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Redesigning the instructional model for the digital transformation of demanding foundational courses

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Abstract: Digital transformation in higher education should go beyond putting teaching materials online or adding technological tools. It calls for a coordinated redesign of learning outcomes, content organization, learning activities, and assessment. Using Methods of Mathematical Physics at a regional university as a case study, this study draws on literature analysis, theoretical synthesis, and reflection on course implementation. To address abstract concepts, derivation-heavy content, fragmented knowledge, and delayed feedback, it proposes an instructional model organized around four coordinated dimensions connected by a three-stage closed loop. In the objective dimension, students progress from knowledge acquisition to modeling, problem solving, and transfer. In the content dimension, question sequences, a knowledge graph, and computational visualization are used to reorganize the course. In the pedagogical dimension, instruction spans pre-class diagnosis, in-class knowledge construction, and post-class extension. In the assessment dimension, low-stakes quizzes, project assignments, peer review, and two-stage examinations are combined. Evidence from course grades, learning-platform records, classroom observations, and student evaluations provides preliminary support for the feasibility of the framework. Initial observations suggest potential improvements in student learning outcomes. The central argument is that digital transformation in demanding foundational courses depends less on the number of tools adopted than on constructive alignment among technological affordances, disciplinary content, learning mechanisms, and assessment evidence. The framework offers transferable design principles for redesigning theory-intensive foundational courses in higher education, although its effectiveness requires further validation through quasi-experimental research.

1. Introduction

Digital technologies are changing how knowledge is produced, organized, and communicated in higher education. Yet uploading slides to a platform, adding online videos, or introducing a piece of software does not in itself amount to digital transformation. Research suggests that digital transformation in higher education requires coordinated changes in instructional processes, organizational culture, and support systems (Castro Benavides et al., 2020). Students, meanwhile, tend to value uses of technology when learning tasks are clear and the tools offer convenience and tangible benefits (Henderson et al., 2017). At the course level, the focus should therefore shift from adopting tools to redesigning the instructional system: clarifying why a technology is used, what learning activity it supports, what evidence it generates, and how it contributes to student development.

Demanding foundational courses provide a useful test of whether digital transformation reaches the core of teaching and learning. Methods of Mathematical Physics is a prerequisite for the four core courses in theoretical physics and requires students to move continually among mathematical language, physical interpretation, and practical application. Previous studies have explored connections across course content, the integration of teaching and research, visualization, and diversified assessment (Zhao et al., 2014; Zhu et al., 2022; Xu and Wang, 2025), but many accounts still center on isolated measures or summaries of teaching experience. Simply placing an online platform, mathematical software, group work, and continuous assessment side by side produces a collection of tools rather than a coherent model. It does little to explain why individual measures work, how they constrain and reinforce one another, or whether they can transfer to other theory-intensive courses.

Against this background, the study uses the continuing implementation of Methods of Mathematical Physics as a case to address three questions. First, what structural barriers limit deep learning in demanding foundational courses? Second, how can modern educational principles and the affordances of digital technologies be coordinated across

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objectives, content, pedagogy, and assessment? Third, through what theoretical mechanisms might this model support student engagement, the organization of knowledge, and complex problem solving, and what are its conditions of use and limits of interpretation? The study contributes by defining course-level digital transformation as a systemic redesign of objectives, content, pedagogy, and assessment. It develops an actionable framework of four-dimensional coordination and a three-stage closed loop, and draws on multiple sources of evidence, with their interpretive limits made explicit, to identify transferable design principles.

2. Framework development and course context

2.1 Course context and sources of the problems

The study was conducted in a Methods of Mathematical Physics course for physics majors at a regional university. The course comprises 64 lecture hours and covers introductory vector analysis and field theory, complex analysis, and equations of mathematical physics. Students need prerequisite knowledge such as calculus and must also learn to state modeling assumptions, formulate governing equations, identify initial and boundary conditions, select solution methods, and interpret results. The course thus provides an important methodological foundation for the four core courses in theoretical physics that follow. Students generally enter with an interest in learning and basic scientific reasoning skills, but their mathematical preparation varies. Lengthy derivations and abstract notation can therefore lead to apprehension, passive learning, and difficulty transferring knowledge.

2.2 Development of the theoretical framework

The study follows a practice-oriented design-based research approach (The Design-Based Research Collective, 2003). An initial design was developed from observed learning difficulties and relevant learning theories, then iteratively refined across successive course offerings with attention to learning tasks, digital resources, and assessment feedback. The evidence examined includes course plans and instructional resources, aggregate grade distributions, activity records from the learning platform, classroom observations, student course evaluations, and outcomes from projects and related competitions. Only aggregate information is reported; no names, student numbers, or other personally identifying information are included.

2.3 Use of implementation evidence and limits of interpretation

The analysis centers on examining theoretical propositions alongside evidence from implementation. It first identifies course difficulties and the learning mechanisms that may underlie them, and then considers whether each design element maintains alignment among objectives, activities, and assessment. Multiple sources of evidence strengthen the credibility of the case analysis, but the available material is not sufficient for rigorous causal identification. The study therefore concentrates on model development, plausible mechanisms, and transferable principles; it does not treat observed trends as fully established net effects.

3. Diagnosing course challenges and the logic of reform

3.1 Abstract concepts and dense derivations create heavy cognitive load

Topics such as gradient, divergence, curl, analytic functions, residues, Fourier transforms, and partial differential equations all require conceptual understanding, symbolic manipulation, and physical interpretation. When students' prerequisite knowledge of mathematics is weak, working memory is consumed by formula manipulation, making it difficult to build stable conceptual schemas. Once students lose the thread of a derivation, confusion about a single step can quickly become apprehension about the course as a whole. A conventional class that prioritizes complete blackboard derivations and uninterrupted exposition may leave students able to copy the procedure without recognizing its critical steps.

3.2 Limited contact hours make it difficult to balance depth and breadth

The course has 64 contact hours. If most of that time is spent explaining foundational formulas, difficult and important topics cannot be explored in depth, leaving little room for advanced applications and authentic problems. An excessive emphasis on applications, however, can leave basic training underdeveloped. The issue is not simply how to add more content. Rather, core, advanced, and extension material must be distinguished; work that students can complete independently should be moved online; and face-to-face time should be reserved for cognitively demanding analysis, derivation, comparison, and explanation.

3.3 Numerous but hidden connections impede knowledge transfer

Students often regard vector analysis and field theory, complex analysis, and equations of mathematical physics as separate blocks. They have only a limited grasp of the common structure linking a physical situation, modeling assumptions, governing equations, initial and boundary conditions, solution methods, and physical interpretation. Although they may imitate worked examples in an examination, they often struggle to select a method when boundary conditions change or a problem is presented in a new context. Course learning must therefore extend beyond procedural calculation. Knowledge networks and sequenced questions are needed to help students organize knowledge around the conditions under which particular ideas and methods apply.

3.4 Overreliance on summative assessment delays feedback

A single final examination can assess cumulative knowledge, but it cannot reveal specific difficulties in concepts, derivations, modeling, and interpretation early enough to address them. When assessment occurs only at the end of a course, it cannot guide ongoing learning and may encourage last-minute revision and mechanical imitation. Assessment needs to be embedded in the learning process so that it can diagnose difficulties, provide feedback, support revision, and promote peer learning. Research on formative assessment likewise shows that feedback advances learning only when assessment evidence is used to adjust teaching and learning (Black and Wiliam, 1998).

Table 1 Diagnosis of challenges in demanding courses and the logic of reform

Main challenge	Typical manifestation	Learning mechanism	Reform response
Heavy cognitive load	Numerous formulas and lengthy derivations Gaps in prerequisite knowledge lead to apprehension	Segmentation, pretraining, and multiple representations reduce extraneous load	Pre-class remediation; key steps left for completion; computational visualization
Tension between depth and breadth	Class time consumed by foundational exposition Insufficient application and transfer	Layered content and blended learning redistribute time	Core, advanced, and extension content; division of work between online and face-to-face learning
Fragmented knowledge	Can solve familiar problems but cannot identify models and methods in new problems	Making conceptual relationships explicit supports schema formation and transfer	Knowledge graph; question sequences; integrative projects
Delayed feedback	Emphasis on outcomes rather than process Concentrated revision shortly before the final examination	Frequent feedback supports self-monitoring and learning regulation	Low-stakes quizzes; peer review; two-stage examinations

4. Theoretical foundations and overall framework

4.1 Constructive alignment to maintain coherence in the reform

Constructive alignment begins by defining objectives as observable performances, then selecting tasks that elicit the corresponding learning activities and using matched assessment evidence to judge attainment (Biggs, 1996). Accordingly, the course does not take coverage of the textbook as its starting point. It begins with what students should be able to do: formulate a physical problem in terms of governing equations and specified initial and boundary conditions, explain when a solution method is valid, carry out the solution, and interpret the result. Objectives, learning activities, and assessment tasks thereby form a closed loop, keeping the reform focused on learning rather than surface-level activity or platform use.

4.2 Cognitive load and multimedia learning

Cognitive load theory suggests that complex problem solving can impede schema formation when it places excessive demands on working memory (Sweller, 1988). The course therefore addresses gaps in prerequisite knowledge before class, segments long derivations into critical steps, combines worked examples with steps left for students to complete, and explicitly links symbolic expressions with corresponding diagrams. Mathematica can turn abstract objects such as Fourier expansions, d'Alembert's formula, separation of variables, and vector fields into dynamic, controllable representations. More visualization is not necessarily better, however; related information should be placed together, processes should be segmented, and essential information should be signaled clearly (Mayer, 2009).

4.3 Active learning, self-regulation, and TPACK

The TPACK framework emphasizes the integration of technological, pedagogical, and content knowledge (Mishra and Koehler, 2006). Guided by this principle, tools are selected for specific instructional functions. The learning platform distributes resources and provides diagnostic data and feedback; the knowledge graph makes disciplinary structure visible; mathematical software supports computational verification and visualization; and online discussion enables asynchronous interaction. Planning before class, monitoring during class, and reflection afterward correspond to key processes in self-regulated learning (Zimmerman, 2002). In-class derivation, discussion, and group explanation move students from passive listening to active cognitive processing. Research in STEM education also shows that well-designed active learning can improve performance and reduce the risk of failure (Freeman et al., 2014).

4.4 Four-dimensional, three-stage framework

The four dimensions are not parallel add-ons. Objectives guide the selection of content, content shapes the types of learning activity, activities generate evidence of the learning process, and assessment results feed back into content and instruction. The three-stage learning sequence provides an implementation order for all four dimensions. Before class, prior knowledge and points of difficulty are identified; during class, students construct concepts and investigate methods; after class, projects, peer review, and extension resources support consolidation and transfer. Modern educational principles provide design guidance, while digital technologies offer affordances for diagnosis, representation, interaction, recording, and feedback. Only when both are aligned around intended learning outcomes does the use of technology move beyond isolated applications and become a redesign of the instructional model.

5. Four-dimensional instructional redesigns

5.1 Learning outcomes: from knowledge to modeling and transfer

Before the reform, course objectives were often expressed as "understand the concepts" and "master the methods," phrases too general to guide activities or assessment directly. The revised outcomes are organized into three progressive levels. The first is foundational understanding and procedural competence: students explain core concepts, reproduce key derivations, and solve standard problems.

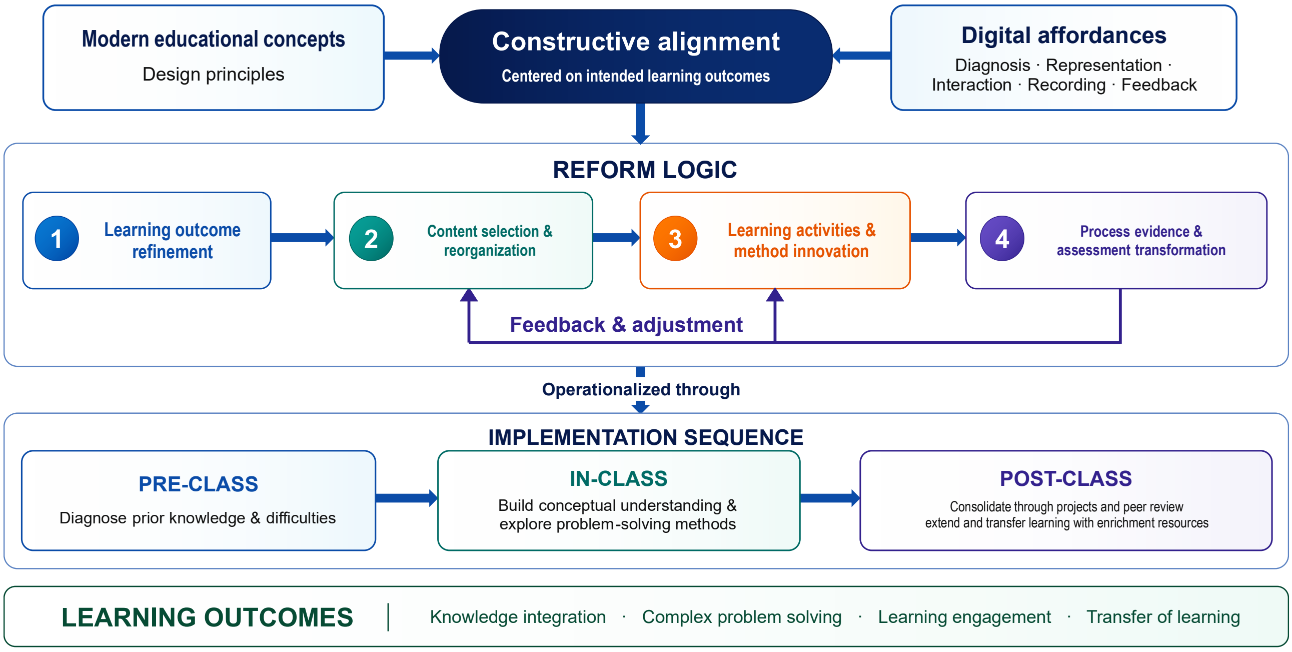

Figure 1 Four-dimensional, three-stage reform framework

Table 2 Outcome–activity–assessment alignment

Outcome level	Observable performance	Main learning activities	Assessment evidence
Foundational understanding and procedural competence	Explain concepts, reproduce key derivations, and solve standard problems	Micro-lesson preparation, worked examples, in-class key-step exercises	Pre-class quizzes, in-class quizzes, individual assignments
Modeling and problem solving	Formulate equations and initial or boundary conditions; compare and select solution methods	Question sequences, group inquiry, integrative examples, two-stage examinations	Modeling processes, derivation records, individual and group scripts
Interpretation and transfer	Check and interpret mathematical solutions; visualize with tools and transfer methods to new contexts	Mathematica labs, project work, presentations, and peer review	Code and figures, physical interpretation, project products, and reflections

The second is modeling and problem solving: students extract assumptions from a physical situation, formulate equations and initial or boundary conditions, and compare and select suitable solution methods. The third is interpretation and transfer: students check dimensional consistency, limiting cases, and boundary behavior; use computational tools to visualize results; and apply methods in later theoretical physics courses or authentic problems. Physics education research suggests that intermediate strategies such as dimensional analysis help students judge whether a result is reasonable and require appropriate scaffolding to develop into more expert-like problem-solving behavior (Burkholder et al., 2020).

This deepening of learning outcomes does not simply make the course more difficult. It turns reasoning that was formerly implicit in the instructor's exposition into observable performances that students can carry out. Confidence in learning, self-monitoring, and collaborative explanation provide process support for higher-order outcomes and give students with different levels of mathematical preparation a viable point of entry. Research on physics problem solving further indicates that expertise lies not only in choosing a formula or checking an answer, but also in flexibly blending conceptual reasoning with formal mathematical reasoning throughout the calculation (Kuo et al., 2013).

5.2 Layered, connected, and applied content

First, the content is organized in layers. The core layer covers concepts, theorems, and methods required in later courses. The advanced layer retains key derivations that clarify where methods come from and when they apply. The extension layer introduces applications in acoustics, heat conduction, electrostatics, wave phenomena, and signal processing. All students complete the core layer, while they may choose advanced and extension material according to their preparation and interests. This arrangement balances common requirements with differentiated development within limited contact hours.

Second, the organization of knowledge is redesigned. A course knowledge graph on the learning platform moves beyond a chapter outline and links physical situations, modeling assumptions, equation types, initial and boundary conditions, solution methods, and interpretation of results. Fourier series, for example, are connected both to orthogonal function systems and to eigenfunction expansions in separation of variables. The residue method in complex analysis is not only a technique for integration; it also supports certain integral transforms and physical calculations. Once these relationships are made explicit, students can more readily understand where a method comes from, the conditions under which it applies, and what it is used for. A related meta-analysis likewise found that schematic representations such as concept and knowledge maps support retention and transfer (Nesbit and Adesope, 2006).

Third, computational visualization opens an additional route to understanding. Mathematica is used to show how a Fourier approximation changes as more terms are included, how an initial disturbance propagates in d'Alembert's solution, how eigenfunctions differ under different boundary conditions, and how divergence and curl appear in vector fields. Students do more than observe the output. They modify parameters, predict changes, compare analytical solutions with numerical plots, and explain anomalous behavior. The software thereby becomes a cognitive tool for testing assumptions and developing intuition rather than a demonstration device. Physics education research also shows that computer simulations can improve conceptual understanding when tasks are explicit and suitable instructional scaffolds are provided (Finkelstein et al., 2005).

5.3 Problem-driven blended learning

The pre-class phase does not require students to master an entire unit in advance. Instead, the classroom interaction platform provides 10-15 minute micro-lectures, a checklist of prerequisite knowledge, and a small number of diagnostic questions. The instructor adjusts the focus of the class using completion rates, patterns in incorrect options, and difficulties flagged by students. Students can pause and replay the material and identify gaps in their knowledge before coming to class. This approach releases class time without turning online learning into an unguided repository of resources. A meta-analysis of flipped classrooms found more consistent benefits when face-to-face time was not reduced or when pre-class material was paired with quizzes (van Alten et al., 2019).

During class, authentic or near-authentic physical problems are developed through progressive question sequences. For a one-dimensional wave, the sequence asks: What determines the force on a small element of the string? Which assumptions are needed to derive the wave equation? What physical constraints are represented by the initial and boundary conditions? How should the two traveling-wave terms in d'Alembert's formula be interpreted? Why does a disturbance affect only a finite region? The instructor leaves key steps for students to complete. Students first answer independently, then compare derivations in groups, and finally discuss common errors as a class. The instructor's role shifts from presenting conclusions to designing tasks, probing reasoning, and using evidence of student understanding.

After class, the learning management system provides micro-lectures, slides, extended readings, sample code, and supplementary videos. Group discussion is organized around common difficulties revealed by classroom evidence. Projects address settings such as heat conduction, string vibration, steady fields, and signal denoising, and require a theoretical derivation, visualized results, and a physical discussion. A meta-analysis of project-based learning found that well-designed projects generally improve academic achievement (Chen and Yang, 2019). Students use rubrics to review one another's work and, in judging its quality, reconsider their own assumptions, arguments, and communication. Research indicates that generating feedback can itself prompt comparison, judgment, and reflection (Nicol et al., 2014).

5.4 Continuous feedback and collaborative assessment

The assessment reform follows three principles: preserve individual accountability, make feedback from the learning process usable, and make higher-order performance visible. Process evidence comes from pre-class diagnosis, in-class quizzes, key derivations, project assignments, platform discussions, and peer review. The final examination continues to assess core course knowledge and integrated problem-solving ability. Different sources of evidence address conceptual understanding, method selection, modeling and derivation, interpretation of results, and transfer to new applications. Simple measures such as the number of platform logins are not treated as substitutes for learning quality.

Two-stage examinations are used for important and difficult material that is best assessed in a concentrated setting. In the first stage, students complete the examination independently, preserving individual accountability. Immediately after submitting their scripts, they are randomly assigned to groups of four or five. Without consulting their individual scripts or receiving an explanation from the instructor, each group works through the same set of core questions in a shorter period and submits one group script. Through articulating positions, diagnosing errors, and reaching a joint decision, the second stage turns the examination into an intensive episode of immediate learning. The group result is used only for a possible upward adjustment; weaker group performance never reduces the score earned in the first stage. This arrangement discourages strategic dependence and protects fairness. Previous research suggests that two-stage examinations are straightforward to implement and promote collaborative explanation and learning within an assessment setting (Rieger and Heiner, 2014).

After each assessment, the instructor prepares feedback from item-level patterns of error. Misconceptions lead back to prerequisite nodes in the knowledge graph; derivation errors are addressed through practice on critical steps; errors in method selection lead to comparative examples; and inadequate interpretation is addressed through visualization and checks of dimensions and limiting cases. Assessment thus ceases to be the endpoint at which a grade is assigned and becomes the starting point for the next instructional decision.

6. Implementing the three-stage closed loop

The essence of the three-stage closed loop is continuity of data and tasks, not a division of online and face-to-face learning into unrelated spaces. Problems revealed by pre-class diagnosis determine how in-class time is allocated.

Table 3 Three-stage implementation

Stage	Instructor activities	Student activities	Tools and outputs
Pre-class diagnosis	Post micro-lectures, a prerequisite checklist, and diagnostic questions; analyze errors and flagged difficulties	Prepare independently, address gaps in prerequisite knowledge, and raise questions	Learning platform; diagnostic learning profile and list of questions for class
In-class construction	Create contexts; organize question sequences, inquiry-based derivations, immediate feedback, and visualization-based verification	Think independently, discuss in groups, explain derivations, and revise answers	In-class quizzes and Mathematica; derivation records and evidence of explanation
Post-class extension	Provide layered resources, assign projects, organize peer review, and offer targeted guidance	Consolidation practice, project modeling, code-based verification, peer review, and reflection	Online course and knowledge graph; project products and reflection records

Answers, derivations, and discussion records generated during class inform the resources provided and the project groups formed afterward. Post-class assignments and peer-review results then feed into diagnosis for the next unit. Students produce visible evidence of learning at every stage, and the instructor adjusts the amount of scaffolding in response to that evidence.

Implementation follows a rhythm of accessible entry, greater cognitive demand at key points, and reflection after completion. Students with weaker preparation can enter the work through prerequisite resources and segmented tasks. All students must think independently about central questions in class, so that group work does not conceal individual difficulties. More advanced students are challenged through extended derivations, parameter exploration, and open-ended projects. What is reduced, therefore, is the barrier unrelated to the learning objective, not the theoretical depth or intellectual challenge the course should retain.

7. Reform outcomes, mechanisms, and implications

7.1 Outcomes from multiple evidence sources

Across successive course offerings, the teaching team drew on grade distributions, learning-platform records, classroom observations, course evaluations, and related learning outcomes to assess the reform. Available evidence shows that overall course grades improved after implementation, the failure rate trended downward, and the proportion of good and excellent grades increased. Classroom questioning, in-class responses, and group discussion became more active, while engagement with online resources and learning activities was sustained. Student course evaluations remained high, and the teaching team repeatedly received excellent ratings. Taken together, these sources support a positive association of the reform with both student engagement and course performance.

In the application of knowledge, the modeling, computation, and interpretation developed through course resources and related training provided a foundation for students entering mathematical modeling, physics experiment, and undergraduate physics competitions. Students accumulated six national awards and more than forty provincial awards. However, competition outcomes are influenced by student selection, the amount of coaching, the prior strength of the team, and other factors. They are therefore treated only as indirect evidence of improved transfer and cannot establish a causal effect of the instructional reform.

7.2 How the framework may work

The difficulty of Methods of Mathematical Physics lies not only in the subject matter itself. Students often lose the thread of a long derivation before reaching its central idea because they are occupied by changes in notation, gaps in prerequisite knowledge, or omitted intermediate steps. Pre-class micro-lectures, layered materials, and prompts at critical steps are intended mainly to address these gaps and reduce unproductive effort spent identifying symbols, recalling formulas, and reconstructing missing steps. Classroom expectations are not lowered: students still have to formulate models, select and compare methods, handle boundary conditions, and interpret results. The reform lowers the barrier to entering a complex task rather than the complexity of the task itself. It may therefore broaden participation while preserving the academic challenge of the course.

A further obstacle is that an expert instructor's process of selecting a method is often compressed into concise blackboard work and derivations. To the instructor, choosing a method from the conditions of a problem may appear obvious. To students, it may not be clear why a Fourier expansion is introduced at a particular point, why one integral transform is chosen over another, or under what conditions different methods apply. The course knowledge graph displays relationships among concepts and methods; question sequences unpack intermediate reasoning that would otherwise remain compressed; and computational visualization helps students see how mathematical forms correspond to physical processes. Students encounter not only a final formula but the full path from recognizing the problem to selecting a method and interpreting the result. This makes it more likely that they can judge whether a method applies in a new context.

In-class quizzes, group inquiry, two-stage examinations, and peer review occur at different points in the course, but all require students to retrieve, explain, and scrutinize what they have learned. In-class quizzes prompt retrieval of concepts and methods from memory, a practice shown to support long-term retention (Roediger and Karpicke, 2006).

Table 4 Reform evidence and interpretive limits

Evidence source	Main observation	Inference supported	Limits of interpretation
Course grades	Overall grades improved; the failure rate fell and the proportion of good and excellent grades rose	Improved knowledge acquisition and integrated problem-solving performance	Cohorts and examination difficulty may differ
Platform records and classroom observations	Preparation, quizzes, discussion, and interaction became more substantial	Stronger engagement and self-monitoring	Behavioral participation is not equivalent to cognitive engagement
Course evaluations	High student satisfaction; the teaching team was repeatedly rated excellent	Good acceptance of the reform and a positive learning experience	Subjective evaluations cannot replace measures of learning outcomes
Related competition outcomes	Six national awards and more than forty provincial awards	A basis for transfer in modeling and application	Affected by multiple factors; indirect evidence only

During group inquiry, students must explain the basis of a derivation in words, equations, or diagrams. A two-stage examination requires an independent response followed by comparison of solution paths through discussion. Peer review asks students to identify weaknesses in an assignment against explicit criteria. In terms of the ICAP framework, these activities do more than secure participation: they engage students in explaining, constructing, and negotiating meaning, creating opportunities for learning to move beyond surface procedures toward deeper cognitive processing (Chi and Wylie, 2014).

Changes in assessment can also alter how students distribute their effort across a semester. When the final examination largely determines the course grade, some students postpone concentrated study until shortly before the examination, allowing unresolved difficulties to accumulate. Once low-stakes quizzes, project processes, peer review, and staged tasks contribute to assessment, preparation, practice, feedback, and revision become continuing learning activities. Process-oriented assessment here is not simply an increase in the number of assessments. It enables instructors and students to identify misconceptions and errors in applying methods earlier, before they carry over into later work. Assessment gradually shifts from an end-of-course check on results to a means of regulating learning.

The purpose of a digital platform is likewise not to accumulate as much data as possible, but to make dispersed learning information visible while it can still be acted upon. Pre-class tasks reveal prerequisite knowledge and points of difficulty. Response distributions from in-class quizzes show which material can be handled briefly and which problems require further explanation. Projects and peer review can indicate when particular students need additional scaffolding. This information helps the instructor adjust emphasis, pacing, and task difficulty. Learning data are nevertheless clues for professional judgment, not substitutes for disciplinary expertise or an informed understanding of students. Digital technology contributes to improvement only when the data are used in specific instructional decisions.

7.3 Implications for digital transformation in higher education

The depth of digital transformation in a course should not be judged solely by whether a platform has been activated, resources have been uploaded, or multiple tools appear in class. If objectives remain unchanged, content follows the same chapter sequence, the instructor still dominates classroom activity, and assessment still rests mainly on a final examination, technology has changed the medium more than the model of teaching. Substantive transformation requires coordinated changes in objectives, content, activities, and assessment, all organized around intended learning outcomes. Evidence generated during learning must also return to instruction and guide adjustments in content and activity design. The depth of transformation is therefore reflected in whether the course has established a coherent cycle of instruction and feedback.

Assessment connects course objectives, learning activities, and the digital platform within this cycle. A platform can record logins, time online, and task completion, but those measures are not equivalent to learning quality. What should be recorded and what it can demonstrate must first be determined by course objectives and learning tasks; technology can then make the collection, organization, and return of evidence more efficient. Low-stakes quizzes show conceptual understanding and retrieval; project assignments reveal integrated application; peer review shows how well students understand standards and judge the quality of work; and individual and collaborative examinations assess, respectively, independent problem solving and the revision of understanding through discussion. These complementary sources offer a fuller account of learning while guarding against the mistake of treating easily counted indicators, such as clicks or time online, as learning itself.

Digital transformation must also address differences in students' preparation and their opportunities to learn. At regional universities, students often vary considerably in mathematical background, learning pace, and capacity for independent study. If digital teaching simply adds resources and tasks, it may widen those differences. Layered resources can supply prerequisite knowledge for students who need it, while open-ended tasks preserve space for deeper inquiry by students who are ready for more. Combining individual accountability with collaborative learning also helps prevent some students from being marginalized in group work. Technology should therefore be selected not only for efficiency, but also for whether it helps students with different starting points enter meaningful learning activities and gradually develop the capacity for independent analysis, sustained learning, and complex problem solving.

7.4 Conditions for use and study limitations

The model is suited to theory-intensive courses with abstract concepts, dense derivations, marked differences in prior preparation, and a need for transfer. Three conditions are important. Instructors must identify the core structure of the discipline accurately, so that a knowledge graph does not become a merely formal exercise. Digital resources must be concise, layered, and directly connected to classroom tasks, rather than adding to students' workload without purpose. Process-oriented assessment requires clear rubrics and moderate weighting, so that frequent check-ins do not displace time for deep learning.

8. Conclusion

Demanding foundational courses are an important test of whether digital transformation in higher education reaches the core of teaching and learning. In Methods of Mathematical Physics, no single method or tool can adequately address the combined problems of abstraction, dense content, fragmented knowledge, and delayed feedback. Modern educational principles can clarify learning mechanisms, while digital technologies can provide diagnosis, representation, interaction, and feedback. When objectives, content, pedagogy, and assessment are redesigned as a coherent system, limited class time can be redirected toward higher-value work in modeling, reasoning, and interpretation. The available evidence from multiple sources shows that reform across the four coordinated dimensions coincided with positive changes in student engagement, the organization of knowledge, complex problem solving, and course performance. Its transferable value lies not in reproducing a particular platform, but in three principles: begin with genuine learning difficulties, select technology by instructional function, and use diverse assessment evidence to close the improvement loop. The framework may inform digital transformation and instructional model redesign in other theory-intensive foundational courses. Its effects, including differences in benefits across student groups, still require more rigorous empirical testing.

Conflicts of interest

The author declares no competing interest.

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