Practical Studies on the Auxiliary Effects of MATLAB Simulation on Encounter and Pursuit Problems in Teaching Process

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Abstract: With the advancement of education informatization, the difficulty in understanding abstract concepts (such as encounter and pursuit problems) in physics teaching urgently needs to be addressed. This study focuses on the auxiliary effects of MATLAB numerical simulation technology in secondary school physics teaching. Taking encounter and pursuit problems as examples, we constructed dynamic simulation models and utilized graphical user interfaces (GUI) to visually demonstrate the relationships between objects' motion states (displacement, velocity) and time. Through comparative analysis and discussion, it was found that MATLAB-assisted teaching demonstrates significant advantages in cultivating students' abilities to understand abstract concepts and analyze complex problems, while effectively helping students establish intuitive motion dynamics and reduce comprehension difficulty. Additionally, due to variations in students' individual abilities and autonomous learning initiative, MATLAB-assisted teaching exhibits distinct impacts on students with different learning capacities, resulting in pronounced polarization in learning outcomes.

Keywords: Encounter and Pursuit Problems; MATLAB Simulation; Auxiliary Effect; Practical Studies

1. Introduction

With the rapid development of information technology, the education sector is actively promoting the deep integration of information technology and teaching to enhance educational outcomes [1]. Abstract concepts such as vibration superposition often lack intuitive representation, which results in students merely having a superficial understanding of mathematical formulas and struggling to grasp the underlying physical laws including their applications [2]. Domestic educational information technology is advancing. In physics teaching, MATLAB has been effectively used to simulate experiments and process data. This helps tackle the challenges in physics education.[3, 4]. For example, Ji et al. [5] found that MATLAB can be used to build a simulation platform for teaching electrostatic fields in high school physics. They designed dynamic models for core knowledge points like electric field intensity and electric potential, which allow for real-time demonstration of electric field distribution and potential changes. Su et al. utilized MATLAB to convert complex formulas and abstract physical concepts into intuitive images, which was achieved through leveraging its functions in curve plotting, experimental data processing, simulation, and visualization. These elements were then deeply integrated into physics teaching to enhance classroom effectiveness [6,7]. Currently, physics teaching confronts substantial challenges. For instance, classroom instruction primarily relies on a combination of lectures and experimental demonstrations. However, traditional teaching methods often result in students' difficulties in comprehending highly abstract content, which in turn impairs their learning interest and efficiency. Thus, there is an urgent need for innovative teaching approaches to enhance classroom effectiveness and improve students' understanding of abstract physical concepts [8, 9].

The teaching dilemma regarding abstract content is also prominent in curriculum resource development. For example, when teachers design courseware, most images or animations are sourced from online platforms. However, those existing materials fail to align with teaching needs, which leads to a lack of innovation in content [10]. Object kinematics, as a foundational component of mechanics, directly affects students' understanding of physical laws.

In teaching encounter and pursuit problems, students often face difficulties, primarily due to inadequacies in their abstract thinking and mathematical modeling abilities [11]. These problems involve dynamic associations between multiple objects and processes. Traditional blackboard teaching struggles to explain relative motion trajectories and critical conditions, resulting in a cognitive gap, where students understand it but cannot effectively apply it. The reasons are as follows: first, the abstract nature of physical models makes it challenging for students to extract reference frame transformations and velocity correlation characteristics from practical problems; second, difficulties in applying mathematical tools can easily lead to computational problems or errors; third, the lack of visualization in dynamic processes means traditional teaching cannot demonstrate continuous displacement-time changes, resulting in a high error rate in critical condition judgments. In contrast, simulation-assisted teaching can significantly enhance the efficiency of model understanding and the accuracy of critical condition judgment [12, 13].

In line with the requirement to "strengthen scientific inquiry and technological application" outlined in the Physical Curriculum Standards for Compulsory Education (2022 Edition) [14], a case study on the deep integration of information technology and physics teaching is presented in the paper, which is achieved by introducing MATLAB simulation technology into the teaching of encounter and pursuit problems. Dynamic visualization of motion trajectories, parameterized control of initial conditions, and real-time verification of model assumptions are employed to provide a new approach to addressing teaching challenges. Within the MATLAB simulation environment, researchers can implement multi-body dynamical systems modeling, which produces simultaneous visual animations and quantitative data outputs. Thereby students should be supported to establish an integrated cognitive structure for systematic knowledge formation [15].

2. Basic Theory and Implementation Plan of the Research Content

2.1 Encounter and Pursuit Problems

The encounter problem describes a scenario where two objects, starting from distinct positions and moving in the same or opposite directions, eventually arrive at the same position at a specific moment, which is described as, . Specifically, the key condition is as follows: for motion in opposite directions, the sum of the two objects' displacements equals the initial distance; for motion in the same direction, the difference between their displacements equals the initial distance. The pursuit problem involves a pursuer attempting to catch up with a pursued object, typically in same-direction motion where the pursuer's velocity must exceed that of the pursued object. The relationship is defined as follows:. Specifically, the key condition is that the pursuer's displacement equals the pursued object's displacement plus the initial distance (assuming a certain initial separation between the two). A dynamic model, in which a school bus travels at a constant velocity (8 m/s), is constructed in the paper while a student accelerates to pursue it, with the student's acceleration adjustable within the range of 0.5–2.0 m/s². The system generates real-time displacement-time graphs and simultaneously displays the state of equal velocities when the two intersect, with the displacement relationship expressed by the formula:. Through multiple sets of parameter-based experiments, students can derive the mathematical relationship between the acceleration threshold and successful pursuit.

2.2 Teaching Design Plan for Practical Instruction

Through multiple sets of parameter-based experiments, students can derive the mathematical relationship between the acceleration threshold and successful pursuit. The second level divides the teaching topic into four segments, with special emphasis on numerical simulation and student activities. The third level primarily focuses on concretizing the teaching aspects outlined in the second level, specifying the tasks for each segment and their respective objectives to be achieved in the graphical user interfaces (GUI) to visually demonstrate the relationships, as shown in Figure 1.

3. Simulation Results and Discussion

3.1 Encounter and Pursuit Problems

Centered on the integration of "scientific inquiry with digital tools," this study introduces problems via real-life examples and employs MATLAB's dynamic visualization analysis and graphical applications to help students establish physical concepts, thus achieving in-depth integration of theory and practice [16]. Encounter and pursuit problems, which are relatively abstract, can be better comprehended by students through real-life scenarios (e.g., vehicle rear-end collisions, athletes racing), thereby stimulating their interest in learning. MATLAB's dynamic simulations further enhance students' comprehension of these abstract concepts by offering a more intuitive understanding [17]. The teaching design adopts constructivist learning principles and employs a "problem-chain inquiry-based" teaching methodology to guide students in constructing knowledge autonomously in stages [18].

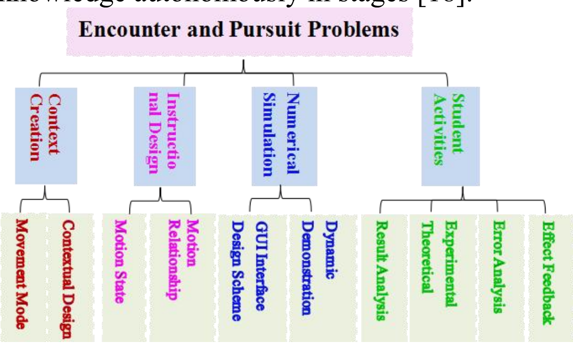

Figure 1. Classroom Teaching Design Scheme for Encounter and Pursuit Problems

Given the abstract nature of encounter and pursuit problems, a MATLAB simulation program was designed by integrating multiple aspects. The program utilizes a GUI with dynamic demonstrations comprising three visualization windows: the main window displays a three-dimensional simulation of vehicle motion, the auxiliary window simultaneously plots displacement-time and velocity-time curves, and the data window outputs key parameters such as the encounter time and position of the two vehicles in real-time. By specifying six parameters, including the initial positions ($s1$_edit, $s2$_edit), initial velocities ($v1$_edit, $v2$_edit), and accelerations ($a1$_edit, $a2$_edit) of the student and the vehicle—the GUI interface demonstrates the changes in position and velocity of both entities over time, as shown in Figure 2. For the s-t motion curve graph, the linear increase in the distance traveled by the car over time indicates uniform linear motion, which enhances the understanding of constant velocity motion ($s=vt$). Meanwhile, the student's *s-t* motion curve forms a parabola, which is perfectly consistent with the relationship between position and time($s=at^2/2$).

Regarding the *v-t* motion relationship curve graph, it elucidates the relationship between velocity and time($s=vt$). The changes in motion velocity imply alterations in an object's motion state, which are caused by acceleration. Thereby the case obviously deepens the students' comprehension of physical quantities describing an object's motion state, such as velocity and acceleration [19]. Furthermore, as originates from the graphs of the *s-t* and *v-t* curve, students can easily determine the encounter time and distance, which are equal to 31.96m and 5.65s, respectively.

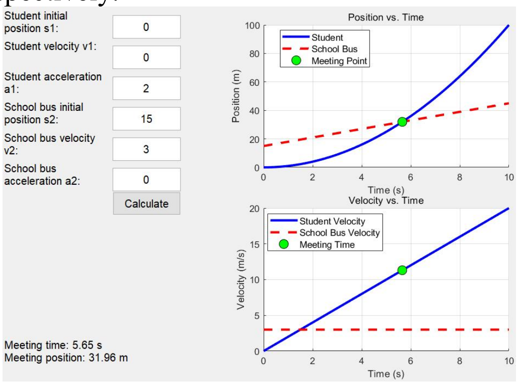

Figure 2. GUI Interface Diagram for Encounter and Pursuit Problems

The upper Diagram Illustrates the Relationship between Position (s) and Time (t), While the Lower Diagram shows the Relationship between Velocity (v) and Time (t).

By utilizing MATLAB software to plot graphs, the processes of distance and velocity changes over time are clearly depicted, converting these abstract concepts into visually dynamic processes. This approach reduces the difficulty students encounter in understanding knowledge and assists them (particularly those with weaker spatial imagination or abstract thinking abilities) in constructing the dynamic relative motion of two objects. It further enhances students' understanding of concepts such as relative velocity, encounter/catch-up timing and duration required. Thereby it providing an intuitive grasp of displacement and velocity. The use of MATLAB software allows for the adjustment of initial conditions in encounter and pursuit problems, which can enable students to compare and analyze how different initial parameters influence these dynamics. The analysis is based on the time-dependent relationships between the positions and velocities of the school bus and the student.

3.2 Discussion of Practical Teaching

Effectiveness

Grounded in considerations of the educational internship cycle and students' knowledge acquisition progression, this study selected two classes with equivalent physics proficiency from the first-year cohort of a high school in Zhanjiang City as the research subjects. Specifically, Class 15 (Grade 10) served as the experimental group, where a novel teaching approach was implemented, while Class 16 (Grade 10) functioned as the control group, adopting traditional teaching methodologies. The sample selection was based on students' performance in school-administered thematic assessments related to the relevant teaching content.

Table 1. Initial Scores and Testing Effects of Two Classes before Implementing MATLAB-Assisted Instruction

Class	Students	Average score	Standard deviation	*t*-value	*p*-value	Confidence interval
experimental class	54	65.13	13.76	0.41	0.69	[-4.19, 6.34]
Control class	55	64.06	14.25			

In the analysis conducted using SPSS software, the *t*-value reflects the magnitude of inter-group differences (hereinafter referred to as the degree of inter-group disparity). Specifically, a *t*-value approaching zero indicates a minimal degree of inter-group disparity, which may suggest that the observed differences may stem from random errors. Conversely, a larger *t*-value signifies more pronounced disparities in inter-group data. The degrees of freedom affect the shape of the t-distribution: when the degrees of freedom are low, the *t*-distribution curve is characterized by flattening with higher tail probabilities. As the degrees of freedom increase, the *t*-distribution curve gradually approximates a normal distribution. Regarding the two-tailed significance test (*p*-value), the p-value which is less than 0.05, justifies rejecting the null hypothesis and confirms significant disparities in inter-group data. In constrast, A *p*-value, exceeding 0.05, is unable to rule out the possibility that observed differences arise from random factors[20]. Additionally, the confidence intervals provide supplementary evidence for interpreting the following results. When a confidence interval includes zero (e.g.,[-1.2, 3.4]), it is consistent with the conclusion of nonsignificant inter-group differences derived from a p-value greater than 0.05. the cases indicate insignificant disparities in inter-group effects. If the confidence interval entirely excludes zero (e.g., [0.5, 4.5]), the interval's confidence level and the significance of the difference indicated by a p-value less than 0.05 mutually reinforce each other.

Table 1 presents the test scores of the two classes on relevant teaching content prior to MATLAB-assisted instruction. The results indicate that there was no significant difference in the pre-instruction scores between the experimental class and the control class. Particularly, the experimental class had a mean score of 65.13 ± 13.76, on the contrary, the control class had a relative low mean score of 64.06 ± 14.25. With a *t*-value of 0.41 and a p-value of 0.69, along with a confidence interval of [-4.19, 6.34] that includes zero, these findings suggest that the initial learning levels of the two groups of students were essentially equivalent, as shown in Table 1. Following the integration of MATLAB-assisted instruction into the experimental group and the adoption of traditional teaching methods in the control group, a comparison of the same data from both classes (as presented

In Table 2) reveals that students in the experimental group demonstrated superior performance in terms of learning, understanding, and mastering the teaching content [21].

In the practical teaching effectiveness test concerning problems of encounter and pursuit, the *t*-values in Table 2 are notably greater than those in Table 1, which indicating larger inter-group data variability and demonstrating a significant effect of MATLAB-assisted teaching. The average score of the experimental class is 2 points higher than that of the control class, with a *p*-value of 0.30, which is apparently lower than the pre-MATLAB-assisted teaching *p*-value of 0.69. This implies that MATLAB-assisted teaching reduces the impact of random factors on inter-group data differences, rendering the scores more authentic. Although the *p*-value does not reach the significance threshold, the upper limit of the confidence interval approaches 6 points, suggesting substantial potential for score improvement among students in the experimental class. In compared with the control class, the experimental class exhibits a significantly larger standard deviation (10.88 vs. 8.89), indicating a pronounced effect of MATLAB-assisted teaching but also leading to a notable differentiation among students with varying learning abilities. In addition, students in the experimental class demonstrate stronger mathematical analytical skills when solving complex problems, whereas students in the control class tend to apply theorems or formulas without adequately considering real-world contexts, further underscoring the significant effectiveness of MATLAB-assisted teaching [22].

Table 2. Specialized Test Scores and Testing Effects of Two Classes after Implementing MATLAB-Assisted Instruction

Class	Average score	Standard deviation	Mean difference	*t*-value	*p*-value	Confidence interval
Experimental class	74.07	10.88	2.00	0.52	0.30	[-1.73, 5.73]
Control class	72.07	8.89				

4. Conclusions

In conclusion, this study has comprehensively explored the application of MATLAB in high school physics teaching. Through a series of research and analysis, it is evident that MATLAB offers significant advantages in enhancing students' understanding of abstract physical concepts, such as displacement, velocity, and relative motion, by transforming them into intuitive dynamic visualizations. The empirical results demonstrate a notable improvement in students' test scores, indicating the effectiveness of MATLAB-assisted teaching in facilitating knowledge acquisition. Moreover, it has been found that the approach can stimulate students' interest in exploring physics knowledge and cultivate their abilities in complex scenario analysis and mathematical modeling. However, there are also some limitations in this research. For instance, the sample size could be further expanded to enhance the generalizability of the findings. Future studies should focus on optimizing the design of MATLAB-based teaching resources and exploring more diverse teaching strategies to maximize the potential of MATLAB in physics education. Overall, MATLAB holds great promise as a powerful tool for improving the quality and efficiency of high school physics teaching.

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