

**DIDACTIC POSSIBILITIES OF INTERACTIVE METHODS AND EXPERIMENTAL-
PRACTICAL ACTIVITIES IN IMPROVING THE EFFECTIVENESS OF TEACHING PHYSICS IN
GENERAL SECONDARY SCHOOLS**

<https://doi.org/10.5281/zenodo.18889889>

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Abstract: *This paper examines how interactive methods and experimental-practical activities can raise the effectiveness of physics teaching in general secondary schools by strengthening conceptual understanding, procedural competence, and sustained learner motivation. In many school settings, physics is still perceived as abstract and formula-driven, which often results in superficial memorization, low transfer to real-life contexts, and weak practical skills. The study argues that a didactic shift is needed: learning should be organized as an active construction of meaning where students observe, manipulate variables, test hypotheses, and explain phenomena using evidence. Interactive methods are treated here as structured forms of student participation that reorganize classroom communication and cognition, including cooperative problem solving, guided inquiry, peer explanation, formative questioning, and lesson micro-modeling. Experimental-practical activities are understood as a continuum from teacher demonstrations to student-led investigations, laboratory tasks, measurement projects, and simple engineering challenges. The core didactic potential of combining these approaches lies in the alignment between scientific reasoning and classroom learning processes: learners encounter a phenomenon, pose questions, design or follow an experimental procedure, collect data, interpret results, and articulate a reasoned claim. This sequence supports the integration of conceptual and operational knowledge, making physics less dependent on symbolic manipulation alone and more grounded in observable regularities. The research synthesizes pedagogical and methodological perspectives and proposes an instructional model that links interactive learning cycles with experimentally verified concepts. Emphasis is placed on lesson design principles such as cognitive conflict, scaffolding, safety and feasibility, error analysis, and reflection as a learning tool. The paper also considers constraints typical for secondary schools, including limited lab resources, time pressure, uneven prior preparation, and assessment practices that undervalue practical competence. To address these constraints, the study outlines low-cost experiment formats, classroom management routines for group work, and assessment strategies that capture both conceptual growth and experimental literacy. The expected outcome is a more resilient understanding of core physics ideas, improved ability to solve qualitative and quantitative problems, and stronger scientific communication skills. The findings suggest that interactive, experiment-centered*

instruction can function as a didactic bridge between curriculum standards and authentic scientific practice, provided that tasks are carefully structured and aligned with clear learning objectives.

Keywords: *interactive methods, inquiry-based learning, physics experiments, practical activities, conceptual understanding, scientific reasoning, formative assessment*

UMUMTA'LIM MAKTABLARIDA FIZIKA FANINI O'QITISH SAMARADORLIGINI OSHIRISHDA INTERFAOL METODLAR VA TAJRIBA-AMALIY MASHG'ULOTLARNING DIDAKTIK IMKONIYATLARI

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Annotatsiya: *Mazkur tezis umumta'lim maktablarida fizika fanini o'qitish samaradorligini oshirishda interfaol metodlar hamda tajriba-amaliy mashg'ulotlarning didaktik imkoniyatlarini yoritadi. Ko'plab maktab amaliyotida fizika mavzulari ko'pincha abstrakt tushunchalar va formulalarni yod olishga tayangan holda o'tiladi, natijada o'quvchilarda mazmunni chuqur anglash, real hayotiy vaziyatlarga qo'llash va tajriba ko'nikmalarini shakllantirish yetarli darajada ta'minlanmaydi. Tadqiqotda interfaol metodlar o'quvchini ta'lim jarayonining faol subyekti sifatida jalb etadigan, muloqot va fikrlashni tashkil qiladigan hamkorlikdagi muammo yechish, savol-javobga tayangan yo'naltirilgan izlanish, tengdoshlar orqali tushuntirish va tezkor formatif baholash kabi yondashuvlar sifatida talqin qilinadi. Tajriba-amaliy mashg'ulotlar esa namoyish tajribalaridan boshlab, o'quvchi bajaradigan laboratoriya ishlari, o'lchash-topshiriqlari, mini-loyihalar va sodda muhandislik vazifalarigacha bo'lgan uzviy tizim sifatida ko'riladi. Ushbu ikki yo'nalish uyg'unlashganda, fizika ta'limi ilmiy bilishning tabiiy ketma-ketligiga yaqinlashadi: hodisani kuzatish, savol qo'yish, taxmin ilgari surish, tajribani rejalashtirish va bajarish, ma'lumot yig'ish, tahlil qilish hamda dalilga tayangan xulosaga kelish. Bunday tashkil etilgan darslar o'quvchilarda tushuncha va amalni birlashtiradi, xatoliklarni tahlil qilish, natijani asoslash va ilmiy nutq madaniyatini rivojlantiradi. Tezida resurslar cheklangan sharoitda ham qo'llash mumkin bo'lgan arzon jihozli tajribalar, guruhli ishni boshqarish algoritmlari va amaliy kompetensiyani baholash mezonlarini taklif etish orqali fizikani o'qitish samaradorligini oshirish yo'llari asoslanadi.*

Kalit so'zlar: *interfaol metodlar, tajriba-amaliy mashg'ulotlar, fizika ta'limi, ilmiy tafakkur, formatif baholash, laboratoriya ko'nikmalari*

INTRODUCTION

Physics education in general secondary schools faces a persistent didactic challenge: how to make abstract models, symbols, and laws meaningful to learners who mostly encounter the physical world through everyday experience rather than formal scientific

reasoning. When instruction is dominated by lecturing and routine problem solving, students often develop a fragmented understanding of concepts, rely on memorized formulas, and experience difficulties in explaining phenomena, interpreting graphs, or designing simple measurements. As a result, achievement becomes strongly dependent on procedural rehearsal, while the deeper aims of physics education, such as building scientific thinking, experimental literacy, and the ability to reason with evidence, remain underdeveloped. This problem is especially visible in topics where intuitive beliefs conflict with scientific explanations, for example, in mechanics, electricity, and thermal phenomena. In such cases, traditional explanatory instruction may not produce conceptual change because learners do not actively test their ideas against observable outcomes.

A widely supported pedagogical view is that physics is learned most effectively when students participate in the practices of science in a developmentally appropriate way. In the school context, this means organizing learning as an active process in which learners predict, observe, measure, compare, argue, and reflect. Interactive methods provide the communicative and cognitive structure for such participation. They include cooperative learning routines, peer instruction, dialogic questioning, guided inquiry, and structured discussion formats that ensure every learner is engaged in meaning-making. Experimental-practical activities provide the material foundation for understanding: they connect theoretical statements with empirical evidence and give students experience with variables, measurement uncertainty, and causal reasoning. The didactic value of experiments is not limited to verifying known laws; it also lies in generating questions, provoking cognitive conflict, and offering a concrete reference point for subsequent modeling.

The integration of interactive methods and experimental-practical activities is therefore not a simple addition of “more group work” and “more lab tasks.” It is a didactic reorganization of the lesson around a learning cycle that moves from phenomenon to explanation and back to application. In a well-designed cycle, students begin with a problem situation or a demonstrative phenomenon, articulate a prediction, and then test it through an experiment that is safe, feasible, and aligned with learning objectives. Data are collected and represented using tables, graphs, or qualitative observations, after which students interpret results and justify claims using appropriate physics concepts. The teacher’s role shifts from primarily transmitting information to orchestrating inquiry, scaffolding reasoning, and ensuring conceptual accuracy. Such instruction supports a transition from inert knowledge to functional competence, where students can explain, calculate, and experimentally substantiate their understanding.

However, secondary schools often face constraints that limit the implementation of this approach. Laboratory equipment may be incomplete or outdated, class sizes can be large, lesson time is limited, and assessment systems may emphasize final answers over reasoning and practical competence. Teachers may also need support in designing experiments that are not resource-intensive but still conceptually powerful, and in

managing interactive learning without losing instructional focus. These constraints make it necessary to identify didactic possibilities that are realistic for typical school conditions, including low-cost experimental formats, structured group-work roles, and assessment tools that capture both conceptual and experimental progress.

The purpose of this study is to analyze the didactic possibilities of interactive methods and experimental-practical activities for improving the effectiveness of physics teaching in general secondary schools. The paper focuses on how these approaches influence conceptual understanding, student motivation, scientific reasoning, and the development of experimental skills. It also proposes practical design principles for lessons and tasks, with particular attention to feasibility, safety, alignment with curriculum outcomes, and formative assessment. By clarifying the mechanisms through which interactive and experiment-centered instruction supports learning, the study aims to provide teachers with a coherent methodological rationale and actionable strategies that can be adapted to diverse classroom contexts.

METHODS

The study applies a practice-oriented methodological framework that combines didactic analysis, instructional design, and classroom-based evaluation. The methodological logic is built around the assumption that effectiveness in physics education should be interpreted as a multi-component construct that includes conceptual understanding, problem-solving competence, experimental literacy, and learning motivation. To examine how interactive methods and experimental-practical activities contribute to these outcomes, the research uses a mixed-methods approach integrating qualitative and quantitative procedures within a quasi-experimental classroom context.

At the design stage, a set of lesson prototypes was developed for core secondary-school physics topics that typically produce learning difficulties, such as uniform and non-uniform motion, Newton's laws, density and buoyancy, series and parallel circuits, and heat transfer. Each prototype was structured as a phenomenon-to-explanation learning cycle with four didactic phases: engagement through a problem situation or demonstrative phenomenon, exploration through student experiment or guided measurement, explanation through interactive concept construction, and consolidation through application tasks and reflection. For the interactive component, the study selected routines that are feasible in ordinary classrooms, including think-pair-share, peer explanation with teacher questioning, cooperative group work with rotating roles, and short formative checks using targeted conceptual questions. For the experimental component, the prototypes prioritized low-cost, safe, and repeatable activities that rely on common materials, smartphone sensors when available, or simplified laboratory kits. Each experimental task was accompanied by a brief procedural card outlining purpose, variables, measurement steps, and expected data representations.

Participants were students of general secondary school classes at the middle and upper levels, representing typical heterogeneity in prior achievement. Two groups were

formed based on existing class divisions. The experimental group studied selected topics using the designed integrated approach, while the comparison group followed the standard instructional format used in the school, which primarily included explanation, textbook exercises, and occasional teacher demonstrations. Because full randomization was not feasible in a school setting, group equivalence was addressed through pre-instruction diagnostics and comparable curricular coverage. Both groups were taught over the same time window, with the same total number of lessons and aligned learning objectives, to reduce exposure differences.

Data collection instruments were chosen to measure both learning outcomes and learning processes. Conceptual understanding was assessed through pre- and post-topic tests that included qualitative conceptual items, graph interpretation tasks, and short problem situations requiring explanation rather than formula substitution. Problem-solving competence was measured using a set of structured tasks that required selecting appropriate principles, identifying known and unknown variables, and justifying solution steps. Experimental literacy was evaluated with performance-based criteria during practical activities, focusing on operational skills such as identifying variables, choosing instruments, recording measurements, representing data, and making evidence-based conclusions. Motivation and engagement were monitored through short student self-report scales, observation checklists, and analysis of classroom participation patterns, such as frequency of peer explanations and student-initiated questions.

To ensure reliability and instructional fidelity, lesson implementation was supported by checklists describing essential components of the interactive and experimental cycle. Observations were conducted during lessons to document how consistently the planned routines were applied, how groups were managed, and how students interacted with experimental evidence. Qualitative field notes captured typical errors, misconceptions, and successful reasoning moves. Student work products, including lab notes, graphs, and short written explanations, were collected to triangulate results. Quantitative analysis compared pre- and post-test gains between groups, with attention to effect patterns across different task types. Qualitative analysis focused on identifying changes in students' reasoning, the structure of explanations, and the nature of classroom discourse during concept formation.

Ethical considerations were addressed through standard school procedures, including informing participants about the educational nature of the activities and ensuring that all students received curriculum-aligned instruction. The comparison group was not deprived of learning opportunities; rather, it continued with the existing program, while key elements of the integrated approach were shared with teachers after the evaluation stage as part of methodological dissemination.

RESULTS

The classroom-based evaluation indicated a consistent advantage for the integrated approach that combined interactive methods with experimental-practical activities. Pre-

instruction diagnostics suggested that the two groups started from comparable baseline levels in core concepts and routine calculation skills, but both groups showed typical difficulties in qualitative reasoning, graph interpretation, and explaining physical phenomena in their own words. After instruction, the experimental group demonstrated clearer conceptual change in topics where everyday intuition often conflicts with scientific explanations. Students more frequently differentiated between force and motion, described net force as a condition for acceleration rather than speed, and used evidence from measurements to justify claims about friction, mass, and acceleration relationships.

In post-topic assessments focused on conceptual understanding, the experimental group showed larger gains in qualitative items requiring explanation, prediction, and interpretation of physical situations. Students were more successful in tasks such as identifying the direction of acceleration from a velocity-time graph, explaining the effect of increasing resistance in a simple circuit, and predicting temperature changes under different heat-transfer conditions. Improvement was especially noticeable in questions that asked students to select and justify a model, rather than only compute a numerical answer. The comparison group improved mainly on standard numeric exercises that mirrored textbook patterns, but their progress on conceptual reasoning tasks was more limited and less stable across contexts.

Performance-based evaluation of experimental literacy also revealed meaningful differences. During practical activities, students in the integrated approach more reliably identified independent and dependent variables, recorded measurements in an organized way, and represented results using simple tables and graphs. They more frequently discussed measurement error and repeated trials when results looked inconsistent. In several lessons, students began to use language typical of scientific reasoning, such as referring to evidence, controlling conditions, and checking assumptions. In the comparison group, experimental activity was less frequent and more demonstration-centered; students tended to treat experiments as confirmation rather than as a source of questions and reasoning, and they rarely produced extended explanations based on data.

Classroom observation and analysis of student work products suggested that the interactive routines strengthened the quality of physics discourse. Peer explanation episodes increased in frequency and became more focused when students had shared experimental data to discuss. Students asked more “why” and “how” questions after observing unexpected outcomes, and the teacher’s questioning more often guided learners to articulate principles in their own language before formalizing them. Written explanations in the experimental group became more structured over time, moving from short, declarative statements to multi-sentence reasoning that referenced observed patterns, relationships between variables, and relevant concepts. This shift was visible even among students who previously participated minimally, indicating that structured interaction and role distribution in group tasks reduced passive learning.

Motivational indicators also improved under the integrated model. Students reported that lessons felt more understandable when phenomena were observed first and then explained, and they expressed greater confidence in approaching unfamiliar problems. Engagement was more evenly distributed across the class, with fewer lessons dominated by a small set of high-achieving students. Importantly, the approach remained feasible under ordinary school constraints. Low-cost experiments using readily available materials, simplified measurement tasks, and occasional smartphone-based sensing were sufficient to create meaningful investigative situations. The results therefore support the didactic claim that interactive, experiment-centered instruction can improve effectiveness not only by increasing activity, but by changing the cognitive structure of learning toward evidence-based concept construction and transferable reasoning.

DISCUSSION

The observed differences between the groups can be interpreted through the lens of didactic alignment between the nature of physics as a discipline and the organization of learning. Physics knowledge is not merely a collection of formulas; it is a structured system of models validated by evidence and expressed through multiple representations. When classroom instruction emphasizes explanation and routine exercises without giving students opportunities to test ideas and negotiate meaning, learners may acquire procedural habits but fail to develop robust conceptual structures. The stronger outcomes in the integrated approach suggest that interactive methods and experimental-practical activities function as complementary didactic mechanisms: interaction organizes thinking and language, while experimentation anchors concepts in observable regularities and provides a shared reference for reasoning.

One important mechanism is the creation of cognitive conflict and its productive resolution. Many physics misconceptions persist because students can solve certain numerical problems while still interpreting phenomena using everyday beliefs. In the integrated lessons, experiments were designed to produce outcomes that challenge intuitive expectations in a safe and manageable way. When students predicted results and then compared them with measurements, discrepancies became visible and discussable. Interactive routines then supported conceptual change by turning individual confusion into collective inquiry. Peer explanation, teacher-guided questioning, and structured discussion helped students articulate assumptions, refine explanations, and coordinate new concepts with existing knowledge. This helps explain why the experimental group improved more on qualitative tasks and transfer-like items that required selecting an appropriate model and justifying reasoning.

A second mechanism concerns representational competence. Physics learning requires translation between words, diagrams, graphs, and mathematical expressions. Experimental-practical tasks naturally generated data that needed representation, and interactive work created opportunities to interpret those representations together. Students who repeatedly practiced linking experimental observations to graphs and

relationships between variables became more comfortable with interpreting trends and using representations to support claims. The comparative limitation of the traditional approach in this area is consistent with the pattern that students may practice calculations extensively yet remain weak in reading graphs or explaining what an equation means physically.

The improvement in experimental literacy highlights a didactic issue often underestimated in secondary schools: practical competence is itself a learning outcome, not only a teaching aid. When learners are responsible for measurement steps, variable control, and error checking, they begin to understand why scientific claims require careful procedure. The observations that students discussed uncertainty, repeated trials, and questioned inconsistent results suggest a shift toward epistemic awareness, meaning that students started to see knowledge as something constructed and validated, not simply received. This dimension is essential for building long-term scientific thinking and is increasingly emphasized in competency-oriented curricula.

At the same time, the results point to conditions that must be met for the approach to work. “Interactivity” alone does not guarantee learning; without clear task structure, group roles, and teacher orchestration, classroom talk can become superficial. Similarly, experiments can fail to produce didactic value if they are treated as entertainment, if results are not interpreted, or if the experiment is too complex to yield reliable observations. The effectiveness observed in the integrated model depended on careful alignment of each activity with a specific conceptual target, explicit attention to variables, and purposeful questioning that guided students from observation to explanation. This implies that teacher preparation and lesson planning are central factors. A practical implication is that schools and methodological associations should support teachers in building a repertoire of low-cost experiments and interactive routines linked to particular curriculum topics.

Resource limitations, often cited as a barrier, appear manageable when the focus is on conceptual leverage rather than expensive equipment. Many core phenomena can be explored through simple materials, structured measurement tasks, and rotating stations. Smartphone sensors, when available, can extend possibilities but should not be treated as a prerequisite. The key is to select experiments that are robust, repeatable, and easy to interpret within the time constraints of a standard lesson. Moreover, formative assessment practices, such as short conceptual checks and feedback on lab notes, are important for maintaining learning focus and for diagnosing misconceptions early.

The findings therefore support a didactic conclusion: interactive methods and experimental-practical activities enhance physics teaching effectiveness when they are integrated into a coherent learning cycle that emphasizes prediction, evidence, explanation, and reflection. This integration strengthens conceptual understanding, develops transferable reasoning, and builds practical scientific skills, which together form the foundation for meaningful physics education in general secondary schools.

CONCLUSION

The study demonstrates that improving the effectiveness of physics teaching in general secondary schools is strongly supported by an integrated didactic strategy that combines interactive methods with experimental-practical activities. When learning is organized around active participation, evidence-based inquiry, and structured classroom dialogue, students move beyond formula memorization toward deeper conceptual understanding and more stable reasoning. The results indicate that interactive methods increase the quality and inclusiveness of learning processes by engaging learners in prediction, explanation, argumentation, and reflection. Experimental-practical activities, in turn, strengthen the empirical foundation of physics concepts and develop students' procedural competence in measurement, variable control, and data interpretation. Together, these components create a learning environment that mirrors essential features of scientific practice in a school-appropriate form.

A key conclusion is that didactic effectiveness depends not on the quantity of activities, but on the internal logic of lesson design. The integrated approach works best when tasks are aligned with clear conceptual goals, when experiments are feasible and conceptually targeted, and when interactive routines are structured to guide students from observation to explanation. Under these conditions, students demonstrate better performance on qualitative conceptual tasks, improved ability to interpret graphs and representations, and stronger skills in constructing evidence-based explanations. The development of experimental literacy also contributes to broader educational aims, including scientific communication, critical evaluation of claims, and responsible handling of uncertainty and error.

The study also shows that typical school constraints do not make this approach unrealistic. Meaningful experimental inquiry can be organized with low-cost materials and simplified procedures, while interactive learning can be implemented through manageable routines such as peer explanation, cooperative roles, and formative questioning. These strategies support more equitable participation and help reduce the gap between high- and low-achieving learners by distributing cognitive work and enabling peer-supported learning. The approach therefore has practical value for secondary-school physics teachers seeking to increase engagement, understanding, and competence within standard lesson time and available resources.

From a methodological perspective, the findings support the adoption of a phenomenon-to-explanation learning cycle as a basic unit of physics lesson planning. Teachers are encouraged to begin with an observable problem situation, elicit predictions, organize experimental exploration, facilitate interactive concept construction, and end with application and reflective consolidation. Assessment should also be adjusted to capture not only final numerical answers but the reasoning process, conceptual clarity, and experimental competence. In sum, the didactic possibilities of interactive methods and experimental-practical activities lie in their capacity to transform physics learning into a

coherent, evidence-based process that fosters durable understanding and skills relevant to further education and everyday life.

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