# Effectiveness of Interactive Microcontroller Based Speed Sensors to Improve Students' Analytic Thinking Skills

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**Abstract**—This research is a science, technology, engineering and mathematics (STEM) implementation at the senior high school level. The purpose of the research was to produce an interactive microcontroller-based speed sensor that was feasible to improve students' analytical thinking skills (ATS) in the impulse and momentum learning. This research is a kind of research & development (R&D) that uses a pre-experimental design with one group pre-test post-test study. Data collection used validation sheet, ATS test, observations sheet, questionnaires, and then analysed using Wilcoxon test, N-gain, and descriptive qualitative analysis. The research findings were the interactive microcontroller-based speed sensor devices and learning materials which were categorised as very valid. The interactive microcontroller-based speed sensor in impulse and momentum learning was effective, as specified by three criteria. First, there was a significant increase in students' ATS at $\alpha = 5\%$. Second, the average N-gain of impulse and momentum learning was categorised as high (.89). Third, students' responses in each learning process were categorised as very positive.

**Keywords**—Analytical thinking, interactive microcontroller, speed sensor

## 1 Introduction

Physics as one of the natural sciences or science that studies the behavior and structure of matter. One important aspect that exists in science is the observation or observation of events starting from the initial planning to the implementation. [1]. Observation is an empirical scientific activity based on facts and texts, through the experience of the five senses without using any manipulation [2]. Presenting facts in-class learning is not an easy thing to do, especially in impulse and momentum material. The physical magnitude which influences the discussion of momentum is mass and velocity. But the speed is difficult to measure using simple tools or manuals because it deals with a very short time. In addition to knowing the consequences of the event of the application of momentum and impulses using a gradual calculation and requires measuring devices based on modern technology such as digital speedometers.

In the 21st century skills and era of the industrial revolution 4.0, human resources with competency standards for students are directed at the importance of critical thinking [3-9], one of which is analytical thinking skills (ATS). ATS is a process that involves the process of breaking down material into small parts and determining how the relationship between parts and between each part and the overall structure [10-16]. Three aspects of ATS according to Anderson & Krathwohl [10-11] include distinguishing, organizing and connecting, while the description of sub-skills for APS [12] includes reviewing ideas, identifying arguments and analyzing arguments [15]. Departing from the need to deliver students to have higher order thinking skills (i.e. ATS), researchers have developed interactive microcontroller-based speed sensors on learning momentum and impulses. The focus of this article is on the effectiveness of interactive microcontroller-based speed sensors to improve students' ATS.

## 2 Literature Review

### 2.1 Interactive microcontroller-based speed sensor

Impulse and momentum observation tools use a speed sensor based on a microcontroller made from the following materials:

- Photodiode Sensor; also called a light sensor, the electronic component functions to change the light signal into electrical output.
- LCD (Liquid Crystal Display); LCD functions as a display of data both characters, letters or graphics. In this study to display the speed before and after the collision, and the coefficient of restitution.
- DC motor; DC motor is an electric motor that functions to provide direct current voltage on the field coil to be converted into mechanical motion energy.
- Power supply or DC Power Supply; the power supply serves as a source of electric power.
- Laser diode; Diode lasers are semiconductor lasers. The wavelength of the laser diode can be measured using a wave meter. A simple way can be done using a diffraction grating.
- Acrylic; Acrylic is a plastic raw material that resembles glass, its characteristics are sturdy and strong and the surface is slippery so that the friction is small.
- Arduino Nano; Arduino is an open source electronic board programmed to be able to read input, process, and provide output as desired.

Circuit diagram of a microcontroller-based speed sensor in Figure 1.

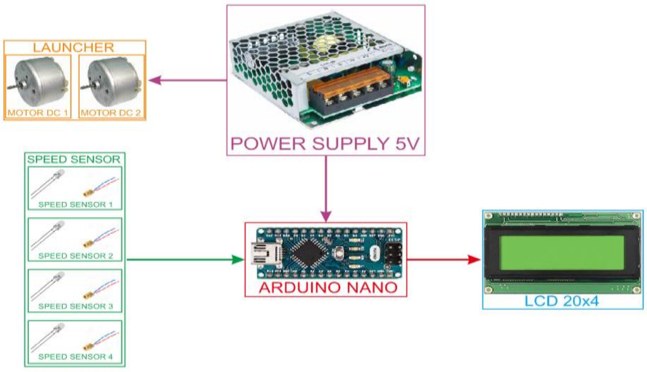


**Fig. 1.** Schematic Microcontroller Circuit

Procedures of interactive microcontroller-based speed sensors:

- Power supply functions to provide power supply to all electronic devices that have been installed, starting from the microcontroller, 20x4 LCD character, speed sensor and launch motor.
- The vehicle moves from the launch motor, where the launch motor provides additional energy to the vehicle unit so that the vehicle can go at the speed set.
- The launcher works using two DC motors with the opposite direction of rotation. One is moving CW (clockwise) and the other is CCW (counterclockwise).
- The voltage consumed by the launcher motor comes from the power supply that is passed to the voltage regulator so that the rotation speed of the motor can be regulated.
- After passing the launch motor, the vehicle moves to the speed sensor at the end of the track. Where the speed sensor there are 4 pairs of light sensors (Laser and Photodiode).
- The light sensor works to detect passing vehicles by comparing the incoming light when it is not blocked by the vehicle and when it is blocked by the vehicle. When blocked by a vehicle, the light from the laser cannot be received by the photodiode sensor. And when the vehicle is not blocked, laser light can be directly received by the photodiode sensor. From these two conditions, the microcontroller can detect the presence or absence of a passing vehicle.
- The speed sensor utilizes several light sensor units. Illustration of the work of the speed sensor in Figure 2.

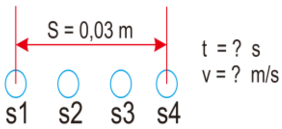


**Fig. 2.** Speed Sensor Input

When the vehicle passes sensor 1 (s1), the microcontroller starts its timing (Timer), until the vehicle reaches sensor 4 (s4). The timer (timer) on the microcontroller gets the time data needed by the vehicle from point S1 to point S4. The distance from S1 and S4 has been determined by the mechanical design as far as 3cm. So, the vehicle speed can be determined by the equation $v = s / t$.

The speed sensor is placed at the end of the track where the vehicle collides. Before the collision, the vehicle moves from s1 to s4 and vice versa after experiencing collision the vehicle moves from s4 to s1.

With the same principle, the microcontroller can determine the speed of the vehicle before the collision (v) and after the collision (v ').

From the two data v and v ', the restitution coefficient (e) can be determined by the equation $e = v' / v$. the speed of the impact media is negligible.

All three data are displayed on a 20x4 LCD character.

The learning media mechanism for observation consists of 5 main components namely the Launcher, Speed Checker, Speed. Sensor of the hot-wheels and the running of the hot-wheels. Activator that functions to move the car to get to Speed Checker and pass the speed sensor. This drive is equipped with a potentiometer to set the desired speed. Speed hecker walls can be replaced with various materials such as acrylic, rubber, iron and other metals.

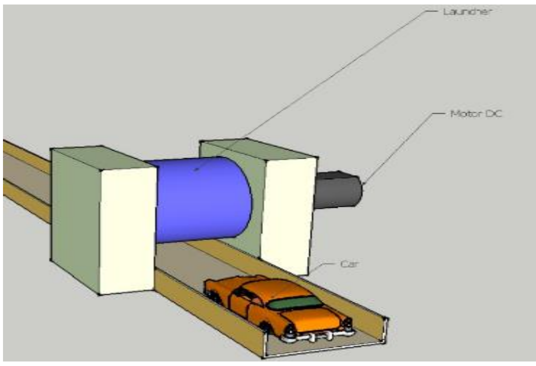


**Fig. 3.** Launcher

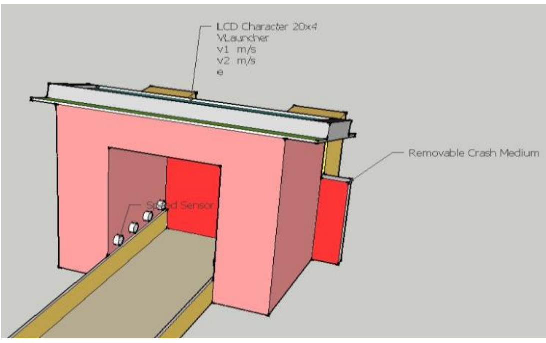


**Fig. 4.** Speed Sensor

After being crushed by hot-wheels, the speed checker can display speed data before the collision, the speed after the collision and the coefficient of restitution. By knowing speed data both before and after the collision and the coefficient of restitution, it is expected that students will be able to analyze the collision event and the impact of the collision.

### 2.2 Analytical thinking skills

Based on the literature review [3-16], in this study, researchers formulated ATS indicators in Table 1.

**Table 1.** Indicators of ATS

| ATS | Science Process Skills |
|---|---|
| Distinguish | Plan an experiment; Measure Classifying; Apply the concept; Communicating results |
| Organize | Make a graph; Predict |
| Connect | Interpret; Apply the concept. |

## 3 Method of Research

This research is a kind of R & D research that uses a pre-experimental design with one group pretest-posttest study [17]. Sample of this research is students in SMAN 1 Kebomas (i.e State Senior High School in Indonesia) with purposive sampling. This research is emphasized on the analysis of the effectiveness interactive microcontroller-based speed sensors by analyzing the increase of students' ATS before and after following the process of impulse and momentum learning. The research began by giving the ATS pretest (O1) by using the ATS test of students, then providing physics learning (i.e. impulse and momentum learning) with assisted interactive microcontroller-based speed sensors. Finally, after the entire impulse and momentum learning process has been completed, students are awarded a posttest (O2) of the ATS with the same materials and problems as in the pretest. The ATS test was reliable and valid.

In order to analyze the effectiveness interactive microcontroller-based speed sensors, an "effective" operational definition is required. The interactive microcontroller-based speed sensors are said to be effective if:

1. There is a significant increase of ATS of students at $\alpha = 5\%$
2. The average N-gain at least in moderate category.
3. Students' responses are at least positive. In order to get increasing level of students' ATS score, the calculation was done by using N-gain [18].

## 4 Results & Discussion

The rating of two validators of speed sensors with very valid values was used in the study with a reliability of 98.20%. In addition to the assessment of the two validators, this speed sensor was also validated by calibrating using a photogate phasco Interface

750. This calibration activity was carried out in the Mechanics laboratory at the physics department of the Faculty of Mathematics and Natural Sciences, Surabaya State University, Indonesia.

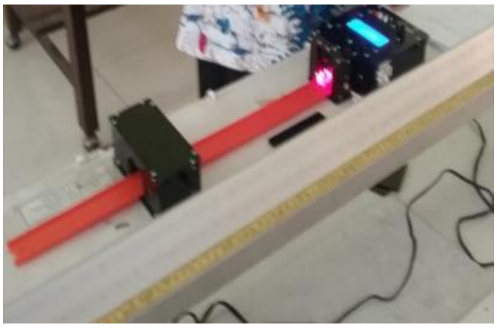

**Fig. 5.** Setting of Speed Sensor

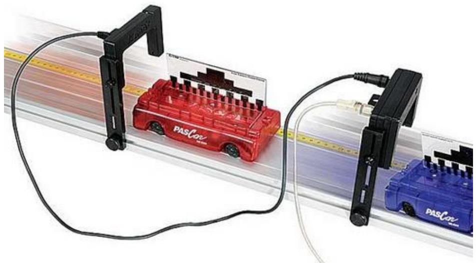

**Fig. 6.** Photo Gate Phasco Interface 750

The calibration results with Photo Gate Phasco Interface 750 obtained the accuracy of the speed sensor reached 99.93%. With the results of the instrument and the calibration results, it can be concluded that this speed sensor is valid for use in research.

**Fig. 7.** Implementation of interactive microcontroller-based speed sensors in impulse and momentum learning to improve students' ATS.

The implementation of learning at each stage of learning meets the category very well. The results of the reliability of the instrument learning sheet obtained 100% which means that learning is carried out properly according to the learning implementation plan.

The students' ATS test is carried out before the pretest at the second meeting and after the presentation of the results of the third meeting (posttest). The pretest is done to find out the ability of students before doing the practicum by using a speed sensor.

While the posttest aims to determine changes in students' ATS after the practical process using impact media is accomplished. In this research, statistical test results show that students' ATS data are homogeneous and normally distributed (except posttest score). Therefore, Wilcoxcon test is used to test the students' ATS data. The Wilcoxcon test results of students' ATS are presented in Table 2.

**Table 2.** The Wilcoxcon test results of students' ATS

| | **Pretest-Postest of students' ATS** |
|---|---|
| Z | $-4.790^{a}$ |
| p (2-tailed) | .000 |

Table 2 shows that the result of Wilcoxcon test is significant, because $p < .05$. Therefore, Z counts the negative value, then clearly there is a significant difference at $\alpha = 5\%$ between the pretest score with the students' ATS posttest. For physics learning with microcontroller-based speed sensor show higher posttest score compared to the pretest score, or the mean scores of students' ATS after impulse and momentum learning process with microcontroller-based speed sensors was higher than before. N-gain score of students' ATS is shown in the Figure 8.

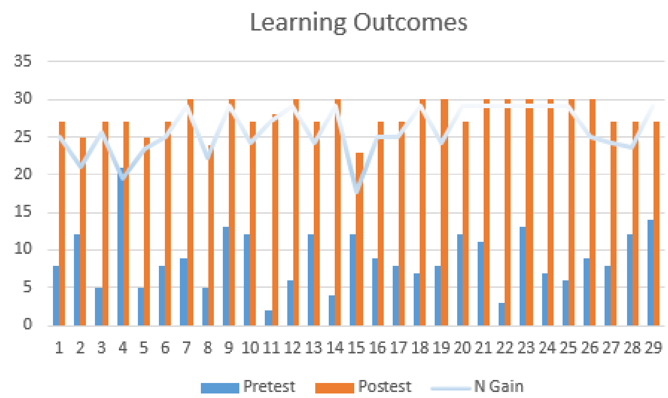


**Fig. 8.** Students' ATS improvement score

The Figure 9 shows that in general students' ATS have improved with the application of speed sensors in impulse and momentum learning. The results of increased ATS of students experienced an increase in N-gain on average by 0.89 with high categories.

Student responses to guided inquiry learning activities were obtained using a questionnaire sheet that was given after the third meeting learning activity was completed. The results of the analysis of student responses to learning by using a speed sensor can be seen in Table 3.

**Table 3.** Student response results to interactive microcontroller-based speed sensors

| **Component Content (Interactive Microcontroller Based Speed Sensors)** | **Student Responses** | |
|---|---|---|
| | ***% Yes*** | ***% No*** |
| Pulling the microcontroller-based speed sensors | 100 | 0 |
| It helps measure speed | 100 | 0 |
| It helps measure the coefficient of restitution | 100 | 0 |
| It helps measure the impulses of objects | 100 | 0 |
| It helps understand impulses = Changes in momentum | 97 | 3 |
| It encourages you to ATS about impulse and momentum | 100 | 0 |
| It motivates to conduct experiments | 97 | 3 |
| It motivates physics learning | 84 | 12 |
| It helps analyze | 100 | 0 |
| Average | 97,6% | 2,4% |

Table 3 show that students' ATS responses after participating in the learning process using a speed sensor with a guided inquiry model 100% of students interested, assisted in the measurement of speed, coefficient of restitution, impulse and momentum. The students feel motivated in learning get 84% and 100% of students agree that speed sensors help analyze collision-related phenomena.

Based on the results and the discussion above shows that interactive microcontroller-based speed sensors have proven to be effective in increasing students' ATS in impulse and momentum learning. The research finding is supported by research results [4,7-8,19-26] which show that media and learning using science, technology, engineering, and mathematics can improve student learning outcomes (i.e. thinking skills).

## 5 Conclusion

Development of interactive microcontroller-based speed sensors to improve students' ATS was valid and feasible to use. The results of the application of the microcontroller-based speed sensors and its devices which are declared valid by a validator and are well calibrated are very effective in terms of the performance using an interactive microcontroller-based speed sensor observed by observers categorized as very good with a percentage of 100% implementation. Learning outcomes in the form of ATS tests. The interactive microcontroller-based speed sensors in impulse and momentum learning to improve students' analytic thinking skills is effective, as indicated by: (a) there was a significant increase in students' ATS at $\alpha = 5\%$; (b) the average N-gain of impulse and momentum learning is categorized as: high (.89); and (c) students' responses in each teaching process were categorized as very positive. The research implication is that interactive microcontroller-based speed sensors can be used as an alternative innovative solution to improve students' ATS.

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