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Research on the Design and Implementation of Inquiry-Based Simple Pendulum Experiment Teaching Using VS Code

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Abstract: The motion of a simple pendulum is a classical mechanics problem in physics practical teaching, involving concepts such as gravity and energy transformation. Students often find it challenging to grasp, and traditional experiments are prone to large data errors and complex procedures due to interference from factors like friction and air resistance. To address these issues, an inquiry-based experimental teaching model for the simple pendulum was developed using VS Code. An HTML-based simulation program was created to model the pendulum's motion under a composite force field combining gravity and magnetic forces, enabling analysis of how initial angle, pendulum mass and varying magnetic environments affect oscillation amplitude and angular velocity. The instructional design integrates contextualized teaching, theory-practice integration, and digital tools to establish a progressive learning pathway—from foundational understanding to in-depth inquiry. The teaching process comprises four stages: introduction, theoretical instruction, experimental exploration, and summary with extension. Inquiry-based and demonstration methods are employed, with VS Code used to visually render motion trajectories and analytical results, thereby overcoming limitations of conventional experiments and enhancing both precision and efficiency. Through group-based hands-on activities, data analysis, and discussions, students gain a solid understanding of pendulum dynamics and physical phenomena in complex force fields, while developing scientific reasoning, inquiry skills, and proficiency in information technology. This approach—driven by authentic contexts, structured in progressive layers, and supported by digital tools—not only stimulates student engagement but also fosters core competencies in physics, offering innovative insights and practical references for the digital transformation of physics experiment instruction.
Keywords: Simple pendulum motion; Magnetic force; VS Code

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1. Introduction

As a classical mechanics problem in physics education, the motion of a simple pendulum involves multiple complex concepts—such as gravity, periodicity, and energy transformation—making it difficult for students to comprehend and thus constituting a significant teaching challenge. Traditional simple pendulum experiments are heavily affected by external factors like friction and air resistance, leading to substantial experimental errors that obscure the true underlying physical laws[1]. Moreover, the entire process of data collection and subsequent analysis in conventional setups is often cumbersome and time-consuming, failing to meet the demands of modern physics instruction for both precision and efficiency. In light of these limitations, there is an urgent need to integrate innovative technological approaches to optimize experimental teaching design[2–3], thereby enabling students to better understand pendulum dynamics and enhancing their capacity for scientific inquiry.

Visual Studio Code (VS Code) is a highly efficient code editor capable of writing and instantly previewing HTML programs[4–5]. Leveraging this software, the experimental system developed in this study can be seamlessly executed within a web browser, allowing for intuitive simulation of the pendulum's motion trajectory and real-time extraction of key physical quantities such as amplitude and angular velocity.

Furthermore, VS Code's built-in data visualization and curve-fitting tools offer powerful analytical capabilities, facilitating in-depth processing and graphical representation of experimental data. This effectively circumvents the adverse effects of friction, air resistance, and other confounding variables inherent in traditional experiments, significantly improving measurement accuracy while streamlining operational procedures. Consequently, this approach opens up new avenues for both pendulum-related research and physics laboratory instruction. The simulation system not only replicates the pendulum's behavior under gravitational force alone but also incorporates magnetic forces, enabling deeper exploration of motion characteristics in a composite force field where gravity and magnetism act simultaneously.

Therefore, from the perspective of digitalized experimental teaching, this paper proposes an inquiry-based instructional model for the simple pendulum experiment built upon VS Code. It focuses on using HTML-based simulations to investigate the pendulum's dynamic behavior in a hybrid force field comprising both gravitational and magnetic components, and specifically analyzes how variables such as pendulum mass and varying magnetic environments influence oscillation amplitude and angular velocity. The primary objective is to address the longstanding issues of large experimental errors and procedural inefficiencies in traditional pendulum labs[6–7], thereby enhancing both the accuracy of experimental data and the effectiveness of instruction. Through this intuitive and efficient simulation environment, students can gain a deeper conceptual understanding of pendulum motion while simultaneously developing essential scientific inquiry and data analysis competencies. This work thus provides innovative insights and practical references for advancing the digital transformation of physics experiment education.

2. Experimental teaching design

2.1. Effect of initial release angle on simple pendulum motion

2.1.1. Situational conflict

(1) **Teacher Guidance:** The teacher asks, "If the initial release angle changes, how will it affect the pendulum's amplitude and angular velocity?" The teacher then uses VS Code to set the relevant parameters: the release angle is set to 30° and 80° respectively, while the mass is set to 43.31 g, the string length to 30 cm, the number of base magnets to 1, and the initial velocity to 0. The teacher then runs the simulation program and presents the resulting graphs (as shown in **Figure 1**).

(2) **Student Response:** After observing the graphs, students notice that when the angle is 30°, the maximum angular velocity reaches 0.08 rad/s and the amplitude is 0.4 rad; when the angle increases to 80°, the angular velocity increases to 0.2 rad/s, and the amplitude also increases to 1.2 rad.

(3) **Teaching Effect:** The data comparison stimulates students' interest in investigating the effect of the release angle and helps them gain an initial understanding of the motion pattern.

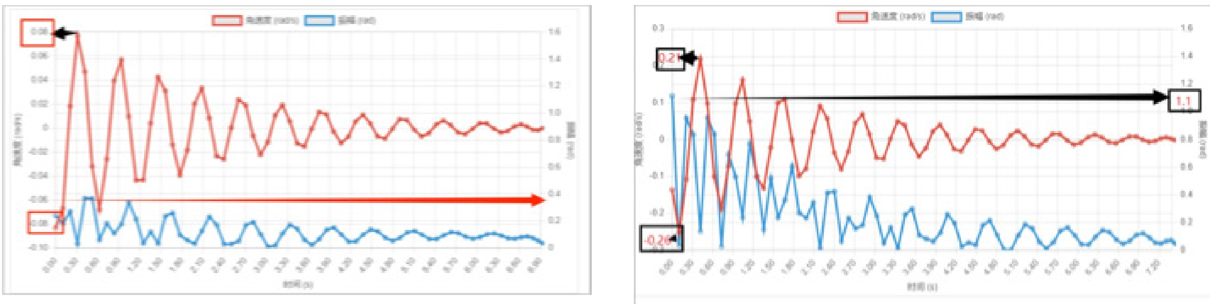
2.1.2. Visual perception

(1) **Teacher Guidance:** The teacher organizes students to work in groups using VS Code. They adjust the release angle, run repeated simulations, observe changes in the motion trajectory, and record the data, with an emphasis on tracking the trends in amplitude and angular velocity.

(2) **Student Response:** Through the hands-on activity, students clearly observe that as the release angle increases,

both the amplitude and angular velocity increase accordingly, and they record the key data.

(3) Teaching Effect: Group-based operation strengthens students' practical skills and enhances their sense of teamwork. Presenting the results visually also enables students to develop a more thorough understanding of the motion patterns.



(a) (b)

Figure 1. Effects of the release angle on simple pendulum motion: (a) 30°; (b) 80°.

2.1.3. Question-based guidance

(1) Teacher Guidance: The teacher asks, "What patterns can you summarize from the data? Why does the initial release angle affect the motion characteristics?" This prompts students to analyze the data and extract conclusions.

(2) Student Response: Students conclude that the larger the initial release angle, the greater the amplitude and angular velocity, resulting in more vigorous motion.

(3) Teaching Effect: Through data analysis, students learn to identify patterns and formulate rules, and their scientific thinking and analytical skills are enhanced.

2.1.4. Teacher's summary

The initial release angle has a significant effect on the motion of a simple pendulum. As this angle increases, both the amplitude and angular velocity of the pendulum increase accordingly. Through simulation-based operation and peer discussion, students successfully grasp the specific pattern of how the release angle influences the motion, and they also enhance their ability to use information technology to solve physics-related problems.

2.2. Effect of pendulum mass on motion

2.2.1. Situational conflict

(1) Teacher Guidance: The teacher asks the students, "After the mass of a simple pendulum changes, how will its motion characteristics be affected?" The teacher then uses VS Code to set relevant parameters: the mass is set to 50 g and 98 g respectively, the string length is set to 30 cm, the number of base magnets is set to 1, and the initial velocity is set to 0. Next, the teacher runs the corresponding simulation program and presents the results (as shown in **Figure 2**).

(2) Student Response: By observing the graphs, students find that with a 50 g mass, the amplitude decays by 0.32 rad in 3.4 s, and the maximum angular velocity is 0.9 rad/s; with a 98 g mass, the amplitude decays by 0.32 rad in 2.5 s, and the maximum angular velocity is 0.06 rad/s.

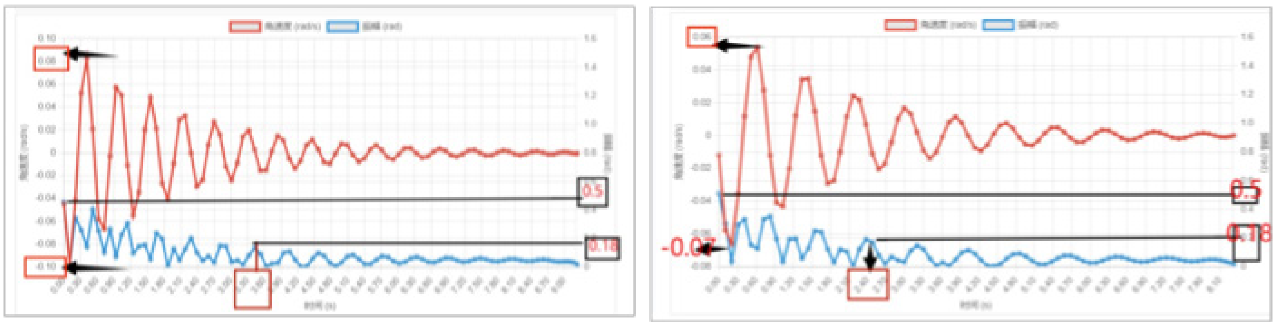
(3) Teaching Effect: The data comparison helps students perceive the effect of mass on motion and stimulates their interest in further inquiry.

2.2.2. Visual perception

(1) Teacher Guidance: The teacher guides students to work in groups to adjust the mass parameter. Through repeated simulations, they carefully observe various changes in the trajectory and record relevant data, with particular attention to the amplitude decay and the trend of changes when angular velocity reaches its peak.

(2) Student Response: Through hands-on operation, students notice that increasing the mass leads to faster amplitude decay and a decrease in angular velocity.

(3) Teaching Effect: The digital simulation provides an intuitive display of how mass affects motion, and students deepen their understanding through practice.



(a) (b)

Figure 2. Effects of different pendulum masses on the motion: (a) 50 g; (b) 98 g.

2.2.3. Question-based guidance

(1) Teacher Guidance: The teacher asks, “Why does mass affect the amplitude and angular velocity? Can you try to explain it from a mechanics perspective?” This prompts students to analyze using principles such as inertia.

(2) Student Response: Students conclude that as mass increases, inertia increases; the amplitude decays faster, and the peak angular velocity decreases.

(3) Teaching Effect: Through analysis and discussion, students develop an initial understanding of the pattern of how mass influences motion, and their logical reasoning ability is strengthened.

2.2.4. Teacher’s summary

When the mass of a simple pendulum increases, the amplitude decays more rapidly, and the peak angular velocity decreases accordingly. This clearly indicates that mass has a significant effect on motion. Through group collaboration and data analysis, students’ scientific inquiry skills and teamwork abilities are enhanced to some extent.

2.3 Effect of the number of base magnets on simple pendulum motion

2.3.1. Situational conflict

(1) Teacher Guidance: The teacher asks the students, “How will changes in the number of base magnets affect the motion of a simple pendulum?” Using VS Code, the teacher adjusts the settings by setting the number of magnets to 1 and 2, respectively. It should be noted that during this process, the mass of each magnet is kept at 43.31 g, and all other parameters remain unchanged. The teacher then runs the simulation under these settings and presents the final results, as shown in **Figure 3.**

(2) Student Response: Students observe that with only one magnet, the maximum amplitude can reach 0.6 rad, and the angular velocity decays by 0.06 rad in 0.3 s; with two magnets, the amplitude decreases to 0.4 rad, and the angular velocity decays by 0.05 rad in 0.36 s.

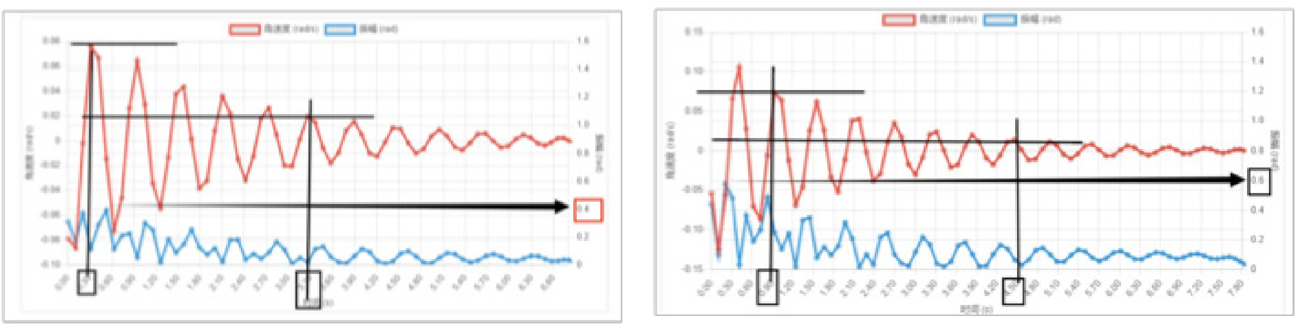
(3) Teaching Effect: The data comparison sparks students’ interest in exploring the influence of magnetic force.

2.3.2. Visual perception

(1) Teacher Guidance: The teacher instructs students to work in groups to adjust the number of magnets, repeat the simulations, observe changes in the trajectory, and record data, emphasizing the trends in amplitude and angular velocity.

(2) Student Response: Through hands-on operation, students perceive that increasing the number of magnets leads to a decrease in amplitude and a slower decay of angular velocity.

(3) Teaching Effect: Through practical work and data recording, students deepen their understanding of the effects of magnetic force.



(a) (b)

Figure 3. Effects of different numbers of base magnets on simple pendulum motion: (a) 1 magnet; (b) 2 magnets.

2.3.3. Question-based guidance

(1) Teacher Guidance: The teacher asks, "Why does the number of magnets affect the motion of a simple pendulum? Can you try to explain this from a mechanics perspective?" This guides students to analyze more deeply the role of magnetic force and its contribution to the motion.

(2) Student Response: Students conclude that increasing the number of magnets strengthens the magnetic force, reduces the amplitude, and slows the decay of angular velocity.

(3) Teaching Effect: Through analysis, students learn to explain phenomena from a mechanics perspective, and their scientific thinking skills improve.

2.3.4. Teacher's summary

When the mass of a simple pendulum increases, the amplitude decays more rapidly, and the peak angular velocity decreases accordingly. This clearly indicates that mass has a significant effect on motion. Through group collaboration and data analysis, students' scientific inquiry skills and teamwork abilities are enhanced to some extent.

3. Summary

This study employed VS Code to design an inquiry-based teaching module on the simple pendulum. It revealed the laws governing pendulum motion in a composite force field formed by gravity and magnetic force, and verified that factors such as the initial release angle, pendulum mass, and the number of magnets can affect both amplitude and angular velocity. Specifically, as the release angle increases, both the amplitude and angular velocity increase accordingly; when the pendulum mass increases, the amplitude decays more rapidly; and as the magnetic force becomes stronger, the amplitude decreases, but the decay of angular velocity is slowed. This research further deepens understanding of theories related to simple harmonic motion and energy conservation, and also provides a scientific basis for students to construct physical models in complex force fields.

Using VS Code as a tool, the instructional design guides students to explore the motion 规　律 of a pendulum oscillating in a composite force field through the structure of “situational conflict–visual perception–question-based guidance–summary.” Through scenario creation, digital simulation, and guided questioning, the teacher stimulates students’ interest in learning and cultivates scientific thinking. In practical application, the VS Code simulation system successfully overcomes limitations of traditional experiments, such as relatively large errors and cumbersome procedures, thereby improving experimental accuracy and teaching efficiency. By means of visual simulations and data analysis, students further enhance their scientific inquiry skills and information-technology literacy. This provides an innovative reference for advancing the digital transformation of physics education and plays an important role in fostering innovative talents.

Unlike traditional simple-pendulum experiments that focus only on gravity, this study innovatively incorporates magnetic force and digital tools, enriching the teaching context. However, it does not provide a more detailed investigation of the effects produced by complex arrangements of multiple magnets, so the realism of the simulation system still requires further validation. In the future, it is recommended to optimize the relevant algorithms, incorporate variables such as air resistance, and develop a wider range of teaching resources to improve universality and practical effectiveness. In this way, the study can offer more comprehensive support for the digital transformation of physics teaching and promote high-quality development in science education.

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Disclosure statement

The author declares no conflict of interest.

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