

# Protocol-Guided Teaching in Junior-Secondary Physics Education: An Analysis of the Learning Protocol for the Velocity Instruction Based on Real-World Circumstances

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**Abstract:** Protocol-guided teaching is a student-centered instructional model in which the teacher creates the learning protocol prior to the lesson in order to direct students toward active and autonomous learning. A well-structured learning protocol is essential for the effective application of this instructional paradigm. This article evaluates the significance of protocol-guided instruction in junior secondary physics education by analyzing the learning protocol for velocity instruction. Protocol emphasizes situation-based learning and the inquiry chain method.

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*The Compulsory Education Course Standards for Physics 2022* emphasize the necessity of learning physics through inquiry based on real-world situations in order to develop key competencies in scientific explorations (Ministry of Education, 2022). To implement the new educational concept of the revised national curriculum program, a student-centered instructional strategy is required. Protocol-guided instruction is an instructional paradigm in which teachers create student learning protocols in advance based on course standards, textbook content, and student learning conditions. These protocols typically include learning objectives, materials, methods, and procedures to help students engage in more independent learning (Wang, 2022). Learning protocols must be well-designed for the protocol-guided teaching model to be implemented effectively.

This article is an analysis of the learning protocol for the velocity lesson, which uses the “Four Steps of Guidance” method of protocol-guided instruction to guide students through the entire learning process, including student preparation before class, classroom inquiry, summary and reflection, and instructional assessment (Wang & Zhu, 2023). Each component of the protocol for learning serves a distinct design purpose. The pre-class learning protocol suggests a variety of introductory activities to help students integrate into learning contexts and generate queries for future explorations. To assist students in addressing queries posed both before and during class, a detailed plan for classroom inquiry activities is developed. The subsequent step of summary and reflection aids students in generalizing research methods and building knowledge structure. Through evaluations, the instructional assessment process aims to deepen students’ conceptual comprehension, solidify their mastery of knowledge and skills, and expand their competencies.

In the unit on motion, which follows those on sound, light, and heat, students are instructed to examine the tangible motion of objects. The lesson on velocity, which is the first section of this course, is comprised of multiple components and is relatively abstract. It includes the development of the concept of velocity, basic calculations using the velocity formula, and the measurement of velocity, establishing the groundwork for the study of other motion-related topics.



## Before-Class Preparation

When creating the pre-class learning procedure, authentic situations are used to introduce the lesson.

### *Understanding the Learning Objectives of this Lesson*

- i. Learn the definition and units of velocity through the ratio definition approach and learn how to compare the speeds of motion of objects through experiments. Understand that velocity is a physical quantity that describes the speed of a moving item.
- ii. Conduct experiments to learn how to measure velocity.
- iii. Use the velocity formula to do basic calculations in relevant exercises.

*(This approach has the dual objectives of emphasizing the subject of this session, namely the building and comprehension of the notion of velocity, and of providing students with a fundamental understanding of the learning materials and procedures of this lesson.)*

### *Pre-Class Learning Tasks*

- i. Initial estimation of velocity (by viewing a race on video or recreating a race): How do you evaluate the running speeds of the runners in the 100-meter race once the starting gun has been fired? How do the referees' running times compare?
- ii. Before class, go over the material in the textbook, and get two paper cones ready as needed.
- iii. Complete the exercise below,

*Student X estimates that he typically walks at 1.2 meters per second, or \_\_\_\_\_ kilometers per hour; X's residence is 720 meters from school. She has to leave home at least how much time in advance to arrive to school on time? (Note the contrasts between the physics calculation format and the one used in mathematics in your writing.) \_\_\_\_\_*

- iv. Ask questions concerning velocity in light of all pre-class assignments.

*(The pre-class activities are structured with the lesson's learning objectives in mind. Students work independently to study textbook material and execute preliminary experiments to encourage deeper thought under the direction of the learning protocol. The purpose of task one is to help students develop a*

*perceptual awareness of the two ways to compare the velocities of moving objects: one is to look at the time required to travel a distance, and the other is to consider the distances reached in a given amount of time. Students can experiment with the two paper cones before class to gauge their speeds when falling from various heights as well as prepare them for use in the classroom inquiry. Since students have had trouble converting between composite units, Task 3's first question is designed to test their prior understanding of the relationships between various velocity units. As this is the first-time students have encountered calculation questions in junior secondary physics instruction, the second question in task three assesses students' comprehension of the accepted practices for solving calculation problems following textbook section readings. The stage of pre-class preparation involves students coming up with a range of velocity-related queries. Some of these are utilized in class as introductory questions and happen to be about the main points of this lesson. This fosters students' initiative in their academic work.)*

## **Classroom Inquiry**

In the textbook section on velocity, there are four main objectives that stand out: teaching students to compare rates of movement; formulating the concept of velocity based on the comparison method, understanding the meaning of velocity, and learning to convert between different units of velocity; learning to measure the velocity of objects by experiment and mastering the techniques of experimental operation, table design, data processing, etc.; and following the standard steps for solving calculation problems. The learning protocol suggests a “question chain” and accompanying activities for classroom inquiry in accordance with the requirements highlighted in the textbook.

### ***Question 1: How can the velocities of the descending paper cones be compared?***

Activity one: Watch the video of renowned Chinese hurdler Xiang Liu in action.

Activity two: Experiments were conducted to compare the falling velocities of two paper cones with differing vertex angles.

- Experiment one: simultaneously drop two paper cones from the same height and compare their falling velocities.
- Experiment two: simultaneously release them from different heights and compare their velocities.

- Derive the methods for comparing the velocities of various objects from the experiments:

*(By observing real-world videos and engaging in hands-on experiments, students gain an understanding of velocity and the two preliminary methodologies for comparing velocities.)*

### ***Question two: What quantities are employed to describe velocity in physics?***

Activity: Group discussions on the significance, definition, calculation formula, and units of velocity including unit conversion.

*(This activity will allow students to establish the concept of velocity through group discussions, develop a mathematical model for velocity, and comprehend the units of velocity via a formula.)*

### ***Question three: How to measure the velocity of the descending paper cone?***

Activity: Measure the velocity of the falling paper cone.

- Pre-experiment preparation: defining the experiment's principle and physical quantities to be measured, preparing experimental equipment, and designing tables for recording experimental results.
- Conduct experiments in groups, document the quantities measured in the tables, and calculate the falling paper cone velocities.
- Reflections: (i) Is it preferable to begin measuring the falling time of a paper cone from the apex or the base? (ii) Is it better to measure the cone's travel time over a lengthier or shorter distance? Why? (iii) Is it more favorable to use the paper cone with a smaller or larger vertex? Why?

*(Measuring physical quantities is a fundamental skill for students to master in physics teaching. This project is designed to teach students how to measure the velocity of objects, which will be useful in their future academic lives and employment. The three reflection questions are designed to get students thinking about how to increase measurement accuracy.)*

### ***Question four: How to solve simple calculation problems with the velocity formula?***

Activity: **Figure 1** depicts a car's position as it travels down the Shanghai-Nanjing Expressway. At its current speed, how long does it take the automobile to reach Shanghai?

*Hints: The velocity indicated on the dashboard is \_\_\_\_\_.  
"180 km" represents \_\_\_\_\_.*



**Figure 1**

*(The purpose of this procedure is to teach students the standard methods for solving physical calculation problems.)*

Teaching Challenges:

It is challenging for students to precisely gauge the speed at which the paper cone is falling. Without guidance from the teacher, students might use the height of their desks to determine the distance, which could lead to large inaccuracies in velocity because of erroneous time measurements. The teacher used PVC pipes that she found on a construction site to create two and a half meter long "rulers" marked with 1-, 1.5-, and 2-meter indicators (as shown in **Figure 2**), allowing students to measure time based on the proper distances and ensuring the accuracy of the paper cone's velocity measurement results.

The teacher can also use images and videos to improve students' comprehension in order to maximize their guiding responsibilities in addressing students' learning issues. To demonstrate the various approaches for comparing the velocities of falling paper cones, **Figure 3** might be used as an example. **Figure 3 (a)** depicts the simultaneous release of two paper cones from the same height and the time it takes for them to fall to the ground (highlighting the same height of descent); **Figure 3 (b)** illustrates the



Figure 2

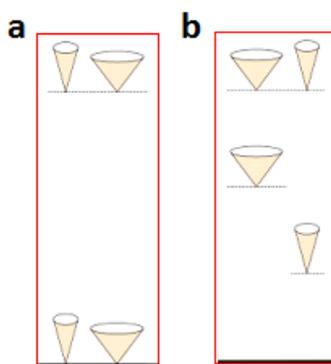


Figure 3



Figure 4

simultaneous release of two paper cones from the same height, but with different distances of movement that are noted and compared at specific points.

The “question chain” is a useful tool for helping students conceptualizes velocity. The foregoing four questions relate to students’ investigative experiences: (i) Identifying phenomena - experimenting with various techniques for measuring speeds and observing the prevalence of velocity across media (Students are shown images like **Figure 4** to remind them that velocity actually affects every aspect of their daily lives. ); (ii) Understanding the concept - formulating a mathematical model for velocity and using the ratio of distance to time to describe velocity; (iii) Researching like an expert - accurately measuring velocity; and (iv) Learning to solve velocity-related calculation issues by using the formula of velocity. The student-centered teaching concept is closely associated with this type of question-oriented learning. The teacher and students can connect and conduct pertinent talks based on the “question chain” to work through challenges together. Through individual research, peer interaction, and instructor assistance, students are likely to develop a thorough comprehension of subjects and learn new approaches to problem solving.

## Summary and Reflection

The purpose of the summary and reflection procedure is to encourage students to assess their classroom inquiry activities and independently construct their own velocity knowledge framework. This procedure’s learning protocol stipulates the following requirements,

- i. Describe three methods for comparing the velocities of distinct objects: the amount of time spent on the same distance, the distances travelled in the same amount of time, and the calculated velocities.
- ii. Generalize the principle ( $v = s/t$ ) for calculating the velocities of falling paper cones and measurement steps.
- iii. Create a knowledge framework of velocity, as shown in **Figure 5**.

## Instructional Assessment

To evaluate teaching and learning outcomes, the learning protocol provides exercises of varying levels of difficulty based on instructional objectives and content.

*Exercise one: Determine the method used to compare velocities by carefully examining pictures A and B. (Figure 6)*

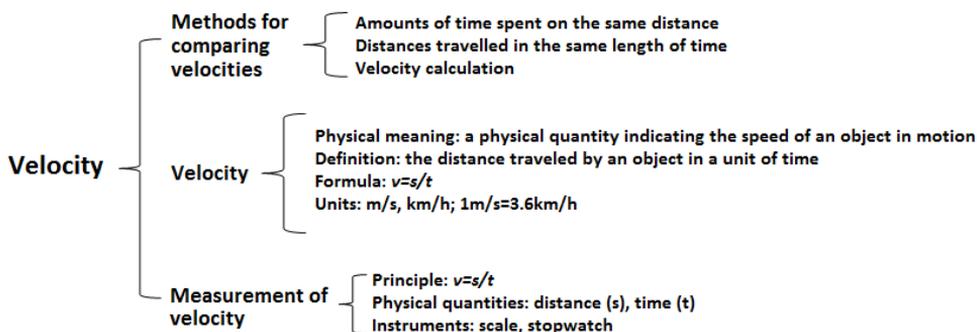


Figure 5. An Example of Students' Knowledge Framework of Velocity.

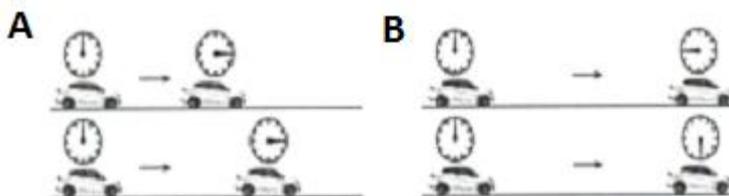


Figure 6

Exercise two: The cheetah can run at speeds of up to 30m/s on land, the sailfish can swim at speeds of up to 100km/h in the ocean, and the swift can fly at speeds of up to 3km/min in the air. Which animal is the quickest on the planet?

Exercise three: The Shanghai-Nanjing expressway's speed limit is indicated by a road sign. The electronic toll collection system maintains a record of a vehicle's entry onto the expressway from Suzhou at 9:00 a.m. and egress from the expressway in Shanghai at 9:40 a.m. Suzhou and Shanghai are separated by 84 kilometers. Is the motorist subject to a speeding fine? Why? (Answer the query using the standard methods for solving the calculation problems.) (Figure 7)

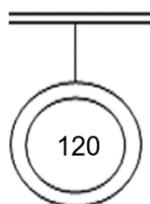
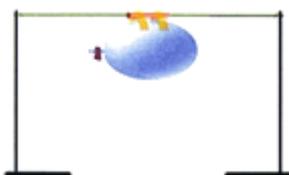


Figure 7

*Exercise four: The accompanying table is a screenshot of a record from Student M's mobile app detailing a jog he completed. It indicates that he completed the \_\_\_\_ km of trek in \_\_\_\_ minutes and that his average step length was \_\_\_\_ meters. (Table 1)*

Table 1	
2,250 Total steps	150 Step frequency: Numbers of steps/min
8.10 Speed: km/h	124 Kilocalories burnt

*Exercise Five (after-class assessment):*



**Figure 8**

*Make a “jet rocket” by following the specified steps (Figure 8):*

- *Inflate a balloon with air, then clip it closed.*
- *Use tape to attach a little piece of straw to the balloon.*
- *Insert a piece of string through the straw, smooth it out, and then unfasten the sealing clip to cause the balloon to move. Please gauge the speed of this “jet rocket.”*

*(Exercises one, two, and three are fundamental queries used to assess students' mastery of fundamental velocity knowledge. The fourth exercise is more challenging and necessitates a higher level of physical aptitude, as it entails not only velocity formula-based calculations but also an analogy between velocity and step frequency. Exercise five is designed to hone students' experimental operation skills. All of these exercises are applicable to real-world situations; consequently, they have the potential to pique students' interest in further investigating velocity-related issues in daily life.*

## **Conclusion**

The learning protocol for this lesson follows the essential principles of the protocol-guided teaching paradigm, making it feasible to deliver instruction that is focused on the needs of each individual learner. The concept of “physical research deriving from lives and contributing to the society” can be better understood by students through learning activities based on real-

world situations. This effectively increases their engagement in classroom inquiry and fosters their enthusiasm for physics study. The findings of both formative and summative assessments demonstrate that students can successfully complete learning goals with the aid of the learning procedure. However, there is still opportunity for advancement in both its conception and execution. Only a few of the questions brought by students can be thoroughly discussed in class due to time restrictions. To foster their spirit of exploration, more answers should be provided to their queries. Classroom experimentation with measuring velocity shows that the use of more sophisticated digital technology would aid in improving the accuracy of experimental results, suggesting that future learning protocols should place more emphasis on the improvement of digital literacy in both the teacher and students for a more successful digital-era physics education.

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