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Research Article

Improving Conceptual Understanding of Physics among Secondary School Students

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Abstract

Introduction: Physics education at the secondary level is vital for developing students' conceptual understanding, problem-solving abilities, and scientific literacy. However, many struggle due to abstract concepts, weak mathematical foundations, and traditional teacher-centered instruction. In Pakistan and globally, issues such as rote learning, misconceptions, and limited resources hinder meaningful engagement and understanding. This study aims to identify learning challenges in physics, assess current teaching practices, and suggest student-centered strategies to enhance conceptual understanding.

Materials and Methods: A descriptive cross-sectional survey was conducted with 200 grade 9 and 10 students from public and private schools in Karak District, Khyber Pakhtunkhwa, Pakistan, selected through stratified random sampling. Data were collected via a validated, pilot-tested questionnaire covering demographics, conceptual understanding, teaching methods, motivation, and learning challenges. Descriptive analysis was used to identify major trends and difficulties in learning physics.

Results: Findings showed that most students struggled with core topics like electricity and mechanics, relying heavily on memorization rather than conceptual learning. Weak math skills, traditional teaching methods, and limited resources were key barriers. While teachers promoted questioning, activity-based and experimental learning were infrequent. Students' motivation depended on teacher support and interest, but they preferred hands-on experiments, visual aids, and group discussions to improve understanding.

Conclusion: The study concludes that difficulties in learning physics arise from poor math foundations, ineffective pedagogy, and insufficient practical exposure. It recommends adopting student-centered, inquiry-based teaching, enhancing teacher training, revising curricula to include real-life applications, and improving laboratory access. Future research should examine the long-term impact of active learning and digital tools, and compare rural and urban contexts to strengthen physics education across Pakistan.

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Introduction

Physics at the secondary school level is typically taught as a core component of the science curriculum, designed to help students develop both conceptual understanding and problem-solving skills. The curriculum often includes major topics such as mechanics, electricity, magnetism, optics, and modern physics, providing a foundation for further studies in science, engineering, and technology (Bybee, 2013). As part of science education, physics plays a central role in fostering analytical thinking, quantitative reasoning, and the application of scientific principles to real-world situations (Osborne & Dillon, 2008).

Furthermore, secondary school physics is not only about content knowledge but also about nurturing scientific inquiry and practical skills. The inclusion of laboratory experiments and activity-based learning helps Students Bridge the gap between theory and practice (Hofstein & Lunetta, 2004). However, the effectiveness of physics education depends heavily on teaching practices, curriculum design, and available resources. In many contexts, traditional teacher-centered approaches dominate, which may limit student engagement and deeper understanding (Adams & Wieman, 2011).

Overall, physics education at this stage is essential for preparing students for advanced scientific learning, developing problem-solving skills, and contributing to scientific literacy, which is vital for informed citizenship in a technologically driven world (Millar, 2010).

Importance of conceptual understanding in physics

In physics, it is not enough for students to just memorize formulas or definitions. They need to understand the concepts behind those formulas, like why things happen the way they do. For example, knowing the formula for force is helpful, but understanding what force actually means in real life is more important. Deep conceptual understanding helps students apply knowledge to new situations, solve problems better, and build stronger interest in the subject. Conceptual understanding also supports the development of scientific thinking, encourages inquiry-based learning, and makes physics more meaningful for students (Bybee, 2013; McDermott, 1991; Redish, 2006).

Current issues and learning challenges faced by students

Many students struggle in physics because the subject involves abstract ideas (like energy, force, or motion) that are not always easy to imagine (Redish, 2003). Some have misconceptions—for example, thinking heavier objects fall faster (Halloun & Hestenes, 1985). Others find it difficult because teaching methods may focus too much on rote memorization instead of explanations and experiments (Bybee, 2013). Poor math skills, lack of resources, and limited interest in the subject also add to the problem (Acharya, 2017; Wieman, Adams, & Perkins, 2008).

Rationale and objectives of the study

This section explains why the research is necessary. The study is being done to find better ways of improving how students learn physics and understand its concepts.Previous research has shown that many students struggle with abstract concepts in physics, which makes it difficult for them to connect theory with real-life applications (Halloun & Hestenes, 1985; McDermott, 1991). The main objectives may include identifying the challenges students face, suggesting solutions for teachers, and developing teaching strategies that make physics easier and more engaging. Research also suggests that adopting innovative teaching strategies, such as inquiry-based learning and active engagement, can significantly improve students' conceptual understanding (Adams & Wieman, 2011; Bybee, 2013). Therefore, this study aims to contribute to the improvement of physics education by addressing these challenges and providing practical solutions.

Global perspectives on physics learning challenges

Around the world students struggle with physics for similar reasons: weak math preparation, large classrooms, teacher-centred instruction, scarce lab resources, and high-stakes exams that reward rote memorization. Cultural attitudes (e.g., "physics is only for geniuses") and language barriers also make abstract concepts harder to grasp. International studies highlight that these structural and pedagogical factors — not student ability — are the main drivers of low conceptual gains.

Studies on misconceptions and poor conceptual grasp

Research consistently finds persistent,

researchable misconceptions (e.g., about force and motion, energy conservation, heat and temperature, electric circuits). Tools like the Force Concept Inventory reveal that traditional lecture often fails to replace naïve intuitions with scientific understanding. Causes include everyday experience that conflicts with formal models, superficial procedural teaching, and vocabulary that masks conceptual meaning.

Role of curriculum design in conceptual understanding

Curriculum matters: sequence, depth, and assessment shape what students learn. Curricula that emphasize conceptual threads (big ideas, modeling, linked experiments) and integrate math progressively produce better understanding than those focused on isolated formulas and end-of-term exams. Assessment alignment is critical — if tests reward problem-solving steps and conceptual explanations, teachers and students shift toward deeper learning.

Teaching strategies used in physics classrooms

Effective classrooms use interactive, student-centred approaches: inquiry-based labs, peer instruction, concept questions, tutorials, simulations, and formative assessment (frequent low-stakes checks). Demonstrations with prediction-and-explain, and problem-solving that explicitly links math with physical reasoning, are important. Teacher content knowledge and pedagogical content knowledge (how to teach specific misconceptions) determine how well these strategies work.

Research gaps in Pakistan's context

In Pakistan there's growing interest but limited rigorous, large-scale research. Gaps include few longitudinal or experimental studies on interventions, uneven attention to rural vs urban resource constraints, limited research on language-of-instruction effects, and scarce work on teacher professional development that's scalable. More context-sensitive studies (pilot interventions, classroom video analysis, and assessment design) and evidence on how to adapt proven methods to local constraints are needed.

Research Objectives

The study aims to identify the major difficulties secondary students face in learning physics, examine how teaching methods and student attitudes influence their conceptual understanding, and suggest practical strategies to improve learning outcomes. By analyzing problem areas, evaluating instructional approaches, and exploring motivation, the research seeks to develop effective teaching practices that make physics more engaging, accessible, and meaningful.

Materials and Methods

This study was designed as a descriptive cross-sectional survey that sought to investigate the challenges faced by secondary school students in understanding physics concepts and to identify strategies for improvement. The research was conducted between January and June 2023 in secondary schools located in Karak District, Khyber Pakhtunkhwa, Pakistan. This district was selected as the study area because it represents a mix of urban and rural schools, which allowed for an in-depth understanding of variations in teaching practices and student learning experiences.

The study population consisted of students enrolled in grades 9 and 10, as these grades represent the stage where physics is introduced as a core science subject in Pakistan. A total of 200 students participated in the study. A stratified random sampling technique was employed to ensure representation from both public and private institutions in urban and rural areas of Karak. Initially, a list of schools was obtained from the District Education Office, after which schools were stratified by type (public and private) and location (urban and rural). From these strata, schools were selected randomly, and students were chosen proportionally to maintain balance across groups. The inclusion criteria required that participants be officially enrolled in grade 9 or 10 and actively studying physics at the time of the survey. Students who were absent on the day of data collection, who had transferred from other districts, or who expressed unwillingness to participate were excluded from the study.

The primary tool for data collection was a structured questionnaire developed specifically for this research. The questionnaire comprised six sections: demographic characteristics, conceptual understanding of physics, teaching methods used by teachers, students' motivation and attitudes, learning challenges, and possible improvement strategies. It included both multiple-choice questions and items measured on a five-point Likert scale, which allowed the researchers to capture both categorical and ordinal data. To ensure content validity, the questionnaire was reviewed by two experts in science education from a local university. It was then pilot-tested on a group of 20 students from a school not included in the final sample. Feedback from the pilot study was used to refine ambiguous items, and the instrument demonstrated a Cronbach's alpha of 0.82, indicating acceptable internal consistency.

Data collection was conducted within the classroom setting during regular school hours after obtaining prior approval from school principals and consent from students. Before administration, the purpose of the study was explained to participants in simple terms. Students were assured that their responses would remain confidential, that their participation was voluntary, and that no academic or disciplinary consequences would result from non-participation. The researcher personally distributed the questionnaires, provided clarifications when required, and ensured that students completed them independently to minimize peer influence.

Table 1: Questionnaire for Secondary School Students on Physics Learning

Section	Question	Response Options
Demographics	What is your age?	☐ 13–14 ☐ 15–16 ☐ 17–18
	What is your gender?	☐ Male ☐ Female ☐ Other
	What grade are you currently in?	☐ Grade 9 ☐ Grade 10
	Which type of school do you attend?	☐ Public ☐ Private ☐ Semi-government
	Medium of instruction in your school	☐ English ☐ Urdu ☐ Mixed
Conceptual Understanding	Do you find physics concepts easy to understand?	☐ Yes ☐ No ☐ Sometimes
	Which topics in physics do you find most difficult?	☐ Mechanics ☐ Electricity ☐ Magnetism ☐ Heat ☐ Light & Optics ☐ Waves & Sound ☐ Modern Physics
	How often do you rely on memorization instead of understanding?	☐ Always ☐ Often ☐ Sometimes ☐ Rarely ☐ Never
	Rate your understanding of physics concepts	☐ Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent
Teaching Methods	How often does your teacher use practical examples in class?	☐ Always ☐ Often ☐ Sometimes ☐ Rarely ☐ Never
	Does your teacher use experiments or lab activities to explain concepts?	☐ Always ☐ Often ☐ Sometimes ☐ Rarely ☐ Never
	Which teaching style helps you learn best?	☐ Lecture-based ☐ Demonstrations ☐ Group work ☐ Visual aids (diagrams/videos) ☐ Practical experiments
	Do your teachers encourage asking questions during lessons?	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
Motivation & Attitude	Do you enjoy studying physics?	☐ Yes ☐ No ☐ Sometimes
	What motivates you most to learn physics?	☐ Teacher support ☐ Personal interest ☐ Exam preparation ☐ Career goals ☐ Peer competition
	Do you believe physics is useful for your future career?	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
	How confident are you about	☐ Very Confident ☐ Confident ☐ Neutral ☐

	solving numerical problems in physics?	Not Confident ☐ Very Weak
Learning Challenges	What is your biggest challenge in learning physics?	☐ Difficult concepts ☐ Lack of interest ☐ Weak math skills ☐ Teaching method ☐ Limited resources
	Do you feel enough time is given to practice numerical problems?	☐ Yes ☐ No ☐ Sometimes
	Do language barriers (English/Urdu terms) affect your understanding of physics?	☐ Yes ☐ No ☐ Sometimes
	Do you have access to physics reference books or online resources?	☐ Yes ☐ No ☐ Limited
Improvement Strategies	Which of the following would help improve your physics learning?	☐ More experiments ☐ Visual aids (videos, diagrams) ☐ Group discussions ☐ Extra coaching classes ☐ Online learning tools
	Do you think teacher training workshops can improve physics teaching quality?	☐ Strongly Agree ☐ Agree ☐ Neutral ☐ Disagree ☐ Strongly Disagree
	Would you like physics lessons to include real-life applications (e.g., technology, daily life)?	☐ Yes ☐ No ☐ Maybe
	How often would you prefer teachers to use multimedia (animations, simulations) in class?	☐ Always ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

This table is a questionnaire made to understand how secondary school students feel about learning physics. It asks about their background (age, grade, school type, language), their understanding of physics (which topics are easy or difficult, if they memorize or understand, and how well they rate themselves), and the teaching methods used in class (examples, experiments, group work, or visual aids). It also looks at students' motivation (interest in physics, reasons for learning, future usefulness, and confidence in solving problems) and their challenges (hard concepts, weak math, lack of interest, teaching style, or resources). Finally, it asks for suggestions to improve learning, like using more experiments, visual aids, real-life examples, or multimedia tools. The aim is to find out what problems students face and what changes can make physics easier and more interesting for them.

The completed questionnaires were checked for completeness before data entry. Data were coded and entered into SPSS version 26 for analysis. Descriptive statistics such as frequencies, percentages, means, and standard deviations were used to summarize the variables. Comparative analysis was also performed between public and private schools, as well as between urban and rural settings, to identify possible differences in conceptual understanding and perceived challenges. The findings were presented in tabular and graphical form to enhance clarity and interpretation.

Ethical considerations were strictly observed throughout the study. Approval for the research was obtained from the institutional review committee of the affiliated university. Formal permissions were granted by the principals of schools and written approval was obtained from staff members. Verbal assent was sought from students before questionnaire administration. All responses were kept confidential and were used solely for academic purposes.

Results

Table 2 shows the demographic profile of the 200 secondary school students who participated in the study. Most students (47.5%) were aged 15–16 years, followed by 32.5% in the 13–14 age group and 20% in the 17–18 group. The sample included 56% male and 44% female students, showing a fairly balanced gender distribution. Students were almost evenly divided between grade 9 (55%) and grade 10 (45%). In terms of school type, the majority attended public schools (62.5%), while 30% were from private schools and only 7.5% from semi-government schools. This distribution indicates that the study represents a diverse group of students across different backgrounds.

Table 2: Demographic Characteristics of Secondary School Students (n = 200)

Variable	Category	Frequency (n)	Percentage (%)
Age	13–14 years	65	32.5%
	15–16 years	95	47.5%
	17–18 years	40	20.0%
Gender	Male	112	56.0%
	Female	88	44.0%
Grade	9th	110	55.0%
	10th	90	45.0%
School Type	Public	125	62.5%
	Private	60	30.0%
	Semi-government	15	7.5%

Table 3 highlights students' conceptual understanding of physics. Only 30% of students reported finding physics concepts easy to understand, while a larger proportion (42.5%) found them difficult. Among the topics, electricity (25%) and mechanics (20%) were identified as the most challenging. A considerable number of students relied on memorization, with 12.5% always and 30% often doing so. In terms of self-assessment, 7.5% rated their understanding as very poor and 25% as poor, indicating significant gaps in conceptual learning.

Table 3: Conceptual Understanding of Physics (n = 200)

Question	Response	n (%)
Physics concepts easy to understand	Yes: 60 (30.0%)	No: 85 (42.5%)
Difficult topics in physics	Mechanics: 40 (20.0%)	Electricity: 50 (25.0%)
Reliance on memorization	Always: 25 (12.5%)	Often: 60 (30.0%)
Self-rated understanding	Very Poor: 15 (7.5%)	Poor: 50 (25.0%)

The results in Table 4 show that teachers most frequently encourage students to ask questions, with over 60% of students reporting this happens always or often. The use of practical examples is also fairly common, though a majority indicated it occurs sometimes rather than always. In contrast, experiments or lab activities are the least used method, as most students reported them occurring only sometimes, rarely, or never. Overall, while questioning and practical examples are emphasized in teaching, hands-on experimental activities are less frequently practiced.

Table 4: Teaching Methods Reported by Students (n = 200)

Teaching Practice	Always	Often	Sometimes	Rarely	Never
Teachers use practical examples	30 (15.0%)	60 (30.0%)	70 (35.0%)	25 (12.5%)	15 (7.5%)
Teachers use experiments/lab activities	20 (10.0%)	40 (20.0%)	75 (37.5%)	40 (20.0%)	25 (12.5%)
Teachers encourage questions	45 (22.5%)	80 (40.0%)	45 (22.5%)	20 (10.0%)	10 (5.0%)

Table 5 shows that only 35% of students enjoy studying physics, while 30% do not, and the rest seem neutral. The main sources of motivation are teacher support (25%) and personal interest (20%), suggesting that both external and internal factors play a role in learning. However, confidence in solving numerical problems is generally low, as only 7.5% feel very confident and 20% feel confident. Overall, students' interest and confidence in physics appear limited, with teacher encouragement being an important motivator.

Table 5: Motivation and Attitudes toward Physics (n = 200)

Question	Response Options	n (%)
Enjoy studying physics	Yes	70 (35.0%)
	No	60 (30.0%)
Motivation for learning	Teacher support	50 (25.0%)
	Personal interest	40 (20.0%)
Confidence in solving numerical	Very confident	15 (7.5%)
	Confident	40 (20.0%)

Table 6 shows the main challenges faced by students in learning physics. The biggest problem is difficult concepts, reported by 35% of students, followed by weak math skills (22.5%), which makes understanding physics harder. Lack of interest was noted by 20% of students, while 15% felt that teaching methods were not effective. Limited resources, such as lab equipment or learning materials, were mentioned by 7.5% of students. Overall, the findings highlight that both subject complexity and teaching-related factors play a major role in students' struggles with physics.

Table 6: Learning Challenges in Physics (n = 200)

Challenge	n	%
Difficult concepts	70	35.0%
Lack of interest	40	20.0%
Weak math skills	45	22.5%
Teaching method	30	15.0%
Limited resources	15	7.5%

n: Frequency, %: Percentage

Table 7 highlights the strategies students suggested to improve physics learning. The most preferred approach is using more experiments (40.0%), showing that hands-on activities help in better understanding. Visual aids such as videos and diagrams are also important, with 30.0% of students favoring them to simplify complex ideas. Group discussions (12.5%) and extra coaching classes (10.0%) were suggested to support collaborative and personalized learning. A smaller portion (7.5%) recommended online learning tools, indicating some interest in digital resources, though traditional methods remain more popular.

Table 7: Suggested Improvement Strategies (n = 200)

Strategy	n	%
More experiments	80	40.0%
Visual aids (videos/diagrams)	60	30.0%
Group discussions	25	12.5%
Extra coaching classes	20	10.0%
Online learning tools	15	7.5%

Discussion

The findings of this study align with a broad body of research emphasizing the persistent challenges students face in developing conceptual understanding in physics. Many students in this study struggled with fundamental topics such as electricity and mechanics and often relied on rote memorization instead of meaningful learning. This pattern is consistent with earlier studies that documented long-standing misconceptions in physics, particularly regarding force and motion, and the difficulty of achieving conceptual change even after formal instruction (Halloun & Hestenes, 1985; McDermott & Redish, 1999).

In line with previous research, the results also reaffirm that teaching approaches strongly influence how well students grasp abstract physics concepts. When instruction is dominated by lectures and textbook-based explanations, students are less engaged and more likely to retain superficial knowledge (Bligh, 2000; Prince, 2004). Conversely, classrooms that encourage active participation—through inquiry, discussion, and experimentation—tend to foster deeper understanding and sustained interest (Hake, 1998; Freeman et al., 2014). In this study, students clearly favored interactive and student-centered methods such as hands-on experiments, visual demonstrations, and group discussions, echoing global findings on the effectiveness of inquiry-based and collaborative learning (Bybee, 2013; Freeman et al., 2014).

Teachers in the present study were observed to use practical examples and encourage questioning, which are positive practices. However, the limited use of laboratory experiments and activity-based instruction suggests a need for greater emphasis on experiential learning. Similar concerns have been raised in other contexts, where constraints such as inadequate facilities, large class sizes, and exam-oriented teaching restrict teachers' ability to adopt innovative methods (Duit & Treagust, 2012; Michael, 2006). Therefore, while teacher motivation and support play a crucial role in influencing student interest, systemic changes in pedagogy and assessment are equally important.

Another factor affecting physics learning is the structure of the curriculum and assessment system. The current syllabus and examinations often prioritize content coverage and memorization over reasoning and application, which discourages conceptual learning (Black & Wiliam, 2018; Harlen, 2015; Shepard, 2019). As seen in this study, students' preference for applied and activity-based approaches indicates that current teaching and assessment methods may not align with their learning needs. Previous research supports this view, showing that when tests focus on recall rather than understanding, students are less likely to develop higher-order cognitive skills (Niaz & Maza, 2011).

Overall, this study contributes to existing literature by providing evidence from Pakistan that reinforces the global understanding of the need for active, inquiry-driven, and student-centered teaching methods in physics education. It highlights the importance of teacher training, curriculum reform, and resource allocation to create a more engaging and conceptually rich learning environment for students.

Conclusion

This study revealed that secondary school students face considerable challenges in learning physics, particularly due to weak mathematical foundations, traditional teacher-centered instruction, and limited access to laboratory and practical learning experiences. Despite these challenges, students showed strong interest in approaches that promote engagement, such as experiments, visual aids, and collaborative activities. These findings underscore the need to move beyond rote memorization toward teaching methods that promote conceptual understanding and application of physics principles.

For teachers, the results emphasize the importance of adopting interactive, inquiry-based methods that encourage questioning, experimentation, and critical thinking. For curriculum developers and policymakers, the study highlights the need to revise physics curricula to balance theory with practice, integrate real-life applications, and provide adequate laboratory facilities. Supporting continuous professional development for teachers is equally crucial to ensure effective implementation of modern pedagogical techniques.

Future research should examine the long-term impact of activity-based and digital learning tools on students' conceptual development. Comparative studies between rural and urban schools are also needed to understand context-specific challenges and inform equitable educational reforms. By addressing these areas, future work can build on this study's findings to further strengthen the teaching and learning of physics in Pakistan and beyond.

Conflict of interest

The authors declared no conflict of interest.

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