning processes, teacher-student interactions) and the *technical component* (the ISS conceived as a digital ecosystem supporting the didactic process in lower secondary mathematics, through logical organization and orchestration of the advanced functionalities of the Moodle platform and FOSS plugins). Methodologically, lower secondary classes are characterized by cognitive heterogeneity and the need for individualized support, which requires systems capable of sustaining continuous formative assessment through ITS-type systems, as differentiated strategies increase learning efficiency by adapting content and tasks to students' levels, and modern educational technologies expand learning environments and facilitate the active integration of students in the educational process *(Astafieva et al., 2024; Zastînceanu, 2021).*

The adopted **research methodology** is mixed, constructed in accordance with international standards for experimental research, combining the IMRaD structure (Introduction, Methods, Results, and Discussion) with the principles of Design-Based Research (DBR). The research includes a quasi-experimental pedagogical design, structured in the stages of ascertaining (pre-test), formative intervention, control (post-test), and re-testing, aimed at verifying short- and medium-term retention. The methodological framework of the study is structured around three complementary categories of methods: *theoretical* (scientific documentation, critical literature review, conceptual modelling and instructional design), *empirical* (pedagogical experiment, analysis of student work products and assessment of student performance) and *statistical* (descriptive measures, pre–post differences, performance level distributions, Levene's test, Student's *t*-test and Cohen's *d*), using Microsoft Excel 365 — Analysis ToolPak. The quantitative findings are further complemented by a qualitative analysis (hermeneutic and pedagogical), based on perception questionnaires administered to both students and teachers via Google Forms.

The **theoretical significance** of the research lies in the coherent integration of formative assessment, educational feedback theory, the principle of individualized and differentiated interventions, and digital assessment into a unified model operationalized through an intelligent support system. The study draws upon the contributions of Black and Wiliam *(1998, 2009)* regarding the role of formative assessment in regulating learning, extending them through automated feedback mechanisms and digital assessment. Also, the research aligns with the paradigm of computer-assisted assessment *(Sangwin, 2013; Davies & Sangwin, 2024),* advancing it by introducing parameterized items and adaptive feedback within an integrated didactic framework *(Hattie & Timperley, 2007).* The model operationalizes concepts from educational psychology, such as the zone of proximal development *(Vygotsky, 1978),* by progressively adapting tasks based on students' responses, thus contributing to the transformation of the educational process in the digital environment.

The **applied value** of the research is demonstrated through the development of digital courses implemented on three Moodle platforms (USM, CEITI, mathmentor.ro), used in various real learning contexts. A key element of this applied value is represented by the methodological guides (for teachers and students), which facilitate technology transfer and the direct use of the system in practice. The implementation and validation of the research results (ISS) have been carried out in educational institutions in Romania and the Republic of Moldova. Curricular integration is evidenced by the development and official endorsement of elective courses at the discretion of schools, confirming the pedagogical relevance of the system. The adaptable nature of the ISS is supported by its involvement in the RO-MD transfer project, while its originality is demonstrated by the development of the author's website *mathmentor.ro.* Implementation also includes activities dedicated to students with special educational needs and those with high potential for school competitions, thereby highlighting the system's impact on both educational inclusion and school performance.

The **research results** have been validated through three articles published in international journals indexed in databases (one article in WOS, ESCI, IF 0.5, Q4; one in EBSCO; one published in proceedings of international conferences indexed in WOS ISI), three articles in national journals (two category B and one category C), participation in 24 scientific events, the majority of which were international, five medals at invention exhibitions, and intellectual property rights (AGEPI).

Overall, the research presents a coherent path from identifying the scientific problem to developing, implementing, validating, and transferring intelligent support systems in mathematics assessment, which optimizes learning, enhances evaluation objectivity and teaching efficiency, and aligns education with the needs of the digital society.

CONTENT OF THE THESIS

1. Theoretical foundation of intelligent educational support systems

Chapter 1 contains a synthesis of studies in digital education conducted prior to this thesis, highlighting the importance of the transition from traditional, product-centered assessment to formative, continuous, and personalized assessment supported by digital technologies. This shift enables the acceleration of school achievement development in comparison to traditional didactic strategies.

A critical analysis of the specialized literature reveals the limitations of current e-learning, particularly in the assessment of mathematics: the inability of classical digital tools to evaluate symbolic reasoning, the lack of personalized feedback, and the vulnerability of assessments based on static items, which increases the risk of academic dishonesty *(Noorbehbahani et al., 2022).* In this context, intelligent support systems are defined as educational solutions capable of facilitating individualized learning and formative assessment through differentiated feedback *(Son, 2024; VanLehn, 2011).* A central role is played by the integration of the Moodle platform with advanced plugins such as STACK, which enables the automatic evaluation of symbolic responses through the use of PRT trees, and CAS systems, which extend assessment from merely verifying the final result to diagnosing the cognitive process *(Davies & Sangwin, 2024; Jungic et al., 2012).* Parameterized items support varied practice, contributing to the development of mathematical metacognition and increasing the validity of assessment *(Branoaea, 2025f; Sangwin, 2013).* The synthesis of empirical studies indicates consistently positive educational effects of intelligent assessment systems ($d \approx 0.47$), exceeding the threshold of practical significance *(Hattie & Timperley, 2007).* These benefits include increased student engagement, greater efficiency in teachers' time management, and improved formative performance *(Lowe, 2020; Sangwin, 2013).* However, the impact is conditioned by the quality of pedagogical design, teacher training, and appropriate curricular integration *(Son, 2024; VanLehn, 2011).* The reviewed literature highlights the predominance of university-level studies, the lack of longitudinal research at the lower secondary level, insufficient psychometric calibration of items, and dependence on technological infrastructure and institutional support *(Astafieva et al., 2024; Castro et al., 2024).* Furthermore, the need to develop teachers' digital competencies and to create collaborative item banks for the effective integration of technology into teaching activities is emphasized *(Holmes et al., 2019).* The analysis of the educational context in Romania and the Republic of Moldova reveals systemic issues such as the low level of mathematical competence *(OECD, 2025),* teacher overload with assessment tasks *(Romanian Ministry of Education, 2024),* inequalities in access to digital resources, and insufficient digital skills *(Frontiers in Education, 2024).*

The comparative analysis of the main learning management systems (LMS) highlights significant differences regarding their pedagogical suitability for automated, personalized, and process-oriented formative assessment. Generalist LMS platforms offer effective organizational and collaborative support, but exhibit limitations in advanced mathematics assessment. The analysis includes both proprietary cloud-based or commercial platforms (Google Classroom and Schoology) and open-source solutions (Moodle), with the classification being based on the development model and the possibilities for customizing educational functionalities. Commercial automated mathematics assessment systems offer advanced functionalities, but their accessibility is limited by cost and technical complexity, which restricts their applicability in pre-university education *(Brănoaea, 2023). In* contrast, Moodle stands out due to its open-source nature, scalability, and interoperability, as well as its flexibility, modular architecture, and the possibility of integrating specialized plugins for symbolic assessment and parameterized item generation. This makes Moodle a suitable infrastructure for advanced mathematical assessment, despite the associated technical requirements *(Moodle Stats, 2025).* The pedagogical foundation of the platform, based on social constructionism, supports active, collaborative, and reflective learning, in line with the requirements of modern formative assessment *(Laurillard, 2012).*

Infrastructure and organizational constraints specific to pre-university education in Romania—particularly the lack of institutional implementation of the Moodle platform, absence of dedicated servers, and lack of specialized technical support—limit the direct application of advanced LMS solutions. To integrate advanced symbolic assessment functionalities and test parameterized items such as those offered by STACK, the Moodle USM platform is used, benefiting from existing infrastructure and specialized technical support. In parallel, the thesis proposes an original solution, materialized through the development of a proprietary educational platform, mathmentor.ro, designed as an independent environment for delivering intelligent digital educational resources.

The typology of items used in digital mathematics assessment reflects a classification based on the degree of automation and cognitive complexity. Correlating item types with the levels of Bloom's taxonomy ensures the construct validity of the assessment and allows for the design of didactic tasks that are progressively adapted to students' cognitive levels, ranging from recognition and application to analysis and synthesis *(Anderson & Krathwohl, 2001).*

The modeling of parameterized items relies on the use of random variables for the automatic generation of curricular-equivalent tasks, contributing to the individualization of assessment, reducing the risk of academic dishonesty, and increasing the sustainability of digital assessment *(Sangwin, 2013).*

The integration of advanced plugins is essential for extending the evaluative capacities of standard items. Among these, STACK stands out through its symbolic assessment capabilities, advanced parameterization, allocation of partial credit, and contextualized feedback based on the potential response tree (PRT) *(Davies & Sangwin, 2024).*

The intelligent support system is conceptualized as an integrated digital educational ecosystem, built on a modular, open, and interoperable architecture, oriented towards optimizing the teaching–learning–assessment process in mathematics. The originality of this approach lies in the coherent integration of various technological, pedagogical, and methodological components into a unified, scalable, and reproducible functional system, capable of generating emergent properties superior to the independent operation of each component *(Brănoaea, 2023; 2025d; 2026b).* The ISS operationalizes a complete digital assessment workflow: *design → generation → experimental application → feedback → analysis → validation.*

Structurally, the ISS is organized into five interdependent functional levels: Moodle infrastructure (providing course, test, and reporting management); mathematical intelligence (plugins such as STACK, WIRIS, Formulas, H5P, enabling symbolic assessment, parameterized items, and adaptive feedback); the IDER library, structured by grade, domain, and difficulty level, including items, tests, and interactive resources; interoperability and automation through GIFT and XML formats for efficient item generation and transfer; and the web infrastructure materialized through the development of the author's website, mathmentor.ro.

A digital educational resource attains the status of "intelligent" when it cumulatively fulfills pedagogical, formative, and analytical functions. Thus, such resources support assisted teaching through individualized engagement with theoretical materials and thematic glossaries, active learning through the application of knowledge in interactive contexts with immediate feedback *(Brănoaea et al., 2025; Castro et al., 2024),* automated assessment through response validation and stage-based scoring *(Black & Wiliam, 2009; Davies & Sangwin, 2024)*, as well as personalized remediation through adaptive feedback and resource recommendations based on identified errors *(Astafieva et al., 2024).* According to context, IDER provides four types of feedback: informative—offering only a short "correct/incorrect" message and raw scores; explanatory—indicating errors and providing procedural feedback; diagnostic—identifying conceptual gaps and recommending remediation resources; and predictive—using learning analytics data to anticipate performance and support pedagogical decision-making *(Black & Wiliam, 2009).*

The educational innovation brought by IDER and the justification for its conformity with modern trends and best practice recommendations are illustrated in Table 1.1, which presents the system's fundamental characteristics and their correlation with current didactic tasks.

Table 1.1. Characteristics of IDER and their didactic roles

No.	Characteristic	Didactic role
1	Parameterized standardization	Each item complies with the official school curriculum, with numerical variables generated randomly, maintaining curricular equivalence at the level of assessed competence *(Sangwin, 2013).*
2	Unlimited repeated use without degradation	Items can be reused indefinitely without losing statistical discrimination power, due to the automated generation of random numerical values *(Wiley & Hilton, 2018).*
3	Equity through unique variants	Each student receives a unique version of the assessment, thereby eliminating the risk of cheating and ensuring equitable evaluation conditions *(Bragaru et al., 2026).*
4	Adaptive symbolic feedback	STACK analyzes the student's expression step-by-step and returns differentiated messages according to error type *(Sangwin, 2013).*
5	Integrated educational analytics	Response data, working time, and remediation pathways are automatically stored in Moodle, supporting evidence-based pedagogical decisions *(Sangwin, 2013).*
6	Disciplinary scalability	The parametric model can be extended to other STEM areas as long as an evaluable symbolic formalism exists *(Bragaru & Arnăut, 2017).*
7	Didactic efficiency	Grading and reporting are automated, allowing the teacher to focus on the roles of designer and mentor, rather than manual evaluator *(OECD, 2022; Bragaru et al., 2026).*
8	Open technological compatibility	IDER is based on Moodle + STACK, allowing free installation and interoperability through the Moodle XML format *(Sangwin, 2013; Bragaru & Arnăut, 2017).*

The design of IDER is grounded in established pedagogical paradigms that support both the validation of the learning process and the optimization of didactic interventions. Pedagogical constructivism emphasizes the role of active interaction and reflection on errors in the construction of knowledge *(Laurillard, 2012);* automated formative assessment aims at the continuous regulation of learning through constant feedback *(Davies & Sangwin, 2024);* digital adaptive pedagogy highlights the role of technology as an active mediator of learning *(Holmes et al., 2019);* and personalized education is facilitated through parameterized items and individualized learning pathways *(Brănoaea, 2025f).* IDER distinguishes itself from classical OERs *(Astafieva et al., 2024)* and linear e-learning tools, as it combines standardization (through direct alignment with the school curriculum) with personalization (an individual item for each student, based on a unique task), and analytics (detailed reporting for the teacher), thus constituting a sustainable model for mathematics assessment at the lower secondary level *(Brănoaea, 2025d).*

In conclusion, Chapter 1 defines the conceptual framework of the research and lays the foundation for Chapter 2, which describes the practical implementation of the didactic model and the design, development, and integration of the ISS as a tool to support effective teaching, learning, and assessment in mathematics.

2. Pedagogical and technological development of the Intelligent Support System

Chapter 2 describes the process of designing, developing, and implementing the Intelligent Support System (ISS) as a didactic tool that supports the teaching–learning–assessment process.

The ISS is capable of generating and evaluating parameterized mathematical items, providing stepwise and personalized feedback, and supplying relevant data to inform pedagogical decisions.

The developed didactic model is grounded in a set of pedagogical principles for mathematics instruction, validated in the specialized literature, and in the potential of advanced educational technologies. The model is operationalized through the ISS, which functions as a mediating environment between curricular content, educational actors, and assessment processes:

- *Continuous formative assessment*, defined as a process in which data about learning progress are used to regulate didactic activities in real time *(Black & Wiliam, 2009; Hattie & Timperley, 2007);*
- *Individualization and differentiation of instruction*, by adjusting content and methods to meet students' specific needs *(Anderson & Krathwohl, 2001; Cao, 2022; Vygotsky, 1978);*
- *Immediate and specific feedback,* essential for developing self-regulation and fostering learning progress, facilitates the transition from the current to the desired level of performance *(Black & Wiliam, 1998; Hattie & Timperley, 2007);*
- *Varied practice,* achieved through parameterized items that provide multiple repetitions and application contexts for competencies *(Sangwin, 2013; Barana et al., 2021; Brănoaea, 2025f);*
- *Evaluative equity*, understood as the standardization of assessment criteria and instruments to ensure consistency and comparability of results within a formal framework *(Black & Wiliam, 1998; Redecker & Johannessen, 2013).*

The didactic model aligns contemporary mathematics education approaches with Bloom's revised taxonomy *(Anderson & Krathwohl, 2001)*, in which learning is conceived as a progressive process of competency development, from understanding and application to analysis and evaluation. In this context, assessment goes beyond a focus on final outcomes and is oriented toward the cognitive processes involved in mathematical activity, becoming an instrument for continuous diagnosis and regulation of learning *(Singer et al., 2015).* Consequently, IDER is designed to activate different cognitive levels, requiring not only the application of procedures but also the interpretation, selection of strategies, and justification of the mathematical approach, with the aim of fostering deep understanding. This approach is supported by the problem-solving framework, which structures mathematical activity into stages from understanding the task and application to analysis and evaluation *(Singer & Voica, 2013).*

From a conceptual perspective, the model aligns with the paradigm of technology-assisted learning, in which digital systems not only deliver content but also support personalization, self-regulation of learning, and error analysis through automated assessment and contextualized feedback *(Laurillard, 2012; Holmes et al., 2019).* The model's structure is organized into four

interdependent components: didactic objectives, teaching–learning–assessment strategies, formative assessment, and educational actors. Within this operational flow, the teacher assumes the role of designer and analyst of the educational process, while the student becomes an active and autonomous participant in learning. The model functions cyclically and self-regulates, based on the sequence: *task generation → problem solving → automated assessment → adaptive feedback → regulation → repetition*, which allows for the continuous optimization of learning and

The research methodology is grounded in the paradigm of the educational sciences, employing a mixed-methods approach (quantitative and qualitative) integrated within the IMRaD structure and operationalized through the principles of Design-Based Research (DBR), which enables coherent articulation of both theoretical and applied dimensions. The IMRaD framework is adapted to the specifics of educational research: the Introduction includes a critical analysis of digital assessment practices and the rationale for the ISS; Methods describe the DBR design, the ISS architecture, instruments, and data collection stages; Results integrate quantitative analyses (performance, statistical indicators) and qualitative analyses (errors, learning behaviors); and Discussion interprets the results in relation to the literature, highlighting the implications and limitations of the model. The DBR methodology is operationalized through an iterative process: *analysis of the educational context → design of the ISS and IDER → implementation in real contexts → evaluation and iterative revision → formulation of theoretical and practical contributions.* This process supports the ecological validity and applied nature of the research *(Design-Based Research Collective, 2003).* To avoid potential methodological interferences between the iterative nature of DBR and the stability requirements specific to the quasi-experimental design, the two approaches were articulated sequentially in the research. Thus, the DBR methodology was used in the preliminary stages of analysis, design, development and piloting of the ISS and the associated REDI, during which iterative adjustments were made based on pedagogical and technical feedback. Subsequently, in the experimental validation stage, the quasi-experimental design with experimental group and control group was applied, using a stabilized version of the SSI, maintained constant throughout the entire period of pre-test administration, pedagogical intervention and post-test, in order to ensure the internal validity of the results.

The research adopts a quasi-experimental design, comparing an experimental group (129 students) with a control group (123 students), both drawn from parallel classes within the same institution. Sample selection aimed to ensure internal validity by controlling confounding variables and verifying group homogeneity using baseline tests, including Student's t-test for mean differences and Levene's test for equality of variances, confirming initial statistical

comparability. Students were initially classified into three competence levels based on diagnostic tests: low level (below 6), medium level (6–7.99), and high level (8–10), in order to differentiate pedagogical interventions and personalize learning tasks.

The formative intervention was applied to the experimental group through the use of the ISS based on REDI, integrated into the Moodle platform, while the control group followed a traditional didactic approach without intelligent digital resources. The experimental/factor variable is represented by the use of IDER within the ISS, the dependent variable is students' mathematical performance, and the independent variables include the national curriculum, calendar planning, learning environment, lesson structure, classical teaching methods, and students' initial preparedness. The effects of the intervention were measured by the average score of each lower secondary class to quantify progress (post-test – pre-test) and retention (re-test – pre-test), as well as by the percentage distribution of grades across intervals (1–5.99; 6–7.99; 8–10) to identify performance dynamics resulting from the use of REDI.

The quantitative (positivist) component aims to objectively evaluate the effects of the intervention through pedagogical experimentation, standardized tests, statistical indicators, and analysis of data from the Moodle platform. The qualitative (interpretative) component investigates learning experiences, error patterns, and user perceptions through observation, questionnaires, and contextual analysis.

Methodological triangulation enables the correlation of quantitative and qualitative data and explains the effects of the intervention at both the impact and pedagogical mechanism levels. The research methodology fully complies with GDPR principles: data collection was conducted based on informed consent from students and parents, and the data are securely stored, accessible only to authorized users, anonymized, and used exclusively for scientific purposes.

Development of the Intelligent Support System

Within the present research, the development, implementation, testing, and validation of ISS were conducted through the prototype electronic course "Matematica Gimnazială Bacău" *(Branoaea & Bragaru, 2025b).* In the context of the lack of Moodle implementations in Romanian pre-university education, the mathmentor.ro platform was developed as a proprietary solution, fully administered by the author with root privileges on the server. The implementation followed a strategy based on FOSS principles and the classic LAMP architecture (Linux, Apache, MariaDB, PHP), using Ubuntu 22.04 LTS on a dedicated VPS with configured hardware resources (2 vCPU, 4 GB RAM, 40 GB SSD, static IP). Administration and development were carried out using MobaXterm, which enabled complete server management (SSH, SFTP, terminal, text editor, X11). Moodle 4.1 LTS was installed manually, with configuration of the MariaDB database, storage directory, and config.php file. The graphical interface was customized using the

Moove theme and SCSS modifications, and functionality was extended with open-source plugins for assessment. Security was ensured through HTTPS (Let's Encrypt), firewall, automated backups, and the application of OWASP methodology (input validation, session protection, prevention of XSS and SQL injection). Email communication uses secure SMTP, and all components were tested and documented. The mathmentor.ro domain is officially registered and linked to its own cloud infrastructure, integrating interdependent components in a continuous improvement cycle, as summarized in Figure 2.1.

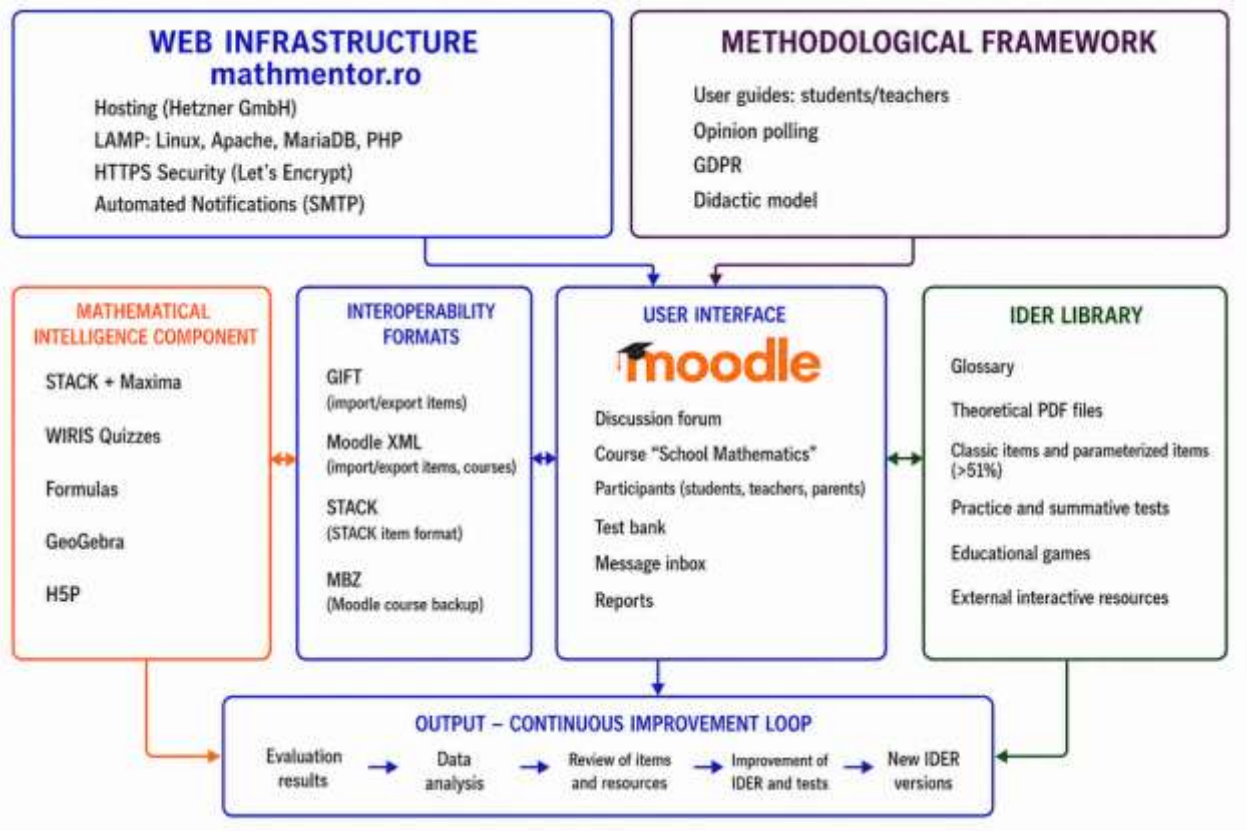

Figure 2.1. Architecture of the Intelligent Support System

The development of IDER was carried out through a logical sequence of stages, starting from the analysis of the lower secondary curriculum and the organization of content into problem families, which group tasks according to competencies and types of mathematical reasoning. The formation of mathematical modeling competence requires the integration of content into a coherent logical-didactic framework, oriented toward applicability and transfer *(Sali, Cozma & Ionel, 2025).* Following the curriculum analysis, 10 problem families were identified in Algebra and 6 in Geometry, thus ensuring comprehensive coverage of the lower secondary mathematics curriculum. Each family is associated with a set of common mathematical concepts, similar solving strategies, the possibility of algorithmic parameterization, and gradual structuring by levels of difficulty—all hosted on the mathmentor.ro website. The curricular alignment of mathematical content between Romania and the Republic of Moldova is regulated by official

curricular documents *(MEN RO, 2017; MECC MD, 2020)* and highlights a significant compatibility of the fundamental content areas, with differences arising only in the chronological distribution of certain subtopics. All materials (theoretical notes, items, tests) bear explicit titles indicating the name of the learning unit and numerical codes, which facilitates rapid identification regardless of the country.

The development of items for import into Moodle is accomplished through a structured process of generation, standardization, and interoperability, based on the use of GIFT, Moodle XML, and STACK formats, depending on the type of assessment and the level of cognitive complexity. The process includes three main workflows: (1) direct creation in Moodle with export/import via XML or backup (.mbz); (2) the use of templates and copying of existing items for reuse and adaptation; and (3) offline development of items in text format (GIFT) with subsequent import into the question bank, enabling the rapid production of large volumes of standardized items *(Brănoaea, 2026a).*

The organization of the item bank (BDI) aims to construct a hierarchical, coherent, and extensible system, based on thematic categories/collections with standardized item identifier coding, which ensures curricular transparency, intuitive navigation, and efficient management of assessment within the ISS. To this end, a hierarchical positional coding scheme was developed and applied, facilitating rapid positioning, filtering, and use of items according to multiple didactic criteria. Thus, each item code fulfills a dual role: unique identifier and standardized name, ensuring consistency between the conceptual database and technical implementation on the platform. The positions of the hierarchical code have the following significance: first position – grade level (5, 6, 7, 8); second position – mathematical domain (A = Algebra, G = Geometry); third position – unit number within the domain; fourth position – Moodle question type (e.g., STACK, Calculated, Cloze, Numeric, Matching, etc.); fifth position – difficulty level (1 = basic, 2 = intermediate, 3 = advanced); sixth position – item sequence number within the category. For example, 7_A_1_STACK_nivel2_01 represents an item for 7th grade, Algebra, first educational unit, STACK type, intermediate difficulty (=2), the first in its category.

The analysis of the workflow for using the intelligent support system in the educational process highlights the functional interaction between educational actors, intelligent digital resources, assessment processes, and the analysis of results. The proposed model aims to achieve a process of self-regulated, adaptive, and student-centered learning, supported by continuous assessment, analysis of results, and constructive feedback. Figure 2.2 highlights the functional architecture and the sequence of stages through which students and teachers interact with the Intelligent Support System, developed on the Moodle platform and extended through open-source plugins that facilitated the creation of intelligent digital educational resources.

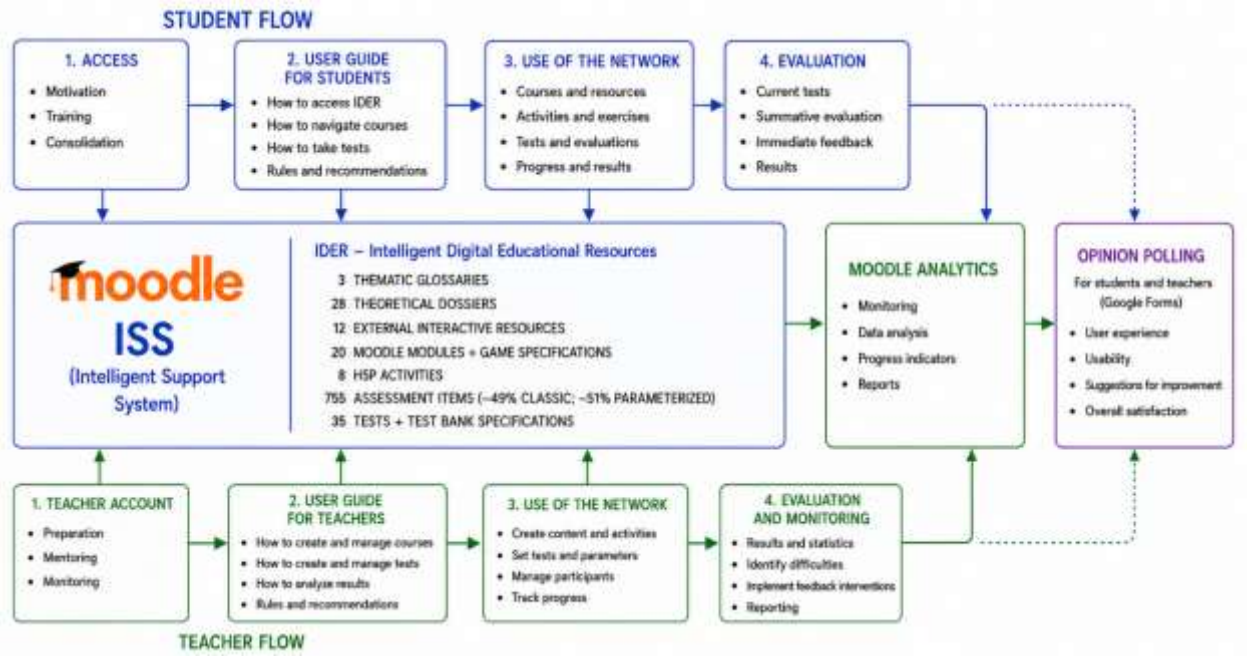

Figure 2.2. Workflow of the Intelligent Support System

The flow of ISS usage is organized differently for the two main categories of users: students and teachers. Initially, both students and teachers are provided with dedicated user guides ('User Guide for Students' and 'User Guide for Teachers'), which facilitate familiarization with the ISS structure and ensure autonomous use of the system from the very first interaction with the platform. The ISS acts as the functional core that coordinates resource management, user access, distribution of educational content, assessment administration, and the collection of data regarding student progress. Integrated within the system, IDER is designed to support the teaching–learning–assessment process in an adaptive and interactive manner. The IDER library includes: 3 thematic glossaries, 28 theoretical folders, 12 external interactive resources, 20 Moodle games, 8 H5P activities, 755 assessment items (over 51% parameterized items), and 35 tests for basic thematic assessment (with multiple repetitions), as well as adaptive digital summative assessment. This structure enables both the consolidation of fundamental mathematical knowledge and the personalization of educational pathways according to each student's level and learning pace. The workflow for using the ISS is differentiated for the two main user categories: students and teachers.

The **student** accesses the system via the "Student Account," where they engage in activities focused on motivation, practice, and the consolidation of mathematical competencies. By accessing REDI, the student interacts with theoretical resources, interactive activities, educational games, and parameterized tests, in a process of self-regulated learning. The self-regulated nature of learning is evidenced by the student's ability to progress through content at their own pace, repeat activities, and receive immediate feedback on performance.

After the learning phase, the student participates in the assessment process via tests. Assessment serves both formative and summative purposes, supported by parameterized items that enable the automatic generation of different exercise variants, minimizing rote memorization and stimulating authentic mathematical thinking. Results are centralized and interpreted through the Moodle Analytics component, which monitors student progress, performance levels, and difficulties encountered. Data analysis leads to the formulation of positive and constructive feedback, serving motivational and self-regulatory functions. Thus, the student is encouraged to continue the learning process, improve performance, and develop autonomy in study.

The **teacher** uses the system through the "Teacher Account," fulfilling complementary roles in teaching, mentoring, monitoring student progress, and adapting instructional strategies for remediation or advancement. The teacher can select, adapt, and organize IDER according to instructional objectives and the specific characteristics of the student cohort.

Digital educational activities within the ISS are supported by the integration of interactive tools such as thematic glossaries and Moodle educational games, which facilitate various learning modalities (collaborative, e-learning, blended learning, m-learning, etc.), providing students with continuous access to resources and immediate feedback *(Holmes et al., 2019; Braicov & Bibic, 2023).* The HTML5 package is an open-source software framework that allows for the creation, editing, and repeated use of interactive educational content directly within e-learning platforms, including Moodle, without requiring advanced programming knowledge. Moodle glossaries organize mathematical content conceptually into three major domains: Algebra, Plane Geometry, and Spatial Geometry, while the educational games included in the digital course are designed as interactive, game-based learning resources. These activities aim to reinforce mathematical vocabulary and conceptual recognition, supporting the development of scientific communication skills and precision in the use of mathematical language *(Brănoaea et al., 2026).* Crossword games are built upon the glossaries, while the "Millionaire" game can be generated either from BDI items with a single correct answer or from thematic tests, including parameterized items. The number of possible different combinations for a short-answer matching item generated randomly from n variants taken k at a time is determined by the formula: $C(n, k) = n!/(k!(n-k)!)$. The number of item combinations is sufficiently large to counteract answer sharing and rote memorization *(Bragaru et al., 2026).* The main goal of the e-test battery is to comprehensively assess students' performance levels in the fundamental domains of lower secondary mathematics—algebra, plane and spatial geometry—by simultaneously verifying theoretical knowledge, algorithmic competencies, and the ability to apply concepts in varied contexts *(Brănoaea, 2025f; Cao, 2022).*

The **test battery** is designed as a dynamic pedagogical tool, supporting progressive learning, stimulating logical thinking, and ensuring equitable, reproducible, and cognitively

differentiated assessment. It is based on the diversity and complementarity of assessment tasks, controlled randomization of numerical values, and the logical structuring of items by difficulty level (Brănoaea, 2025a; Black & Wiliam, 2009). Overall, the battery includes 35 e-tests, distributed as follows: Grade 5: 11 tests; Grade 6: 10 tests; Grade 7: 6 tests; Grade 8: 8 tests. By assessment type, 20 tests (≈57%) are assessment (summative or competency verification) tests, 9 tests (≈26%) are practice tests, and 6 tests (≈17%) are consolidation tests. Each e-test is structured into three levels: Level I – classic, low-complexity items for grades 5–6; Level II – classic or numeric, medium-complexity items for grades 7–8; and Level III – high-complexity items of the Calculated or STACK&WIRIS type, for grades 9–10. A distinctive feature of this battery is the 100% parameterized tests, which allow for the automatic generation of an unlimited number of variants, ensuring equity, reduced risk of fraud, and a personalized learning process. Of the 35 e-tests, 12 tests (34%) contain exclusively parameterized items. The 100% parameterized tests are designed to ensure uniqueness, automatic grading, adaptability, and pedagogical relevance. Only two types of digital items integrated into Moodle are used: Calculated and STACK, each with specific assessment functionalities, providing every student with a personalized, objective, and user-friendly testing experience. An essential component is the "Set Parameters – Generate Tests" feature, which allows the level of difficulty to be adapted to students' actual needs, thereby supporting differentiated instruction and individualization, and increasing the efficiency of didactic activity.

The data resulting from assessments is extracted from Moodle Analytics, processed in MS Excel, and interpreted at both individual and group levels. This process facilitates continuous resource improvement, identification of learning gaps, and early pedagogical intervention. The ISS usage workflow concludes with the completion of opinion questionnaires aimed at identifying users' perceived satisfaction levels. In this way, the ISS functions as an intelligent educational environment, capable of optimizing the acquisition of mathematical competencies by lower secondary students and supporting teachers' work through modern tools for personalization and educational analytics.

Cost–benefit analysis of ISS implementation in a typical lower secondary school

The cost–benefit analysis evaluates the efficiency of ISS implementation by comparing initial and operational costs to the educational and institutional benefits obtained over a five-year horizon, applying a discount rate of 3% in accordance with OECD (2025) recommendations.

The model contrasts the main dysfunctions of traditional assessment (fraud and copying, time-consuming grading, delayed feedback, lack of personalization, and recurring logistical costs) with the digital solutions provided by the ISS, which are based on parameterized items, automated grading, adaptive feedback, and dynamic test generation. The results indicate that the estimated

initial investment is gradually offset by a significant reduction in operational costs and increased efficiency in assessment processes. The main benefits include reduced grading time, elimination of costs associated with paper-based assessment, increased objectivity and fairness of evaluation, and support for personalized learning through immediate and adaptive feedback. The analysis suggests a favorable cost–benefit ratio (ROI > 1), meaning that the estimated educational and institutional benefits exceed the costs of implementing and operating the system, and the initial investment can be recovered within a relatively short period of approximately 3–5 years, depending on the degree of institutional adoption and system usage. It is noted that a comprehensive and fully validated economic evaluation would require the involvement of specialists in educational economics, public policy analysis, and project management, to refine assumptions, validate cost models, and calibrate long-term benefits. In this respect, the present analysis is indicative and exploratory, appropriate for the aims of the doctoral research and the conceptual foundation of ISS implementation.

Overall, Chapter 2 focuses on the design and development of the didactic model based on the ISS, coherently integrating the pedagogical and technological dimensions to support automated formative assessment through parameterized items, adaptive feedback, and educational analytics.

The organization of the item bank (BDI), the curricular alignment between Romania and Moldova, and the practical implementation on the USM, CEITI, and mathmentor.ro platforms confirm the applied nature of the system, while the cost–benefit analysis highlights the sustainability and feasibility of scaling ISS to typical lower secondary schools.

3. Validation of the Intelligent Support System in lower secondary education

Chapter 3 aims to evaluate the ISS as a support tool for learning and assessing mathematics and to validate it through a controlled pedagogical experiment designed for the comparative analysis of the effectiveness of using IDER in relation to traditional assessment methods.

The implementation of the Intelligent Support System (ISS) was carried out through an elective course, “Mathematics through Digital Games,” during the 2024–2025 school year, in class VIII B at Secondary School No. 10 Bacău. The system is being experimentally extended to grades V, VI, and VII through an in-depth curriculum chosen by the school and approved by the Bacău County School Inspectorate, structured as an additional weekly hour dedicated to advanced mathematics.

Specifically, the final month of the 2024–2025 school year was allocated exclusively to the use of Intelligent Digital Educational Resources (IDER) on the mathmentor.ro platform and digital assessment. The formative activity involved initial training, a diagnostic test, five thematic modules with interactive exercises, adaptive feedback, educational games, and a final assessment,

enabling the monitoring of student progress in a gradual and controlled environment. The conduct of the pedagogical experiment included both internal and external analyses to evaluate the impact of the intelligent support system on students' academic performance.

T**he internal (intra-subject) comparison** was conducted by analyzing the performance of the same group of students from the experimental classes using tests with similar curricular objectives but different formats: traditional (paper-based) and digital (via IDER).

The evolution of the grades of students in the experimental classes, on both traditional tests and IDER tests, from pre-test to post-test across numerical intervals, can be seen in Figure 3.1.

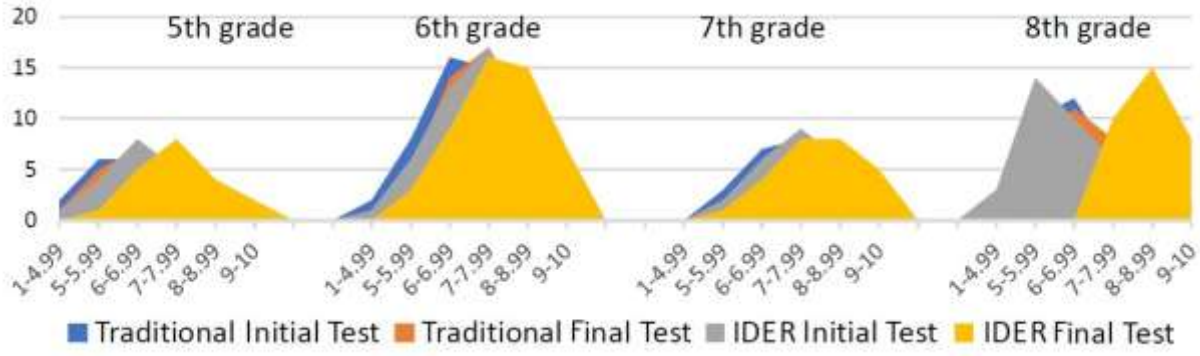

Figure 3.1. Evolution of students' grades across numerical intervals

In all experimental lower secondary classes (grades V–VIII), a shift was observed in results from the low-performance range (below 6) toward the medium and higher intervals after exposure to digital assessment supported by the ISS.

Figure 3.2 presents the evolution of average scores on summative tests for each experimental class in the lower secondary cycle, in two distinct contexts: traditional testing versus digital testing.

Figure 3.2. Internal comparison (traditional vs. IDER) from pre-test to post-test

Based on the data summarized in Figure 3.2, it can be observed that, for all analyzed grade levels, student performance is superior in the digital IDER variant compared to traditional testing. Even in cases where the differences are smaller in absolute terms (e.g., Grade V: +0.05; Grade VII: +0.06), the increase is consistent and stable, indicating a clear trend of progress associated with the digital intervention. An essential factor explaining differences in progress between classes is the heterogeneous composition of the groups, especially in Grade V A, which includes

students with special educational needs and specific learning disorders, naturally influencing the class average values. Another relevant aspect concerns students capable of high mathematical performance, such as one from Grade VI, who was awarded a gold medal at the 2025 online national competition CampioMATE (Romania), reflecting accelerated progress in mathematics learning through the use of IDER. This intra-subject approach isolated the added value of IDER by maintaining constant pedagogical variables (teacher, planning, content, teaching style, and pace). The findings reveal an approximately 10% increase in the experimental group's average performance between pre-test and post-test, associated with IDER use.

An essential contribution to the empirical validation of ISS effectiveness is the analysis of the experimental group students' performance during the **re-testing phase.** This stage played a strategic role in assessing the retention and stability of mathematical achievements acquired through the use of IDER on Moodle. After completing the experimental phase in the 2024–2025 school year, students in the experimental group benefited from a vacation period without formal activities, followed by a gradual reintegration into the learning process through digitally assisted interactive review sessions. In this context, the tests administered during the re-test phase (September 2025) were identical to those used in the post-test (June 2025), thus allowing for the verification of retention after a break in experimental activities. The results demonstrate that, in all lower secondary classes subjected to re-testing, performance levels remained higher than the initial baseline (pre-test), even after the vacation period, confirming a high degree of stability between the post-test and re-test stages, with statistically insignificant decreases (on average below 0.2 points). This indicates robust cognitive retention and confirms the lasting formative effect of the system. In the case of the eighth grade, the re-test phase was not conducted, as these students completed lower secondary education in June 2025 and transitioned to upper secondary education.

The external comparison (inter-subject: experimental group vs. control group) provides an objective framework for validating the effectiveness of the ISS, since both samples were statistically equivalent before the pedagogical experiment and studied the same learning units, with the only difference being the instructional method (digital vs. traditional).

The statistical comparison was conducted using Levene's test to assess the homogeneity of variances, followed by the independent samples t-test. Effect size was quantified using Cohen's d. At pre-test, the results confirm the statistical equivalence of the groups ($p = 0.63–0.87$, $d \approx 0$), thereby validating the experimental design. In the post-test, the experimental group exhibited higher mean scores across all analyzed grades, with small to moderate effect sizes ($d = 0.19–0.54$), reaching statistical significance in the eighth grade ($t(62) = 2.18$, $p = 0.03$). Figure 3.3 illustrates

the external comparison between the control and experimental groups for each lower secondary class, regarding the evolution of average scores across all summative assessments.

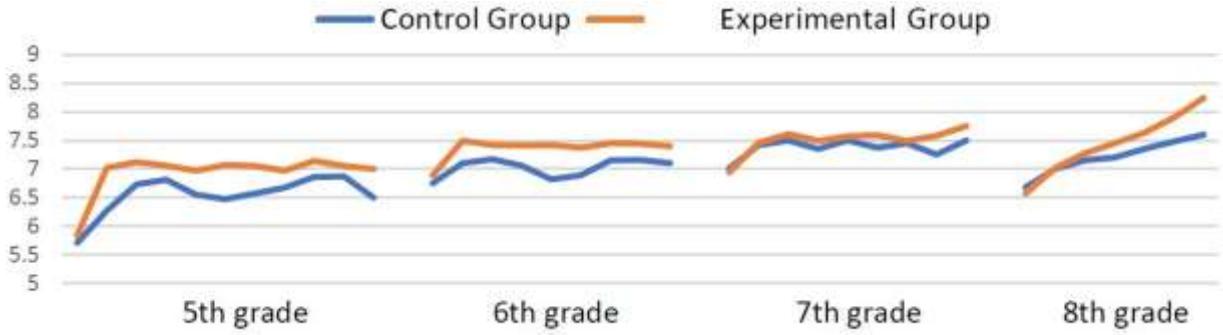

Figure 3.3. External comparison from pre-test to post-test

The comparative results indicate the following progress differences achieved by the experimental group relative to the control group: Grade V – +0.37 points, Grade VI – +0.16 points, Grade VII – +0.31 points, and Grade VIII – +0.75 points. The weighted arithmetic mean of these values, calculated according to the number of students in each class, indicates an overall difference of +0.47 points out of 10 in favor of the experimental group. This confirms that IDER generated an average increase of approximately 5% in overall performance compared to the traditional approach. The integration of IDER did not exclude the traditional component, but rather enhanced it, confirming that a correctly implemented digital intervention, adapted to age and content, leads to improved academic performance when strategically integrated into the learning process.

The analysis of arithmetic means of the two samples, corroborated with the analysis by scoring intervals and grade distributions, highlights a clear trend of progress in the experimental sample, with a consistent increase in performance both relative to its own baseline (pre-test) and in comparison to the control group results.

Validation of the ISS based on Moodle reports

Validation of the ISS using Moodle reports provides complementary information regarding measurement stability, conceptual homogeneity of tests, and the accuracy of automated grading. Comparative analysis of statistical indicators such as mean score, standard deviation, skewness, kurtosis, internal consistency coefficient, and standard error allows for a rigorous quantitative validation of the system's functionality and didactic quality. The cumulative analysis demonstrates that the system succeeded in maintaining a balance between difficulty, discrimination, and individual progress, thus ensuring the conditions for genuine formative assessment.

Parameterized items of the Calculated type enable repetitive practice of algorithms without any additional effort from teachers in editing or grading assessments over time. The use of STACK allows for the validation of exact symbolic expressions, avoiding numerical

approximations and strengthening formal reasoning. The reliability coefficient values ($\alpha = 0.69–0.88$) indicate a good level of internal consistency; the measurement error, ranging from 5% to 10%, falls within optimal limits for educational assessment, and positive discrimination indices demonstrate the didactic adequacy of the items and the efficiency of automated test generation. Thus, indicators of internal consistency and mean scores validate the ISS as a reliable and relevant tool for mathematics assessment, while standard deviation and error ratio highlight the importance of item calibration.

Transferability and broader validation

The promotion of IDER within the international project "Enhancing Academic Performance in ICT through the Implementation of Standardized Assessment Tools on the Moodle E-learning Platform" aimed to demonstrate the transferability and sustainability of IDER in technical and vocational education in the Republic of Moldova. Within the joint Romanian–Moldovan research team (RO-MD), the author served as developer of parameterized mathematical items and coordinator for curricular alignment between the official curricula of the two education systems. IDER was transferred to the digital platform of the Center of Excellence in Informatics and Information Technologies (CEITI). Experimental implementation was carried out at the Cahul Medical College as well as in five other partner institutions, enabling the system to be tested in diverse educational contexts. The experimental stage focused on the topic "Geometric Figures in the Plane," applied to a sample of 25 tenth-grade students at the Cahul Medical College. Results indicate a positive mean difference in favor of digital assessment (+0.59 points), suggesting a slight increase in performance when using parameterized items and automated feedback. Pedagogical interpretation highlights increased accuracy and fairness of assessment, reduced test anxiety, standardization of grading, and the strengthening of formative feedback. Overall, implementation on the CEITI platform in all partner institutions confirms the transferability, curricular compatibility, and functional robustness of the ISS in various educational contexts.

Validation of the ISS based on user opinion questionnaires

To support the research hypothesis, two opinion questionnaires were created and administered via Google Forms: one for students in the experimental group ($N = 129$) and one for mathematics and ICT teachers participating in the research ($N = 16$). By applying the Kano model, the analysis of IDER user satisfaction aimed to correlate basic (required), performance (optimizable), and attractive (innovative) elements, thus providing a conceptual framework for interpreting data from the student and teacher questionnaires.

Basic requirements (such as Moodle functionality and assessment accuracy), performance requirements (the quality of feedback and items), attractive requirements (educational games, interactive elements), and indifferent requirements (design aspects) were identified. This model

helps correlate the technical dimension (platform functionalities) with the pedagogical dimension (perceived quality of learning and assessment), enabling concrete directions for improving the educational experience in digital environments. The two questionnaires were structured in parallel to ensure analysis of both users' experience (see Table 3.1).

Table 3.1. Structure of student and teacher questionnaires and ISS validation

Thematic section	Students/Teachers	Contribution to ISS validation
I. Clarity of online assessment	E1–E5 / P1–P5	Validates assessment design: structure, difficulty, stress.
II. Objectivity and fairness	E6–E9 / P6–P9	Validates fairness: anti-fraud, transparency.
III. Pedagogical impact	E10–E14 / P10–P14	Validates impact on learning, motivation, self-assessment.
IV. Preferred item types	E15–E20 / P15–P19	Validates preference for types of exercises.
V. System efficiency	E21–E24 / P20–P23	Validates efficiency compared to traditional methods.
VI. Acceptability	E25–E28 / P24–P27	Validates scalability and potential integration level.
VII. Concrete preferences	E29–E30 / P28–P29	Supports decisions on ISS extension based on preferences.
VIII. Open questions	E31–E33 / P30–P32	Provides qualitative data for feedback and improvement.
IX. Teachers only	– / P33–P39	Validates managerial functions of the ISS.

Results from the questionnaires administered to students and teachers provide external validation of the utility and functionality of the ISS:

1. *Pedagogical relevance:* 66% of students perceived online assessment as clearer and less stressful than traditional assessment; 93% of teachers confirmed the objectivity and efficiency of automated assessment; over 75% of teachers reported a reduction in fraud through parameterization; over 75% of teachers found automated feedback clear and useful, confirming the formative function of the test.
2. *Didactic efficiency:* 70% of students valued automated feedback as a resource for understanding mistakes; 60% reported increased motivation for mathematics due to the clarity of items; 65% consider parameterized items the most useful for practice and assessment; 87% of teachers confirm that ISS assessment contributes to the development of students' digital skills and 68% appreciate the positive impact on student self-regulation.
3. *Validity of the ISS is confirmed from complementary perspectives: content validity* (items comply with national curricula and are transnationally compatible RO-MD); *construct validity* (correlations between feedback, self-assessment, and self-regulated progress confirm the system's internal coherence);

   predictive validity (identifying students' error patterns facilitates the anticipation of learning difficulties, providing support for teachers in developing remedial or progress plans and in adapting instructional strategies).

4. *Sustainability and scalability:* 81.25% of teachers fully agree that extensive implementation of online assessment modernizes the educational process; 75% wish to extend its use in their own institution; and 68.75% recommend extending online assessment to other subjects, confirming the system's strategic relevance and development potential.
5. *Contributions to the digital transformation of education* include reducing the administrative effort required of teachers in the assessment process; increasing the objectivity of assessment through the use of parameterized items; personalizing instruction based on error pattern identification; and aligning the planned, taught, and assessed curriculum—a point confirmed by 87.5% of teachers.

Overall, the results confirm consistent positive effects of the ISS on pre–post test progress, on assessment equity, and on the efficiency of the didactic process, through the integration of automated assessment, adaptive feedback, and curricular standardization. Although the ISS was validated through experimental data and positive feedback, the interpretation of results is carried out with reference to the **methodological limitations** encountered and the mitigation solutions provided.

1. *Technical and digital literacy limitations.* Initial difficulties in usage were partially compensated by guides and pre-configured resources, with the system being successfully implemented in partner institutions within the RO-MD project.
2. *Organizational constraints.* The integration of the ISS was conditioned by curricular structure and school timetable, but was facilitated by utilizing school-based curriculum hours, without requiring major changes to the organization of teaching activities.
3. *Sample and Institutional Context.* Although validation included different contexts, full generalizability requires extension to more diverse socio-educational environments; this limitation was partially addressed through transnational implementation in Romania and the Republic of Moldova.
4. *Duration of the intervention.* The study covers a one-year school interval, providing relevant short- term results, but longitudinal research is needed to evaluate long-term effects.
5. *Potential usage biases.* Effects such as novelty, digital anxiety, or strategic behavior during testing were reduced through repeated use and progressive familiarization with the system.
6. *Non-cognitive dimension.* Motivation and engagement were treated as secondary effects, although data confirmed a consistently positive impact.

Despite these identified limitations, the implemented mitigation measures allow for the validation of the developed model, demonstrate consistency and relevance for contexts similar to

the experimental one presented, and highlight the effectiveness of the ISS in relation to the objectives and hypothesis of the research.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

The Doctoral thesis is situated at the intersection of the paradigm of formative assessment, theories of self-regulated learning, and the new directions of intelligent educational support systems, adopting an integrative approach in which technology is not merely a support, but an epistemic vector for transforming the learning process. The intelligent support system developed and implemented contributes to bridging the gap between technological potential and actual educational practice through the design and validation of an innovative didactic model based on automated formative assessment and adaptive feedback, implemented via an intelligent support system, thus addressing the scientific problem formulated in the Introduction.

The **thesis purpose** regarding the theoretical-methodological foundation and experimental validation of a didactic formative assessment model based on an intelligent support system has been **achieved**, as demonstrated by the attainment of all research objectives.

Objectives 1 and 2, targeting the analysis of the theoretical framework and comparison of digital platforms, were accomplished in Chapter 1. These are reflected in the systematization of the theoretical and methodological framework of formative assessment and intelligent support systems, as well as the critical analysis of existing digital tools, which allowed the identification of concrete opportunities for integrating digital assessment in lower secondary education and highlighted the limitations of current practices, justifying the need for the ISS model.

Objectives 3 and 4, relating to the design of the didactic model and the development of the intelligent support system, were achieved in Chapter 2. The design of the formative assessment didactic model is grounded in pedagogical principles validated by the specialized literature, promoting formative assessment through adaptive feedback mechanisms and continuous regulation of learning. The methodological structure ensures the connection between learning objectives, curricular content, and ISS technology, aiming to enhance the teaching process and effectively develop mathematical competencies among lower secondary students. The development of the intelligent support system led to the operationalization of the didactic model through the integration of the Moodle platform, FOSS plugins, and intelligent digital educational resources (REDI) into a fully functional digital course ready for use in real learning contexts.

Objectives 5 and 6 were accomplished in Chapter 3 through the experimental implementation and validation of the ISS, using a complex methodological design based on the triangulation of quantitative and qualitative data to increase the internal and external validity of the research. The intra-group and inter-group analysis, conducted on a sample of 129 students in the experimental group and 123 in the control group, demonstrates an average performance

increase of +1.02 points (≈10%) in the experimental group and a comparative advantage of +0.47 points (≈5%) over the control group, with consistent progress at all lower secondary levels and a reduction in disparities among students with different performance levels.

Subsequently, the limitations of the study were analyzed: (1) technical and digital literacy limitations, which were mitigated through a pre-configured system, methodological guides, and ready-to-use REDI resources; (2) institutional organizational constraints, which were reduced by integrating ISS into elective courses and teacher-directed classes; (3) the limited duration of the intervention, which was compensated by implementation within the RO–MD project and by extending its use in various contexts; (4) students' behavioral biases, which were diminished through repeated use and gradual familiarization with the system. These limitations represent relevant explanatory factors for the magnitude of the statistical effects obtained (d = 0.19–0.54), whose small to moderate values reflect the complexity of the real educational context, where uncontrolled variables naturally attenuate the amplitude of measurable effects.

Psychometric validation of the test battery, based on indicators provided by Moodle Analytics, confirms a high level of reliability, optimally distributed difficulty, and positive discrimination indices, demonstrating the didactic adequacy of the items and the efficiency of automated test generation. The qualitative component highlights a favorable user perception, with 87% of students and 93% of teachers reporting positive experiences and significant benefits in terms of engagement, efficiency, and optimization of the assessment process.

Despite these identified limitations, the remedial measures implemented ensure that the **research results** are consistent with the stated aims and objectives and align with the specialized literature regarding the effectiveness of intelligent systems in mathematics assessment.

Result 1 (theoretical): A didactic model based on automated formative assessment and adaptive feedback in the context of lower secondary digital mathematics education was theoretically grounded and developed.

Result 2 (technological): The ISS was designed, developed, and implemented on the Moodle platform using advanced FOSS plugins and a custom-coded author website.

Result 3 (didactic): An IDER bank was developed, implemented, and validated.

Result 4 (experimental): A quasi-experimental pedagogical design involving control and experimental groups was conducted, and the statistical results demonstrated that the use of the ISS leads to significant increases in student performance and retention of mathematical concepts.

Result 5 (applicative–transferable): The direct applicability and transferability of the ISS were demonstrated through national and transnational implementations within elective courses, school-based curricula, and educational partnerships.

The results obtained **confirm the research hypothesis**, *according to which the use of the intelligent support system by lower secondary students—implemented on the Moodle platform and integrating intelligent digital educational resources for formative assessment with automated feedback—leads to significant improvements in mathematical achievement, compared to the traditional didactic strategy*, as evidenced by pre-to-post-test differences with small to moderate effect sizes, which are nonetheless practically relevant and consistent with the benchmarks in the specialized literature on e-learning interventions.

The **personal contribution** consists of designing the didactic model based on the principle of individualization and differentiation of instruction; developing the ISS through the integration of FOSS technologies; copyright protection of the Moodle digital course; full technical development of the educational platform on the author's website mathmentor.ro; the creation and application of mathematical performance assessment tools and opinion questionnaires; drafting guidance manuals for teachers and students; implementing IDER in innovation and technology transfer projects between Romania and the Republic of Moldova; as well as collecting, statistically analyzing data, and validating the results. This research demonstrates that intelligent digital assessment, pedagogically grounded and systemically implemented, can become a vector for profound transformation of the educational process.

Based on the research results, **recommendations** are formulated for teaching staff and educational management with the aim of optimizing the instructional process. It is recommended to integrate IDER into current didactic practice, both in consolidation and review activities and in formative and summative assessment, making use of parameterized items and adaptive feedback for progress monitoring and personalized learning. Furthermore, it is recommended to use the ISS in complementary educational contexts, such as remedial programs, activities for students with special educational needs, centers of excellence, or hybrid learning environments, where the system can support pedagogical differentiation. At the managerial level, the implementation of the ISS within institutional platforms dedicated to assessment and exam preparation is proposed, in order to standardize assessment practices, increase equity, and base educational decisions.

Future research directions include expanding the proposed model through application in diverse educational contexts and conducting longitudinal studies to highlight the impact on student performance and metacognitive processes. It is also recommended to develop and extend digital infrastructure by creating a national platform equipped with IDER and by integrating anti-fraud security mechanisms necessary for large-scale assessment.

The research can be furthered through the transfer of methodology to other STEM disciplines and the integration of AI, such as conversational agents and predictive educational analytics, in order to develop a fully adaptive and intelligent educational system.

In conclusion, this thesis provides a theoretical foundation, experimental validation, and practical demonstration that the proposed intelligent support system represents a viable, scalable, and transferable didactic and technological solution. It contributes significantly to optimizing assessment and accelerating mathematical achievement in lower secondary education, while also offering a methodological reference point for the sustainable transformation of the teaching–learning–assessment paradigm in contemporary education.

BIBLIOGRAPHY (selective)

1. ALBULESCU, I., CATALANO, H. (2020) *Sinteze de pedagogie generală. Ghid pentru pregatirea examenelor de titularizare, definitivat si gradul didactic II.* București: Didactica Publishing House. ISBN: 978-606-048-145-4.
2. ANDERSON, L. W., KRATHWOHL, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York, NY: Longman.
3. ASTAFIEVA, M. M., HLUSHAK, O. M., & LYTVYN, O. S. (2024). *Using STACK to support adaptive mathematics learning în LMS Moodle*. În *Proceedings of the 4th Workshop on Digital Education and Learning Technologies (DELT-2024)* (Vol. 3781, pp. 12–19). CEUR Workshop Proceedings. Available: https://ceur-ws.org/Vol-3781/paper02.pdf [Accesed: 01.05.2026].
4. BLACK, P., WILIAM, D. (2009). *Developing the theory of formative assessment.* Educational Assessment, Evaluation and Accountability, 21(1), 5–31. Available: https://doi.org/10.1007/s11092-008-9068-5 [Accesed: 01.05.2026].
5. BOCOȘ, M-D. (2013) *Instruirea interactivă.* Iași: Polirom. ISBN: 978-973-46-3248-0.
6. BELDIGA, M., BRAGARU, T. (2025). *Studiu de caz: aplicarea inteligenței artificiale (IA) în educație. In Studia Universitatis Moldaviae. Seria „Științe ale educației"*. nr. 5(185), pp. 215–219. ISSN 1857-2103. Available: https://doi.org/10.59295/sum5(185)2025_26 [Accesed: 01.05.2026].
7. BRAGARU, T., ARNĂUT, V. (2017). *Dezvoltarea resurselor educaționale digitale: Cadru metodologic*. Chișinău: CEP USM. ISBN 978-9975-71-932-2.
8. BRAICOV, A., BIBIC, A. (2023). Simbioza competența matematică–competența digitală. În Proceedings of the 30th Conference on Applied and Industrial Mathematics, CAIM 2023, Iași, pp. 34–40. ISBN: 978-606-13-7848-7.
9. CAO, W. (2022). *Using technology to personalize middle school math instruction.* Frontiers in Education, **7**, 646471. Available: https://doi.org/10.3389/feduc.2022.646471 [Accesed: 01.05.2026].
10. CĂPĂȚÂNĂ, G., BRAGARU, T., BELDIGA, M. (2015). *An Intelligent Support System for Evaluation Items Development*, În 2015 20th International Conference on Control Systems and Computer Science, Bucharest, Romania, pp. 424-427, doi: 10.1109/CSCS.2015.151, Available: https://ieeexplore.ieee.org/document/7168464 [Accesed: 01.05.2026].
11. CASTRO, M. Á., GONZÁLEZ, D., PÉREZ, J., & MARTÍNEZ, F. (2024). *Integration of self-learning and assessment activities using STACK în a course of mathematics în engineering*. *Revista Iberoamericana de Tecnologías del Aprendizaje, 19*(3), 145–154. Available: https://rua.ua.es/bitstream/10045/148612/3/Castro_etal_2024_IEEERevIberoamTecnolAprendiz.pdf [Accesed: 01.05.2026].
12. CUCOȘ, C. (2008) *Teoria și metodologia evaluării*. Iași: Polirom. ISBN: 978-973-46-0936-9.
13. DAVIES, A., SANGWIN, C. (2024). *Symbolic assessment systems în mathematics education*. Oxford: Oxford University Press.
14. Design-Based Research Collective. (2003). *Design-based research: An emerging paradigm for educational inquiry*. Educational Researcher, *32*(1), pp. 5–8. Available: https://doi.org/10.3102/0013189X032001005 [Accesed: 01.05.2026].
15. DULAMĂ, M.E. (2020) *De la teorie spre practică în evaluarea online*. Cluj-Napoca: Presa Universitară Clujeană. Acta Didactica Vol 20 ISBN978-606-37-0958-6. Available: https://editura.ubbcluj.ro/index.php/puc/catalog/view/2477/22993/5463 [Accesed: 01.05.2026].
16. Frontiers in Education (2024). *Comparative analysis of frequently used e-learning platforms*. *Frontiers in Education*. Available: https://doi.org/10.3389/feduc.2024.1431531 [Accesed: 01.05.2026].
17. GUȚU, V., VICOL, M. (2014). *Tratat de pedagogie: între modernism și postmodernism*. Iași: Performantica. ISBN 978-606-685-170-1.
18. HATTIE, J., TIMPERLEY, H. (2007). *The Power of Feedback*. Review of Educational Research, 77(1), pp. 81–112. Available: https://doi.org/10.3102/003465430298487 [Accesed: 01.05.2026].
19. HODGES, C. B.; MOORE, S.; LOCKEE, B. B.; TRUST, T.; BOND, M. A**.** (2020). *The difference between emergency remote teaching and online learning.* EDUCAUSE Review. Available: https://er.educause.edu/articles/2020/3/the-difference-between-emergency-remote-teaching-and-online-learning [Accesed: 01.05.2026].

20. HOLMES, W., BIALIK, M., FADEL, C. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning.* Boston: Center for Curriculum Redesign. ISBN 978-1794293700. Available:

https://www.researchgate.net/publication/332180327_Artificial_Intelligence_in_Education_Promise_and_Implications_for_Teaching_and_Learning [Accesed: 01.05.2026].
21.JUNGIC, V., KENT, D., & MENZ, P. (2012). *STACK: System for Teaching and Assessment using a Computer algebra Kernel.* International Journal of Mathematical Education în Science and Technology, 43(4), pp. 501–512. Available: https://doi.org/10.1080/0020739X.2011.618559 [Accesed: 01.05.2026].
22.LAURILLARD, D. (2012). *Teaching as a Design Science: Building Pedagogical Patterns for Learning and Technology* (1st ed.). London: Routledge. ISBN 978-0415803878. Available: https://doi.org/10.4324/9780203125083 [Accesed: 01.05.2026].
23.Lowe, T. W. (2020). *Using STACK to support student learning at master's level* [Technical report]. The Open University. Available: https://oro.open.ac.uk/59062/1/STACKMSc.pdf [Accesed: 01.05.2026].
24.MARIN, M. (2017). *Mijloace didactice digitale de concepție proprie – sursă importantă în dinamica progresului academic al studenților.* Acta et Commentationes, nr. 1(10), pp. 114–124.
25.Ministerul Educației Naționale. (2017). *Ordin nr. 3393 din 28 februarie 2017 privind aprobarea programelor școlare pentru învățământul gimnazial. Matematică și Științe Umaniste și ale Educației* . București: MEN. https://rocnee.eu/images/rocnee/fisiere/planuri-cadru/gimnazial/21102024/OMEN%203393_MATEMATICA%20SI%20STIINTE%20ALE%20NATURII.pdf [Accesed: 01.05.2026].
26.Ministerul Educației României. (2024). *Raport privind starea învățământului preuniversitar din România 2023–2024.* https://www.edu.ro/sites/default/files/_fi%C8%99iere/Minister/2024/div/Rapoarte_sistem/Raport_Stare_invatamant_preuniv-2023-2024.pdf [Accesed: 01.05.2026].
27.Ministerul Educației, Culturii și Cercetării Al Republicii Moldova, (2020). C*urriculum Național Matematică Clasele V-IX. Curriculum disciplinar. Ghid de implementare Chişinău, 2020.* Available: https://mecc.gov.md/sites/default/files/matematica_gimnaziu_ro.pdf. [Accesed: 01.05.2026].
28.Moodle Stats. (2025). *Statistics about the Moodle project*. Available: https://stats.Moodle .org [Accessed at: 01.05.2026].
29.NEACȘU, I. (2015). *Învățarea eficientă: fundamente şi practici de succes*. Iași: Polirom.
30.NOORBEHBAHANI, F., MOHAMMADI, A., AMINAZADEH, M. (2022). *A systematic review of research on cheating în online exams from 2010 to 2021*. Education and Information Technologies, 27, pp. 8413–8460. Available: https://doi.org/10.1007/s10639-022-10927-7 [Accesed: 01.05.2026].
31.OECD. (2025). *Education and skills in Romania: Reviews of national policies for education*. OECD Publishing. Available: https://doi.org/10.1787/594cbb5d-en [Accesed: 01.05.2026].
32.POTOLEA, D., MANOLESCU, M. (2005). *Teoria și practica evaluării educaționale*. București: Ministerul Educației.
33.SALI, L.; COZMA, D.; IONEL, M. (2025). *Analiza logico-didactică a conținuturilor orientate spre formarea competenței de modelare matematică.* În: Abordări inter/transdisciplinare în predarea ştiinţelor reale (concept STEAM). Chișinău: CEP UPSC, pp. 201–206.
34.SANGWIN, C.J. (2013). *Computer Aided Assessment of Mathematics: Technologies and Research.* Oxford: Oxford University Press. ISBN 978-0-19-966035-3.
35.SINGER, F.M. (2007). Beyond conceptual change: Using representations to integrate domain-specific structural models in learning mathematics. *Mind, Brain, and Education*, 1(2), pp. 84–97. Available: DOI:10.1111/j.1751-228X.2007.00009.x [Accesed: 01.05.2026].
36.SON, T. (2024). *Intelligent tutoring systems in mathematics education: A systematic review*. *Computers, 13*(10), Article 270. Available: https://doi.org/10.3390/computers13100270 [Accesed: 01.05.2026].
37.VANLEHN, K. (2011). *The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems.* Educational Psychologist, 46(4), pp. 197–221. Available: https://doi.org/10.1080/00461520.2011.611369 [Accesed: 01.05.2026].
38.ZASTÎNCEANU, L. (2021). Evaluarea la matematică prin intermediul soft-urilor. Reflecții metodice În: Acta et Commentationes, Sciences of Education, nr. 4(26), 2021, pp.86-94 ISSN 1857-0623.

LIST OF THE AUTHOR'S PUBLICATIONS ON THE THESIS TOPIC

1. Articles in Scientific Journals

1.1. In journals indexed in international databases: Web of Science, EBSCO

1.1.1. BRĂNOAEA, G. C. (2025d) *Neuroadaptive Digital Assessment în Mathematics: A Parametric Approach with STACK and AI-Powered Feedback*. In: BRAIN. Broad Research în Artificial Intelligence and Neuroscience, vol. 16, nr. 3, pp. 489–504. ISSN e-2067-3957, p-2068-0473. Available: https://doi.org/10.70594/brain/16.3/11, Indexat Web of Science (ESCI, IF 0.5, Q4)] [Accesed: 01.05.2026].

1.1.2. BRĂNOAEA, G. C. (2026a) *Parametric Generation of Advanced Mathematics Assessment Items Using ChatGPT for Moodle Integration.* In: Didactica Danubiensis, 6.1: pp. 274-288. Available: https://dj.univ-danubius.ro/index.php/DD/article/view/3633, EBSCO Publishing database [Accesed: 01.05.2026].

1.2. In journals listed in the National Register of Specialized Journals (with category specified)

1.2.1. BRĂNOAEA, G.C. (2025f) *Parametric assessment în Moodle for improving mathematical performance în middle school*. In: Studia Universitatis Moldaviae. Științe ale Educației, nr. 5(185), pp. 113–123. ISSN 1857-2103.DOI: https://doi.org/10.59295/sum5(185)2025_13 Categoria B, CEP USM. [Accesed: 01.05.2026]

1.2.2. BRAGARU T., **BRĂNOAEA**, G.C., IESEANU D., BELDIGA M. (2026) *Bune practici de (auto-) evaluare pe Moodle*, In: Akademos, Categoria B, p.33-41. Available: https://ibn.idsi.md/sites/default/files/j_nr_file/Akademos_1_2026_WEB_compressed.pdf [Accesed: 01.05.2026].

1.2.3. BRĂNOAEA, G.C., BRAICOV A., BRAGARU T. (2026) *Pattern-uri de eroare în evaluarea digitală parametrizată la matematică,* In: Acta et Commentationes, Sciences of Education, categoria C, p. 7-19. Available: https://revistaust.upsc.md/index.php/acta_educatie/article/view/1203/1174 [Accesed: 01.05.2026].

2. Articles in Conference Proceedings and Other Scientific Events

2.1. In the proceedings of scientific events indexed in Web of Science

2.1.1. BRĂNOAEA, G. C. (2026b) *Optimization of Symbolic Digital Assessment: A Parametric Approach Using STACK in Mathematics Education.* In: Moldovan, L., Gligor, A. (eds) Proceedings of the 19th International Conference Inter-Eng 2025 Interdisciplinarity in Engineering Held During 3–4 October 2025. Inter-ENG 2025. Lecture Notes in Networks and Systems, vol 1812. Springer, Cham. (ISI Web of Science) Available: https://doi.org/10.1007/978-3-032-17033-0_11 [Accesed: 01.05.2026].

2.2. In the proceedings of international scientific events included in other databases recognized by ANACEC

2.2.1. BRĂNOAEA, G.C. (2023) *Intelligent Support System Applied to School Mathematics Lessons*. În: The Scientific Bulletin Addendum The Official Catalogue of the "Cadet INOVA" The International Student Innovation And Scientific Research Exhibition, Sibiu, nr. 8/2023, pp. 219–227. ISSN 2501-3157. Available: https://ibn.idsi.md/sites/default/files/imag_file/23p-219-227.pdf [Accesed: 01.05.2026].

2.2.2. BRĂNOAEA, G.C. (2024) *Tehnici de inteligență artificială aplicate elevilor cu aptitudini matematice înalte*. In: Materialele conferinței științifice internaționale Statul, securitatea și drepturile omului în era digitală, Chișinău: CEP USM, vol. 2, pp. 60–65. ISBN 978-9975-62-529-6. Available: https://ibn.idsi.md/sites/default/files/imag_file/60-65_41.pdf [Accesed: 01.05.2026].

2.2.3. BRĂNOAEA, G.C. (2025a) *Creșterea achizițiilor matematice la elevii de gimnaziu prin itemi personalizați*. In: Materialele conferinței științifice internaționale „Instruire prin cercetare pentru o societate prosperă", Chișinău, 1–2 martie 2025, vol. II, pp. 19–23. ISBN 978-9975-48-249-3, CZU: 373.016:51. 10.46727/c.v2.01-02-03-2025.p19-23 Available: http://dir.upsc.md:8080/xmlui/123456789/7665 [Accesed: 01.05.2026].

2.2.4. BRĂNOAEA, G.C., BRAGARU, T. (2025a) *Best Practices for Parametric Testing în Mathematics.* In: Materialele conferinței științifice internaționale TELE-2025, Chișinău, martie 2025. Available: https://irek.ase.md:443/xmlui/handle/123456789/4087 [Accesed: 01.05.2026].

2.2.5. BRÂNOAEA, G.C. (2025g) *Digitalizarea educației matematice: între inovație pedagogică și respectarea drepturilor omului.* In: International Conference State, security and human rights. p. 602-609. Available: https://ibn.idsi.md/ro/vizualizare_articol/235947 [Accesed: 01.05.2026].

2.2.6. BRĂNOAEA, G. C. (2025h) *Dezvoltare inteligentă RED pentru matematică în Moodle: învățare adaptivă prin evaluarea parametrizată.* În: Materialele conferinței științifice internaționale Știință și

educație: noi abordări și perspective, Vol. 3: Științe exacte. Disponibil la http://dir.upsc.md:8080/xmlui/123456789/7947 [Accesed: 01.05.2026].

2.2.7. BRĂNOAEA, G.C. (2025i) *Aplicații ale inteligenței artificiale în educația matematică.* In: Materialele conferinței științifice naționale cu participare internațională Știință și educație: noi abordări și perspective: „Integrare prin cercetare și inovare", Chișinău, pp. 712–718. CZU: 004.8:51(072.3):37.03. DOI: https://doi.org/10.59295/spd2024n.98 [Accesed: 01.05.2026].

2.2.8. BRĂNOAEA G.C. (2025j) *Intelligent Support System Applied to School Mathematics Lessons*. In: Proceedings of European Exhibition of Creativity and Innovation EUROINVENT 2023, Iași, România, ISSN Print: 2601-4564, Online: 2601-4572, p. 144–145.

2.2.9. BRĂNOAEA, G.C. (2025k) *Sistem suport inteligent aplicat la orele de matematică din gimnaziu.* In: International Conference Mathematics and Information Technologies: Research and Education, Chișinău, p. 98. Available: https://ibn.idsi.md/sites/default/files/imag_file/98_28.pdf [Accesed: 01.05.2026].

2.2.10. BRĂNOAEA, G.C. (2025l) *Benefits of Using Intelligent E-Learning Platforms în Mathematics Learning.* In: Materialele conferinței științifice naționale cu participare internațională Științele Naturii în Dialogul Generațiilor, Chișinău, p. 260. Available: https://ibn.idsi.md/sites/default/files/imag_file/260_7.pdf [Accesed: 01.05.2026].

2.2.11. BRĂNOAEA, G.C. (2025m) *Engineering Optimization of Parametric Digital Assessment în Mathematics Using STACK and Symbolic Computation*. In: OPROTEH 2025 – The 20th International Conference of Constructive Design and Technological Optimization în Machine Building Field, Bacău, România, mai 2025. Editura: „Alma Mater", ISBN 2457-3388, p. 192.

2.2.12. BRĂNOAEA, G. C., BRAGARU, T., IEȘEANU, D. (2025) *Potențialul jocurilor tematice pe Moodle pentru consolidarea cunoștințelor*. În: MITRE-2025: The 10th International Conference „Mathematics & IT: Research and Education", Chișinău, Republica Moldova, 26–29 iunie 2025. *Rezumat publicat*, pp. 112–113. Available: https://mitre.usm.md/sites/default/files/Abstracts_MITRE_2025.pdf [Accesed: 01.05.2026].

2.2.13. IEȘEANU, D., BRAGARU, T., **BRĂNOAEA**, G. C. (2025) *Potențialul e-testării pe Moodle pentru studiul matematicii și informaticii*. În: MITRE-2025: The 10th International Conference „Mathematics & IT: Research and Education", Chișinău, Republica Moldova, 26–29 iunie 2025. Rezumat publicat, pp. 123–124. Available: https://mitre.usm.md/sites/default/files/Abstracts_MITRE_2025.pdf [Accesed: 01.05.2026].

2.2.14. IEȘEANU, E., DRĂGAN, G., **BRĂNOAEA**, G. C. (2025) *Învățarea matematicii prin itemi parametrizați.* În: MITRE-2025: The 10th International Conference „Mathematics & IT: Research and Education", Chișinău, Republica Moldova, 26–29 iunie 2025. Rezumat publicat, pp. 124–125. Available: https://mitre.usm.md/sites/default/files/Abstracts_MITRE_2025.pdf [Accesed: 01.05.2026].

2.2.15. BRĂNOAEA G.C. (2025n) *Automatizarea procesului de creare a itemilor pentru evaluarea la matematică cu ajutorul tehnologiei CHATGPT*. In: *Book of Abstracts*, The International Conference on Transversal Education (ICTE), USAMV Cluj-Napoca, 20 iunie 2025, p. 39–40.

2.2.16. BRĂNOAEA, G.C. (2025e) *H5P-Based digital tools in Moodle for adaptive mathematics education*. In: Materialele conferinței științifice naționale cu participare internațională Științele Naturii în Dialogul Generațiilor, Chișinău, p. 213. Disponibil la https://agarm.md/wp-content/uploads/2025/09/2_Conference_Abstract-book_final-22.09.2025.pdf [Accesed: 01.05.2026].

2.2.17. BRĂNOAEA, G.C., BRAGARU, T. (2025b) *Validarea unui sistem suport inteligent pentru evaluarea automatizată la matematică prin analiza feedback-ului elevilor*. În: Integrare prin cercetare și inovare: conferința științifică națională cu participare internațională, 6-7 noiembrie 2025. Științe Sociale. Chișinău: CEP USM. ISBN 978-9975-62-990-4 (PDF). Available: https://doi.org/10.59295/spd2025s https://msuir.usm.md/handle/123456789/19719 [Accesed: 01.05.2026]

3. Patents and Other Intellectual Property Objects (IPOs)

3.1.1. BRĂNOAEA, G. C., BRAGARU, T., USM (2025c) *Drept de autor asupra produsului program direct utilizabil și extensibil-adaptabil „Sistem Suport Inteligent Pentru Matematica Gimnazială"* înregistrat la AGEPI, Certificat seria PC nr. 8336 din 18.12.2025, Available: https://www.db.agepi.md/opere/Details.aspx?RealID=7764&lang=ro [Accesed: 01.05.2026]

ANNOTATION

Brănoaea Gabriela Cristina

INTELLIGENT SUPPORT SYSTEM FOR ENHANCING MATHEMATICAL LEARNING IN HIGH SCHOOL STUDENTS

Doctoral thesis in the specialty 532.02. School didactics

Chișinău, 2026

Volume and structure: The thesis is written in Romanian as a manuscript, technically edited on the computer. The thesis is organized into introduction, 3 chapters, conclusions and recommendations and bibliography, containing 126 titles, and 12 appendices. The core text spans146 pages, including 13 figures and 41 tables. The research results are published in 23 scientific papers and reported at 24 scientific events.

Keywords: ISS, FOSS, REDI, middle school mathematics, digital education, Moodle platform, didactic model, parameterized items, adaptive feedback, mathmentor.ro.

The purpose of the research is to provide a theoretical and methodological foundation, develop and experimentally validate a didactic model of formative assessment, based on an Intelligent Support System (ISS) for learning and assessing mathematics at the secondary school level, achieved by integrating the Moodle platform with FOSS (Free and Open Source Software) plugins and Intelligent Digital Educational Resources (IDER). ISS supports the automatic generation and correction of standardized assessments, with adaptive feedback, in order to accelerate students' mathematical acquisitions and streamline teachers' work.

The objectives of the research: 1. Analysis of the theoretical and methodological framework regarding formative assessment and the use of intelligent educational support systems in mathematics teaching. 2. Comparison of the main learning management systems, in order to identify opportunities for integrating intelligent digital assessment in secondary education. 3. Design of the didactic model of formative assessment, based on pedagogical principles validated in the specialized literature. 4. Development of SSI, by integrating the Moodle platform with advanced FOSS plugins and developing intelligent digital educational resources. 5. Implementation of the didactic model and SSI, by conducting a quasi-experimental study in the real educational environment. 6. Validation of SSI, through quantitative analysis of student performance, through psychometric indicators specific to digital assessment and through qualitative analysis of participants' perceptions.

The scientific novelty and originality are demonstrated by updating and operationalizing the concept of formative assessment by integrating parameterized items and adaptive feedback into a didactic model based on an intelligent support system implemented on its own digital platform, mathmentor.ro, with customized code and experimentally validated IDER.

Results obtained: 1. Student performance: the average score of the experimental group increased by ≈1.02p. from pre-test to post-test via IDER and by ≈0.47p. compared to the control group. 2. Teachers reported a decrease in correction time from ≈4h to <45min/test. 3. High level of acceptance and satisfaction: 92% of students and 100% of teachers rated ISS as "very useful". The results led to a reduction in the discrepancy between the didactic potential of digital educational systems and their use in secondary school practice in RO/MD.

Theoretical significance and practical applicability: Substantiation of an integrated ISS model for digital formative assessment in mathematics teaching, has contributions to the theory of technology-assisted assessment and direct applicability in middle school education, including for students with special educational needs or high performance. ISS contributes to improving students' mathematical achievement, reduces teachers' workload and supports educational management, being a directly applicable, adaptable and easily transferable system in other STEM disciplines or in the high school cycle.

The implementation of the scientific results: The ISS model was operationalized through a digital course protected by intellectual property rights, implemented on three Moodle platforms (USM, CEITI and mathmentor.ro) and experimentally applied in several educational institutions in Romania and the Republic of Moldova, including within a RO–MD technology transfer project. The results were also validated by medals at international invention salons.

ADNOTARE

Brănoaea Gabriela Cristina

SISTEM SUPORT INTELIGENT PENTRU ACCELERAREA ACHIZIȚIILOR MATEMATICE LA ELEVII DE GIMNAZIU

Teză de doctorat la Specialitatea 532.02. Didactică școlară

Chișinău, 2026

Volumul și structura tezei: Teza este scrisă în limba română cu titlu de manuscris, tehnoredactată la calculator și imprimată. Lucrarea este structurată în introducere, trei capitole, concluzii generale și recomandări, bibliografie cu 126 de titluri și 12 anexe. Textul de bază se întinde pe 146 de pagini, cuprinzând 13 figuri și 41 de tabele. Rezultatele cercetării sunt publicate în 23 lucrări științifice și raportate la 24 de evenimente științifice.

Cuvinte-cheie: SSI, FOSS, REDI, matematică gimnazială, educație digitală, platforma Moodle, model didactic, itemi parametrizați, feedback adaptiv, mathmentor.ro.

Scopul tezei constă în fundamentarea teoretico-metodologică, elaborarea și validarea experimentală a unui model didactic de evaluare formativă, bazat pe un Sistem Suport Inteligent (SSI), realizat prin integrarea platformei Moodle cu pluginuri FOSS (Free and Open Source Software) și Resurse Educaționale Digitale Inteligente (REDI), orientat spre generarea și corectarea automată a evaluărilor standardizate, cu feedback adaptiv, în vederea accelerării achizițiilor matematice ale elevilor de gimnaziu și eficientizării activității profesorilor.

Obiectivele cercetării: 1.Analiza cadrului teoretic și metodologic privind evaluarea formativă și utilizarea sistemelor inteligente de suport educațional în didactica matematicii. 2.Compararea principalelor sisteme de management al învățării, în vederea identificării oportunităților de integrare a evaluării digitale inteligente în învățământul gimnazial. 3.Proiectarea modelului didactic de evaluare formativă, bazat pe principii pedagogice validate în literatura de specialitate. 4.Dezvoltarea SSI, prin integrarea platformei Moodle cu pluginurile avansate FOSS și elaborarea resurselor educaționale digitale inteligente. 5.Implementarea modelului didactic și SSI, prin realizarea unui studiu cvasi-experimental în mediul educațional real. 6.Validarea SSI, prin analiza cantitativă a performanțelor elevilor, prin indicatori psihometrici specifici evaluării digitale și prin analiza calitativă a percepțiilor participanților.

Noutatea și originalitatea științifică sunt demonstrate prin actualizarea și operaționalizarea conceptului de evaluare formativă prin integrarea itemilor parametrizați și a feedbackului adaptiv într-un model didactic bazat pe un sistem suport inteligent implementat pe platformă digitală proprie, mathmentor.ro, cu cod personalizat și REDI validate experimental.

Rezultatele obținute în urma implementării SSI: 1. Performanța elevilor: nota medie a grupului experimental a crescut cu ≈1,02p. de la pre-test la post-test prin REDI și cu ≈ 0,47p. față de grupul de control. 2. Economie de timp: profesorii au raportat scăderea timpului de corectare de la ≈ 4 h la < 45 min/test. 3. Nivel ridicat de acceptare și satisfacție: 92% elevi și 100 % profesori au evaluat ISS drept „foarte util”. Rezultatele au condus la reducerea discrepanței dintre potențialul didactic al sistemelor educaționale digitale și utilizarea lor în practica școlară din RO/MD.

Semnificația teoretică și valoarea aplicativă: Fundamentarea unui model integrat ISS pentru evaluare formativă digitală în didactica matematicii, are contribuții la teoria evaluării asistate de tehnologie și aplicabilitate directă în învățământul gimnazial, inclusiv pentru elevii cu cerințe educaționale speciale sau performanțe înalte. ISS contribuie la accelerarea achizițiilor matematice ale elevilor de gimnaziu, reduce sarcina profesorilor și sprijină managementul educațional, fiind un sistem direct aplicabil, adaptabil și ușor transferabil în alte discipline STEM sau în ciclul liceal.

Implementarea rezultatelor științifice: Modelul ISS a fost operaționalizat printr-un curs digital protejat prin drepturi de proprietate intelectuală, implementat pe trei platforme Moodle (USM, CEITI și mathmentor.ro) și aplicat experimental în mai multe instituții de învățământ din România și Republica Moldova, inclusiv în cadrul unui proiect de transfer tehnologic RO–MD. Rezultatele au fost validate și prin medalii la saloane de inventică internaționale.

АННОТАЦИЯ

Brănoaea Gabriela Cristina

ИНТЕЛЛЕКТУАЛЬНАЯ СИСТЕМА ПОДДЕРЖКИ ДЛЯ УСКОРЕННОГО ИЗУЧЕНИЯ МАТЕМАТИКИ У УЧАЩИХСЯ СТАРШИХ КЛАССОВ

Докторская диссертация по специальности 532.02. Школьная дидактика

Кишинёв, 2026

Объем и структура диссертации: Диссертация написана на румынском языке в виде рукописи, набрана и отпечатана на компьютере. Работа состоит из введения, трех глав, общих выводов и рекомендаций, библиографии из 126 наименований и 12 приложений. Объем основного текста составляет 146 страниц, включая 13 рисунков и 41 таблиц. Результаты опубликованы в 23 научных статьях и представлены на 24 мероприятиях.

Ключевые слова: SSI, FOSS, REDI, математика для средней школы, цифровое образование, платформа Moodle, дидактическая модель, параметризованные элементы, адаптивная обратная связь, mathmentor.ro.

Цель диссертации —предоставить теоретическую и методологическую основу, разработать и экспериментально подтвердить дидактическую модель формирующего оценивания на основе интеллектуальной системы поддержки (ИСС) для обучения и оценивания математики на уровне средней школы. Эта система реализована путем интеграции платформы Moodle с плагинами на основе свободного и открытого программного обеспечения (FOSS) и интеллектуальными цифровыми образовательными ресурсами (REDI). ИСС поддерживает автоматическую генерацию и проверку стандартизированных оценок с адаптивной обратной связью для ускорения обучения учащихся и оптимизации работы учителя.

Цели исследования: 1. Анализ теоретической и методологической основы формирующего оценивания и использования интеллектуальных систем поддержки обучения в преподавании математики. 2. Сравнение основных систем управления обучением с целью выявления возможностей интеграции интеллектуального цифрового оценивания в среднее образование. 3. Разработка дидактической модели формирующего оценивания на основе педагогических принципов, подтвержденных в специализированной литературе. 4. Разработка системы поддержки обучения (SSI) путем интеграции платформы Moodle с передовыми плагинами FOSS и создания интеллектуальных цифровых образовательных ресурсов. 5. Внедрение дидактической модели и системы поддержки обучения (SSI) путем проведения квазиэкспериментального исследования в реальной образовательной среде. 6. Валидация системы поддержки обучения (SSI) посредством количественного анализа успеваемости учащихся, с помощью психометрических показателей, специфичных для цифрового оценивания, и посредством качественного анализа восприятия участников.

Научная новизна и оригинальность демонстрируются путем обновления и операционализации концепции формирующего оценивания посредством интеграции параметризованных заданий и адаптивной обратной связи в дидактическую модель, основанную на интеллектуальной системе поддержки, реализованной на собственной цифровой платформе mathmentor.ro, с использованием специально разработанного кода и экспериментально подтвержденной REDI.

Результаты, полученные благодаря внедрению SSI: 1. Успеваемость учащихся: средний балл экспериментальной группы увеличился примерно на 1,02 балла по сравнению с предварительным и итоговым тестированием с помощью REDI и примерно на 0,47 балла по сравнению с контрольной группой. 2. Экономия времени для учителей: с ≈4 часов до <45 минут на тест. 3. Высокая степень принятия и удовлетворённости: 92% учащихся и 100% учителей оценили ISS как «очень полезный». Результаты привели к уменьшению расхождения между дидактическим потенциалом цифровых образовательных систем и их использованием в практике средних школ в Румынии/Республики Молдова.

Теоретическая значимость и практическая применимость: Обоснование интегрированной модели ISS для цифрового формирующего оценивания в преподавании математики вносит вклад в теорию оценивания с использованием технологий и имеет непосредственное применение в среднем школьном образовании, в том числе для учащихся с особыми образовательными потребностями или высокими показателями успеваемости. ISS способствует ускорению освоения математики учащимися средней школы, снижает нагрузку на учителей и поддерживает управление образованием, являясь непосредственно применимой, адаптируемой и легко переносимой системой в другие STEM-дисциплины или в старшую школу.

Внедрение научных результатов: Методика ISS была внедрена в виде цифрового курса, защищённого правами интеллектуальной собственности, реализованного на трех платформах Moodle (USM, CEITI и mathmentor.ro) и экспериментально применённого в нескольких образовательных учреждениях Румынии и Республики Молдова, в том числе в рамках проекта трансфера технологий между Румынией и Молдовой. Результаты также были подтверждены наградами на международных салонах изобретений.

BRĂNOAEA GABRIELA – CRISTINA

INTELLIGENT SUPPORT SYSTEM FOR ACCELERATE MATHEMATICS ACHIEVEMENT IN HIGH SCHOOL STUDENTS

532.02. SCHOOL DIDACTICS
(BY STAGES AND EDUCATIONAL DISCIPLINES)

Summary of the Doctoral Thesis in Educational Sciences

Approved for printing: 15.06.2026	Format 60x84 1/16
Offset paper. Offset pattern.	Circulation ex. 10
Sheets of print: 2	Order no. 47/26

The Editorial-Polygraph Center of the Moldova State University
A. Mateevici str., 60, Chisinau, MD- 2009