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Guided Inquiry Labs Strengthen Data Analysis Skills in Electricity and Magnetism Experiments

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Abstract: In the teaching of electromagnetism experiments, the cultivation of data analysis abilities faces issues such as non-graded task design, fragmented method guidance, and singular tool application, which restrict the improvement of learners' abilities. Based on this background, this paper proposes the idea of relying on guided inquiry experiments to strengthen this ability, designs step-by-step tasks to clarify analysis goals, enhances method guidance to improve data processing abilities, and introduces diverse tools to optimize analysis efficiency. Practice shows that this experiment can reduce the deviation rate of data calculation, deepen the exploration of patterns, and shorten the processing time of massive data, effectively enhancing learners' data analysis abilities in electromagnetism experiments and forming a positive analysis loop.

Keywords: Guided Inquiry Experiment; Electromagnetism Experiment; Data Analysis Ability

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1. Introduction

Electromagnetism experiments are an important part of physics teaching, serving as a key vehicle for verifying electromagnetism theories and deepening the understanding of principles. The data analysis component directly affects the scientific nature of experimental conclusions and the cultivation of learners' scientific thinking. Currently, there are bottlenecks in the cultivation of data analysis abilities in this teaching: non-graded task design leads to vague goals, fragmented method guidance makes it difficult to form systematic thinking, and singular tool application restricts efficiency and accuracy. These issues affect the in-depth processing of data and the exploration of patterns, failing to meet the requirements for core ability cultivation. Guided inquiry experiments, with their unique design and model, provide a feasible solution to these problems.

2. Existing Problems in the Cultivation of Data Analysis Abilities in Electromagnetism Experiments

When cultivating data analysis skills in electromagnetism experiments, the experimental task design often lacks gradation and is primarily focused on single verification goals without breaking down the requirements according to the cognitive laws of learners[1]. Learners find it difficult to understand the key points of analysis at each stage and to build a complete chain of thinking. When facing complex analyses such as the relationship between magnetic field strength and Hall voltage in the Hall effect, they are prone to becoming confused about the goals. Guidance on data analysis methods is fragmented, mostly focusing on the explanation of calculation steps, with insufficient guidance on identifying sources of error and handling abnormal data. Learners find it hard to grasp scientific thinking when dealing with experimental errors and to recognize the electromagnetic laws behind the data. The application of data processing tools is also singular, mostly relying on manual work or basic spreadsheet software without introducing professional tools that are suitable for the job. When processing multiple sets of data such as the relationship between magnetic field strength and resistance value changes in magnetoresistance experiments, the efficiency is low, and errors are easily made. It is also difficult to deepen the understanding of results by leveraging the advantages of the tools.

3. Strategies for Strengthening Data Analysis Abilities through Guided Inquiry Experiments

3.1. Designing Step-by-Step Tasks to Clarify Analysis Goals

The tiered task design should be integrated with the knowledge system of electromagnetic experiments and the cognitive progression of learners, decomposing data analysis objectives from basic to complex. In the initial stage, focusing on the experiment of using a multimeter, the goals are to clearly define the standardized recording format for voltage and resistance measurement values, and to ensure accurate results in calculating the equivalent resistance of a circuit based on Ohm's law. This helps learners systematically master the key points of data classification, organization, and preliminary operations, laying a foundation for the improvement of subsequent analytical skills. In the middle stage, targeting the Hall effect experiment, the objective of data correlation analysis is added. Learners are guided to pay attention to how changes in magnetic field strength and control current affect the Hall voltage data, and to explore the relationship among the three. In the advanced stage, focusing on the magnetoresistance experiment, the objectives are to predict data trends (such as the change in resistance value with increasing magnetic field strength) and to extract underlying patterns (such as the relationship between the sensitivity of the magnetoresistance effect and magnetic field strength). This encourages learners to delve into the essence beyond the data phenomena and gradually build a complete and logical framework for data analysis thinking.

3.2. Enhancing Method Guidance to Improve Data Processing Abilities

Enhancing method guidance needs to focus on the key links in the data analysis of electromagnetism experiments and form a systematic guidance system for data error and abnormal data processing. In terms of data error analysis, combining common instrument precision errors (such as measurement errors of multimeters at different ranges) and environmental interference errors (such as external magnetic field interference in the Hall effect experiment), explain methods for identifying sources of error. For example, compare the data differences in measuring the resistance of the same circuit with multimeters of different accuracies to clarify the specific causes of error. For abnormal data processing, use standard deviation to judge the dispersion of data and combine electromagnetic principles (such as in the magnetoresistance experiment, where a resistance value deviating significantly from the baseline when the magnetic field strength is zero is considered abnormal) to screen and process abnormal values. Data interpretation skills should also be integrated into the guidance process to help understand the intrinsic connection between data and electromagnetic laws, effectively improving the scientific and accuracy of data processing.

3.3. Introducing Diverse Tools to Optimize Data Analysis Efficiency

Introducing diverse tools needs to combine the characteristics of electromagnetism experiment data and integrate suitable professional tools into the experimental process[2]. For large amounts of data such as multiple sets of circuit parameters measured by a multimeter (e.g., voltage and current values under different loads), advanced Excel functions can be used. Pivot tables can be employed to calculate the average current within different voltage ranges, and chart functions can convert the data into intuitive curves to quickly present trends. For complex data in the Hall effect experiment, such as the relationship between magnetic field strength and Hall voltage, professional software like MATLAB can be utilized. With its data modeling and analysis capabilities, data fitting and pattern prediction can be achieved, such as fitting the relevant data to verify the linear relationship between Hall voltage and magnetic field strength. The rational use of these tools reduces the complexity and errors of manual calculations, increases data processing speed, and deepens the exploration of the essence of electromagnetic data through tool analysis functions, thereby optimizing overall data analysis efficiency.

4. Efficacy of Guided Inquiry Experiments in Enhancing Data Analysis Abilities

Guided inquiry experiments have demonstrated significant multifaceted improvements in enhancing data analysis abilities in electromagnetism experiments. In terms of data processing accuracy, under the guidance of step-by-step tasks and systematic methods, learners can accurately identify instrument precision errors (such as improper range selection of multimeters) and reasonably handle outliers (such as abnormal voltages caused by accidental interference) when dealing with voltage and current data in multimeter experiments. This has led to a substantial reduction in the deviation rate of calculation results compared to traditional experimental models[3]. Regarding the depth of data pattern exploration, with the aid of diverse tools and correlation analysis training, learners can quickly discover the quantitative relationships between magnetic field strength, control current, and Hall voltage through curve fitting when processing data from the Hall effect experiments. This breakthrough in capturing detailed patterns that are difficult to identify through traditional manual calculations (such as accurately calculating the Hall coefficient) enables a cognitive progression from data recording to pattern extraction. In terms of analysis efficiency, the application of professional tools has shortened the processing time for massive data in magnetoresistance experiments and reduced repetitive calculation errors. This allows learners to focus more on interpreting the electromagnetic principles behind the data, forming a virtuous cycle of “accurate processing—deep pattern extraction—efficient completion.”

5. Conclusion

The cultivation of data analysis abilities in electromagnetism experiments is crucial for ensuring the scientific nature of experimental conclusions and fostering learners’ scientific thinking. Guided inquiry experiments, through targeted design, effectively break through the bottlenecks in task design, method guidance, and tool application. This approach transforms data processing from being vague and inefficient to being precise and systematic, thereby truly meeting the core ability cultivation requirements of experimental teaching. This model provides a feasible path for optimizing electromagnetism experiment teaching. Future work can further refine the design in combination with actual teaching practices of experiments such as multimeter usage, the Hall effect, and magnetoresistance, continuously leveraging its value in strengthening data analysis abilities and contributing to the overall improvement of electromagnetism experiment teaching quality and learners’ comprehensive literacy.

Disclosure statement

The author declares no conflict of interest.

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