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Kinematics on Handmade Rubber Car using Tracker Experiment Design in Learning Force and Motion

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Abstract

Experimental activity in learning science allows students to develop critical thinking, active learning, creativity, scientific, and collaboration skills. This study aims to create an alternative experimental design for learning force and motion, which analyzes the kinematics aspect of handmade rubber cars using Tracker. The method used is the R&D method with the ADDIE model to develop the experimental design on the material of force and motion for grade 7 junior high school students. The Tracker application was used to evaluate trial data on handmade rubber cars to calculate the acceleration, force, and time needed by the vehicle with varying the number of rubber turned. Then, to evaluate the experimental design, this study used a questionnaire instrument, and the experimental design was implemented in four classrooms of junior high school students in the seventh grade. The results were examined based on the percentage of students who answered each statement. The kinematics analysis of handmade rubber cars using Tracker shows that the more significant the number of turns given to the vehicle, the more acceleration and force decrease. Meanwhile, the car still travels longer when the number of rubbers turned is higher. This happened because the car took longer to reach maximum speed, and the rubber band detaches when more rubber is turned on. Moreover, the experimental activity of making handmade rubber cars using Tracker was well received by students, as seen from the response questionnaire scores, which were categorized as high. This study suggests that further research can implement different independent variables as the experiment design parameters based on this result. Teachers and other researchers can utilize the developed experimental design as an alternative strategy in learning force and motion topics.

Keywords: Experiment, Force, Motion, Rubber car, Tracker

INTRODUCTION

Applying experiments in learning science is essential for students to achieve better competence. With the changes in the Indonesian curriculum to the Merdeka curriculum, the learning process requires teachers' and students' innovation, self-learning, and creativity (Sherly, Dharma, & Sihombing, 2020), which can be highly supported by promoting experiments on the activity. The preferred approach for examining causal links between dependent and independent variables is widely thought to be an experiment (Kranz, Baur, & Möller, 2023). Experimental activity can enhance students' creative thinking (Fauziah, Nuvitalia, & Saptaningrum, 2018), student interest in learning (Adam, Apni, Rosalia, & Aisyah, 2022), students critical thinking (Hajjah, Munawaroh, Yuniasti, Wulandari, & Hidayati, 2022), improving scientific skills (Shofiyah, Fitria, & Wulandari, 2018), and promote collaboration skills (Masruroh & Arif, 2021). However, students still lack an understanding of sciences due to the limitations of the experiment activity in the science learning process (Fitri, 2021). Less practical science skills allow learning to meet the objective (Braaten & Sheth, 2017). Thus, the lack of experiment activity in science learning can lead students to have a low understanding of science

Based on the newest Indonesian curriculum, the Merdeka curriculum, the subjects are divided into six phases, from phase A until phase F. Science subjects are targeted in phase D. There are two main elements: learning science, including science understanding and process skills. There are six inquiry skills that students need based on the Merdeka curriculum, which are: (1) observing; (2) questioning and predicting; (3) planning and investigating; (4) processing and analyzing information and data; (5) evaluating and reflecting; and (6) communicating results. One of the topics in phase D is force and motion. Based on the curriculum, the learning objectives of force and motion topics are: (1) Students can measure the physical aspects they encounter and utilize various motions and forces; and (2) Students understand motion, force, and pressure, including simple planes.

There are still concepts of science that need to be clarified for students, including the topic of force and motion. A Study by Mufit (2019) shows students' misconceptions about force in vertical and circular motion, the resultant force, and the velocity vector, force, and parabolic and straightforward pendulum motion. The suspected factor that causes low understanding of students is that the learning process still needs to be entirely student-centered and a small portion of experimental activities (Mufit, 2019). Most of the experimental activity still uses a piece of manual equipment that has a weakness, including less accurate experimental data (Anshory & Suana, 2015; Diatri, Abdurrahman, & Rosidin, 2014; Solehan, Yunginger,& Payu, 2022). Thus, digital technology equipment can be one of the best alternative tools for conducting experimental activity (Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020).

Despite the many digital tools used for experimental activity, Tracker Video Analysis has been utilized by many studies to analyze kinematics in some instances. Tracker video analysis is free software that can evaluate the kinematic aspects of a movement on the video (Wee, Chew, Goh, Tan, & Lee, 2012). Trackers can determine specific movements' velocity, time travel, position, acceleration, momentum, and kinetic energy. The strength of kinematic analysis using Tracker is that the values deduced from video analysis are consistent with real-world data of gravitational acceleration on the earth's surface (Wee, Chew, Goh, Tan, & Lee 2012). Compared to traditional tools such as using timer stickers in learning physics, Tracker video analysis has proven most kinematic aspects in an inclined plane and free fall motion (Renika, Prima, & Amprasto, 2024).

Tracker has been used as an alternative tool for conducting kinematics practicum during the COVID-19 Pandemic (Tiandho, 2021). Another study utilized Tracker Video Analysis to construct impulse and momentum concepts in the collision model experiment (Utari & Prima, 2019). In the case of high school students, Tracker was used to support the experiments in learning the law of conservation of mechanical energy (Fahrunnisa, Rismawati, Sinaga, & Rusdiana, 2021). The results show that Tracker has been a helpful tool in supporting the experiment process and could help the learning process to achieve the students' indicators in learning the topic understudy (Fahrunnisa et al., 2021). The kinematics analysis in a prolling down object on an inclined plane can also utilize Tracker, which has been proven by the study of Prima, Mawaddah, and Sriwulan (2015). The study shows that Tracker video analysis could satisfy 80% of the students (Prima et al., 2015). Tracker also effectively supported the development of 2D air track tools for one- and two-dimensional motion experiments since it can show various kinematics graphs to deepen the kinematic analysis (Dewi, Wibowo, Sudjito, & Rondonuwu, 2020). Furthermore, Tracker can also accurately analyze the kinematics aspect in assisted toy cars with remote control, resulting in 98.4% and 97.2% accuracy on time and speed while 95.53% and 95.5% accuracy in the acceleration and velocity values (Yolanda, 2023).

However, there still needs to be studies that utilize Tracker in learning force and motion as an alternative tool that students use in experiment activities. Therefore, the novelty of this study is that it uses Tracker to analyze the kinematic aspect of handmade rubber cars. Thus, this study aims to create a handmade rubber car as an experimental activity since it only requires low costs in learning force and motion topics by utilizing Tracker to evaluate the kinematic aspects. This study also aims to analyze the relationship between the number of rubber turned and the force as well as the acceleration resulting based on Newton's second law from the handmade rubber car.

METHOD

This study used the R&D method with the ADDIE model, which consists of the stages of analysis, Design, Development, Implementation, and Evaluation (Azari, Wilujeng, & Nurohman, 2023; Branch, 2010). ADDIE is a creative process that adapts ideas and theories to particular situations. The flow of research design is based on

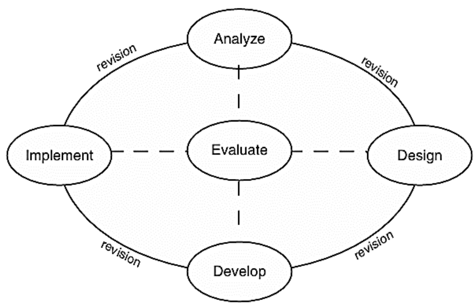


Figure 1. ADDIE model research

(Branch, 2010), which is shown in Figure 1. In detail, the experimental design development is discussed as follows:

Analyze

The analysis stage identifies a problem in the science learning process (Kamaliya, Fibonacci, & Azizati, 2020). The analysis phase is done by doing a literature review of relevant studies. Then, this study identified that students need help learning force and motion topics due to the limitations of their experimental activities (Mufit, 2019). This study also found that Tracker video analysis has been effectively used as an alternative tool for learning various topics in science. Thus, this study tries to develop an alternative experimental design by utilizing Tracker video analysis in learning force and motion. This study's experimental design is an analysis of the kinematics aspect, and the relationship between the number of rubber turns given to the car with the force and acceleration resulting in a handmade rubber car.

This study also analyzes the principle applied in handmade rubber cars during this stage. A handmade rubber car using the Tracker experiment was developed based on the principle of linear motion, Newton's Law, and Hooke's Law. The experiment will primarily relate to Newton's I and II laws. Newton's first law of motion stated that *until an external force causes an object to change shape, the object will always remain at rest or move uniformly in a straight line.* The tendency of an object to resist any attempt to change its velocity is called the inertia of the object (Halliday, Resnick, & Walker, 2013). Meanwhile, Newton's II law states that *the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass*. The relation between force, acceleration, and mass is also shown by the following mathematical statement of Newton's second law:

$$\sum F = ma$$

The handmade rubber car will also move on a straight surface which will follow several principles in linear motion which will be related to:

(1) Distance (Δs)
(2) Displacement ($\Delta\vec{r}$)
(3) Speed (U)

$$U = \frac{\Delta s}{\Delta t}$$

(4) Velocity ($\vec{v}$)

$$\vec{v} = \frac{\Delta\vec{r}}{\Delta t}$$

(5) Acceleration ($\vec{a}$)

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

There are several equations will apply to the calculation of the motion, including

(1) First equation

$$v = u + at$$

Where u is an initial speed

(2) Second equation

$$s = \frac{(u + v)}{2}\, t$$

(3) Third equation

$$s = ut + \frac{1}{2}\, at^2$$

(4) Fourth equation

$$v^2 = u^2 + 2as$$

Since handmade cars use rubber, Hooke's principle will also apply to them. Hooke's law explains that *the extension of an elastic object or a spring is proportional to the stretching force* (Duncan & Kennett, 2014). It can be expressed in the mathematical equation:

$$k = \frac{-F}{\Delta x}$$

$$F = -k\Delta x$$

Design

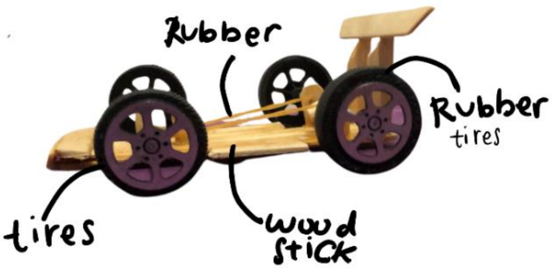


Figure 2. Car design from the side

The design phase consisted of creating the product design that would be developed (Branch, 2010). During this stage, this study formulated the materials and equipment needed to make a handmade rubber car, the experimental parameters or variables, the experimental procedure, and the vehicle's design. The materials and equipment used in the experiment are shown in Table 1.

Table 1. Experiment Materials and Equipment

Materials	Equipment
Wood stick	Vernier caliper
Tires	Camera
Rubber bands and rubber wheel	Tripod
Chopstick	Stand and clamp
Glue	Laptop device
Yarn	Ruler
Mass	Digital balance
Hanging slotted mass	

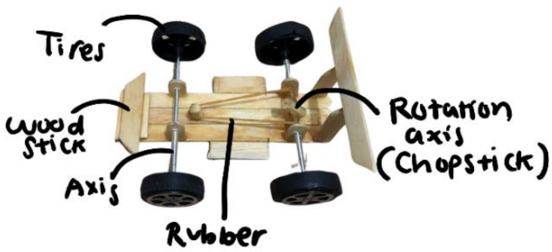


Figure 3. Car design from the upper side

This study used video analysis, using the newest version of Tracker video analysis, Tracker 6.1.5 (Oct 2023), for Windows to evaluate the kinematics of handmade rubber cars. The software was accessed at physlets.org/tracker/.

This experiment consists of three variables: independent, dependent, and controlled. Table 2 describes the detailed variables.

Table 2. Experiment Parameter

Parameter	Details
Independent	Number of rubbers turned (1 until 4 turns)
Dependent	The acceleration and force resulted.
Control	Mass of the car, materials of the vehicle and tires, diameter of the tires, rubber thickness, the track surface

Based on prior literacy, this study first hypothesized that the more the turn given to the car, the bigger the force given to the vehicle, and the higher acceleration resulted. However, the natural phenomena and trends will be further proven and explained after experimenting.

Figures 2 and 3 show the car's design from the side and upper side, including the details of

Making the main body handmade rubber car

↓

Add the attachment wood for the rubber in the centre of main body and the centre of back axis's tires

↓

Determine the factor influencing the rubber (mass of car, diameter of rubber, diameter of axis, diameter of tires, distance travel by one turn of tire)

↓

Calculate the distance travel by one turn of rubber

↓

Hang the rubber with different load starting from 10 grams until 100 grams

↓

Note the length of rubber extension and input the data to Excel

↓

Determine the *k* from linear equation resulted

↓

Set the layout video

↓

Move the car with different amount of rubber turned starting from 1-4

↓

Record the car using camera then input the video into Tracker

Figure 4. The flowchart of the experimental procedure

materials. The car itself should consist of the rotation axis with the wood to attach the rubber, including the wood to attach the rubber to the body. The detailed procedure is shown in Figure 4, which tabulates the flowchart of the procedure.

After making the handmade rubber car, it is necessary to determine the factors influencing the car to calculate the distance traveled by one turn of a rubber. Figure 5 (a) shows the diagram of factors influencing the car. Further analysis of the tires is needed to formulate the equation. First is the analysis of the tires, which are:

$$1\,rod = \frac{s}{R} = 1$$

$$S = r$$

Then from Figure 4 (b), it shows that the first and second angles will be equal, so:

$$\emptyset_1 = \emptyset_2$$

$$\frac{s_1}{r_1} = \frac{s_2}{r_2}$$

$$s_2 = \frac{r_2}{r_1}\, x\, s_1$$

The radius of the axis itself can be calculated from its diameter over two plus the rubber thickness over two, which the mathematical equation can express:

$$r_2 = \frac{d_2}{2} + \frac{rubber\ thickness}{2}$$

To calculate the distance traveled by one turn of rubber, the mathematical equation will be:

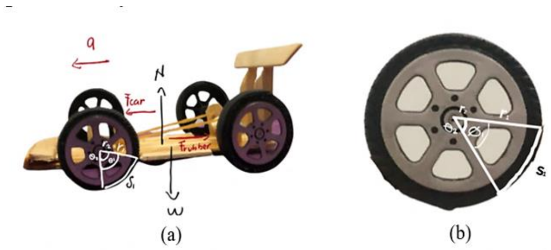


Figure 5. (a) diagram factor influences the car; (b) the detail of t

$$s_2 = \frac{\frac{d_2}{2} + \frac{Rthickness}{2}}{\frac{d_1}{2}}\, x\, s_1$$

$$s_2 = \frac{\frac{1}{2}\,(d_2 + Rthickness)}{\frac{1}{2}\,(d_1)}\, x\, s_1$$

$$s_2 = \frac{d_2 + Rthickness}{d_1}\, x\, s_1$$

Where s_1 is the distance of one turn of tires, s_2 is the distance traveled by one turn of rubber, r_1 is the radius of tires, and r_2 is the radius of the axis.

Besides analyzing every factor that can influence the car, another aspect that needs to be calculated is the spring constant from the rubber used. The calculation of the force constant of the rubber will be evaluated from the graph results. The force constant will be reviewed by hanging the rubber with ten masses, starting from 10 to 100 grams. Then, after calculating all the requirements needed, the car continues to be used based on four turns, which are 1 turn, 2 turns, 3 turns, and 4 turns. When the car moves, the motion will be recorded was analyzed using Tracker Video Analysis.

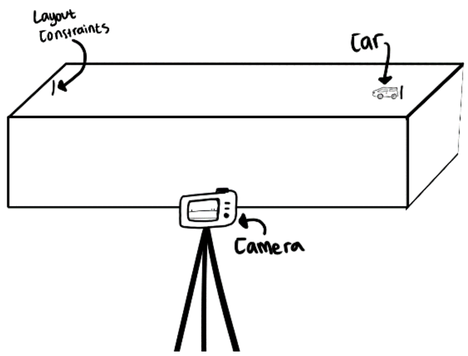


Figure 6. An experimental setting illustration

Figure 6 shows the schematic experimental setting or procedure. After recording the car's motion for each turn, the video will be exported to Tracker and analyzed using an automatic track. However, before doing the automatic track, it is necessary to calibrate the video to make sure that the distance for the layout video should be determined when recording the video. The result of the automatic track from Tracker will consist of evaluating the time for each movement, the distance traveled by the car concerning time, and the car's velocity concerning time. All the data from Tracker will be further analyzed in Excel to compose time-distance and time-velocity graphs. The equation of acceleration and deceleration will be produced from the time-velocity graph. Thus, the acceleration and the force from each car turn can be evaluated. However, the maximum velocity and the time the rubber detached must be determined to have a deep analysis.

Develop

The development stage was consisting the process of generating and validating the product that will be developed (Branch, 2010). This research develops the experimental design for analyzing the kinematics of handmade rubber cars. The handmade rubber car and its experimental worksheet have been validated by three experts: one professor in science education and two experts with doctoral degrees. The experts test the vehicle and discuss several suggestions with the researcher, whether related to the product or the experimental procedure shown in the worksheet.

Implementation

The implementation stage is done to test the appropriateness and evaluate the experimental design that has been created. The subject in the implementation stage is four classes of 7th grade in one of the private Junior High schools in Bandung. The total subjects are 81 students with 16 groups. Techniques for gathering data are implemented through the questionnaire approach. The questionnaire form used in this study is adapted from (Liana, Prima, & Sinaga, 2023), consisting of 17 statements. The statements are divided into 4 categories, which are (1) practicum significance, (2) learning motivation, (3) practicum usefulness, and (4) product creation skills (Kurnia & Daningsih, 2021). The statement that best fits the student's experience can be chosen. Each statement has four options: Strongly Agree, Agree, Disagree, and Strongly Disagree. The responses vary from positive to negative. Student responses were analyzed using a Likert scale. The response questionnaire rating scale is shown in Table 3.

Table 3. The rating scale for response

Positive Statements		Negative Statements	
Strongly Agree	= 4	Strongly Agree	= 1
Agree	= 3	Agree	= 2
Disagree	= 2	Disagree	= 3
Strongly Disagree	= 1	Strongly Disagree	= 4

Percentage of each instrument item numbers obtained by the formula:

$$\frac{Total\ Score\ of\ Students'Answers}{ideal\ score}\ x\ 100\%$$

The percentage of students will be categorized based on Riduwan (2016), as shown in Table 4.

Table 4. Students' response categorization

Percentage (%)	Category
80 – 100	Very High
60 – 79	High
40 – 59	Enough
20 – 39	Low

Evaluation

The evaluation stage aimed to revise the experimental design based on the experts' suggestions and the implementation's analysis. From this stage, it can be seen whether or not the experimental design has been successfully developed.

RESULT AND DISCUSSION

Force Constant of the Rubber

Table 5 shows the rubber's extension for each mass given. The unit is converted from gram to kilogram, and the extension unit is on the meter to follow the standard unit. The data is transformed into a graph to get the linear equation and the accurate result of constant force. Figure 7 shows the graph of the extension distance-force result and the linear equation.

Table 5. The result of rubber extension

Mass (Kg)	F (N) (m x g)	x (m)
0.01	0.1	0.002
0.02	0.2	0.007
0.03	0.3	0.010
0.04	0.4	0.013
0.05	0.5	0.014
0.06	0.6	0.020
0.07	0.7	0.028
0.08	0.8	0.033
0.09	0.9	0.038
0.1	1	0.048

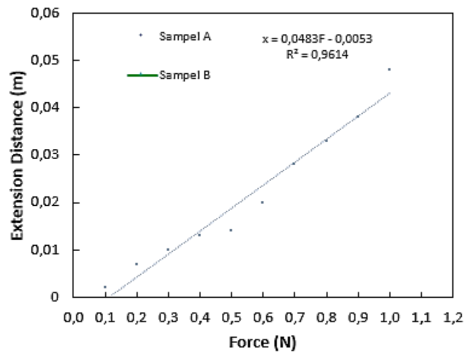


Figure 7. Linear equation resulted

From the linear equation result, as is shown in Figure 7, the calculation of force constant becomes:

X= 0.0483 F – 0.0053

$$k = \frac{1}{0.0483}$$

k = 20.7 N/m

Thus, the force constant value from the rubber used on the car is 20.7 N/m.

Distance Travelled by One Turn of Rubber

To calculate the distance traveled by one turn of rubber, the mass, tire's diameter, axis diameter, rubber thickness, and the distance of one turn of the tire must be determined. The results of each measurement are shown in Table 6.

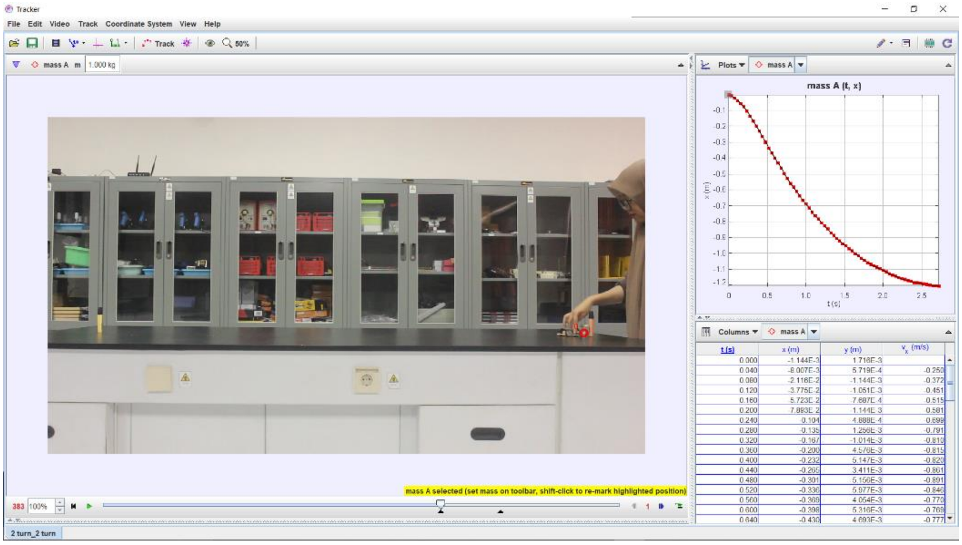


Figure 8. Analysis on Tracker Video Analysis

Table 6. Measurement result

Measurement	Result
Mass of the car	22.7 gram
Tire diameter	32.02 mm
Axis diameter	1.38 mm
Rubber thickness	0.83 mm
Distance traveled by one turn of the tire	103 mm

Based on the data in Table 5, the distance traveled by one turn of rubber can be calculated by adding the axis diameter and rubber thickness and multiplying it by the distance traveled by one turn of the tire. After that, the final calculation divides the result by the tire diameter, showing that the distance traveled by one rubber turn is 7.11 mm. This calculation was done based on the same θ that the axis rod and the tire have because it was on the same axis; the illustration is shown in Figure 4.

Time and Distance

After calculating the force constant of the rubber and the distance traveled by one rubber turn, the car is ready to be used by applying different turns starting from one to four. The rubber on the vehicle is only rotated four times because the width of the car's main body is not wide enough. Therefore, the calculations for the car's main body must be paid more attention to. Each turn's kinematic result should be recorded using a high-quality camera to support the video analysis on Tracker. Then, the video will be analyzed on Tracker, as shown in Figure 8.

Figure 9 shows the time-distance graph for each turn given to the car. The relation between time and distance travel results in a quadratic equation that allows the identification of the vehicle's final position for each turn. The result shows that as the turn given to the vehicle

Table 7. Linear equation of acceleration and deceleration and the quadratic equation of position

Settings	Acceleration	Deceleration	Position
1 Turn	$a = 1.7243t + 0.0441$	$v = -0.3667t + 0.7319$	$y = -0.1422t^2 + 0.6264x - 0.0653$
2 Turns	$a = 1.6600t + 0.2059$	$v = -0.3712t + 0.9963$	$y = -0.1705t^2 + 0.9379x - 0.0847$
3 Turns	$a = 1.6414t + 0.3162$	$v = -0.4198t + 1.1799$	$y = -0.1966t^2 + 1.1274x - 0.095$
4 Turns	$a = 1.6062t + 0.423$	$v = -0.4244t + 1.3031$	$y = -0.2086t^2 + 1.2776x - 0.1092$

Table 8. Student's response to the experimental activity

No	Sub Variable	Percentage of student response (%)	Category
1	Practicum significance	69.14	High
2	Learning Motivation	72.84	High
3	Practical usefulness	69.63	High
4	Product creation skills	74.90	High
	Average	71.63	High

increases, so does the time. Moreover, the distance also increases. This is in line with one of the principles of motion on speed:

$$U = \frac{\Delta s}{\Delta t}$$

which explained that the distance traveled is directly proportional to the time traveled by the car. These results align with a study done by (Vankó, 2005) in the case of a pullback car; as the vehicle experiences a higher pullback distance, the higher the distance traveled by the car.

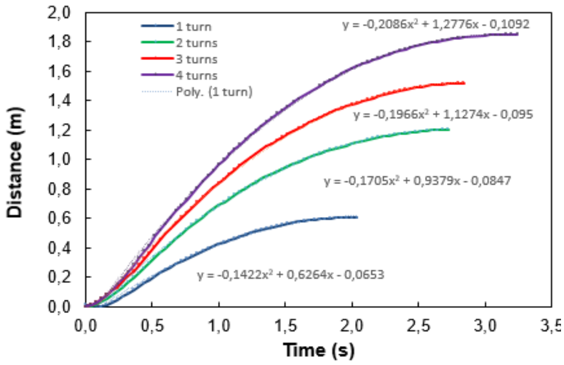


Figure 9. Time and distance graph

Velocity and Time

Figure 10 presents the car's velocity on each turn concerning the time. The vehicle first experiences acceleration until it reaches the maximum velocity at a particular time. After reaching the maximum velocity, the vehicle starts to experience deceleration until the vehicle stops. The car applied the same principle as the pullback car, where the energy is stored in the spring so when the vehicle is released, the stored energy will transform into kinetic energy (Bertoncelj & Blagotinšek, 2001; Boland, 2021). The acceleration measurement and analysis cannot be directly measured. Numerical differentiation can determine acceleration and deceleration from the velocity versus time graph (Vankó, 2005). In this The study's

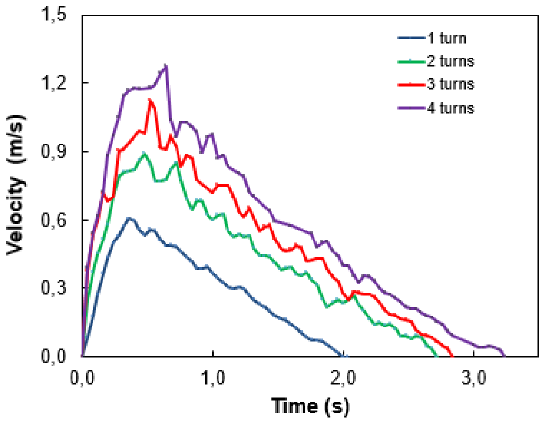


Figure 10. Velocity and time graph

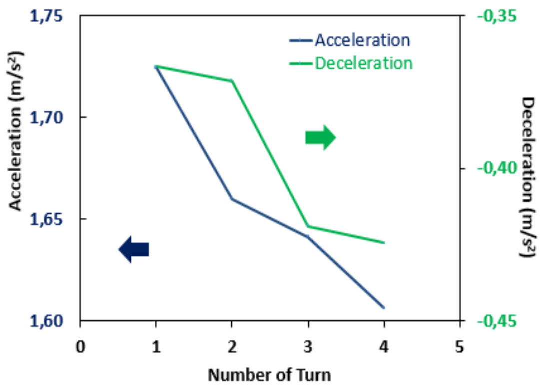


Figure 11. Deceleration and acceleration on each turn

acceleration and deceleration, presented in Figure 10, show that the more turns given to the car, the more the acceleration value decreases. On the other hand, the car's deceleration gets lower as the number of turns given to the car increases. The linear equation resulting from each turn can identify the value of acceleration and deceleration. Table 7 shows the overall linear equation of acceleration and deceleration and the quadratic position equation from each turn given to the car.

Figure 11 and Table 7 show the car's deceleration on four rubber turnsturns. The negative sign on the result means that the vehicle is slowing down. The deceleration value is increased; however, since the sign is negative, the deceleration value is smaller. This happened because more rubber turns were given to the car, so the force given to the car lasted longer. Thus, the more turns were given to the vehicle, the smaller the car's deceleration value. This means the car will take longer to stop as the number of turns given to the vehicle increases.

The car's acceleration decreases as more turns are given to the car. Based on the results, this study is against the proposed hypothesis, which states that as the number of turns given to the car increases, the acceleration and force of the car increase. However, these results align with a study on pullback cars by Vankó (2005), which shows that the car's acceleration decreases as the pullback distance increases. To analyze the reason behind the phenomena occurring in the acceleration results, the time of maximum velocity and the time of rubber detached are determined. As shown in Figure 13 (a) and Table 8, the time the car takes to reach maximum velocity increases as the number of turns increases. The same patterns also occur when the rubber is detached from the car. Moreover, the time of maximum velocity is always shorter than the time the rubber detached. Since the car still travels longer but has a lower acceleration when a more significant number of turns are given, as shown in Figure 13 (a), the leading cause of the phenomena is related to the rubber duration.

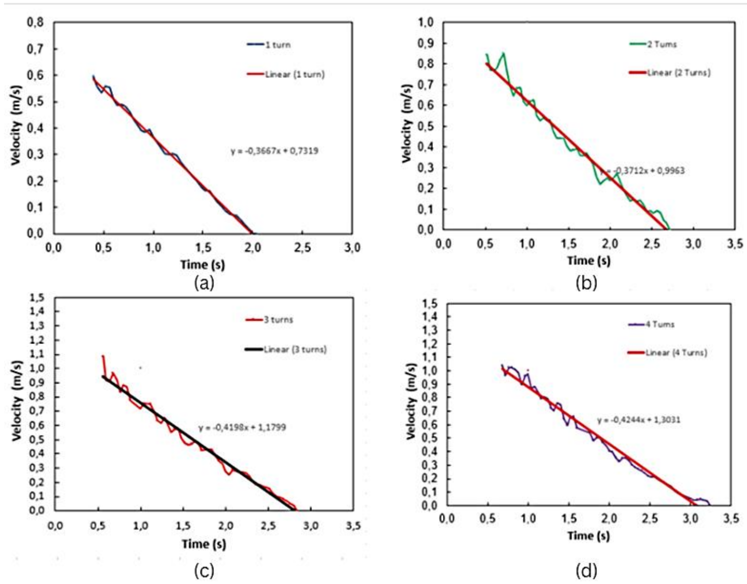
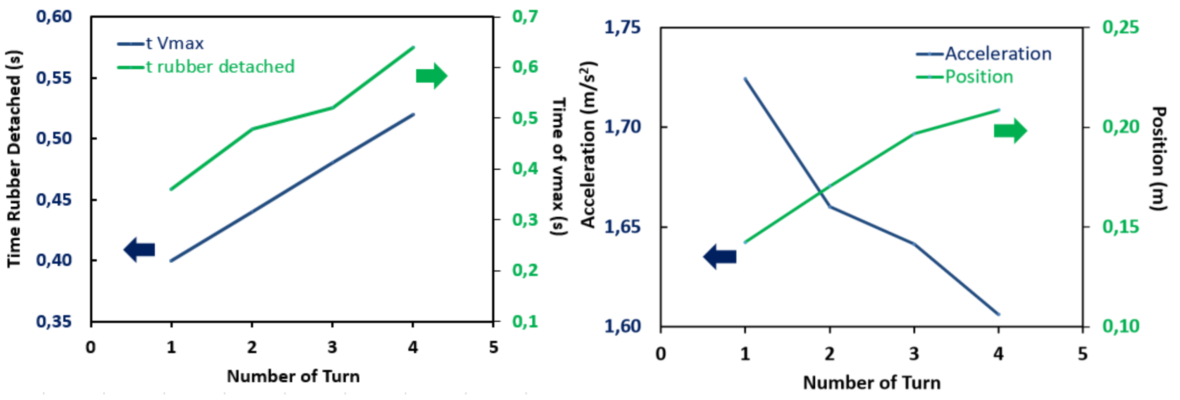


Figure 12. (a) one turn; (b) two turns; (c) three turns; and (d) four turns



(a) (b)

Figure 13. (a) Time of v_{max} and time rubber detached respect to the number of turns; & (b) acceleration and position respect to the number of turns

attached to the car. As it takes longer for the rubber to detach when the turn is four, so the car will have more extended distance travel and more extended time travel with lower deceleration. When the number of rubbers turned given to the car is higher, even if the force value is lower, the force acting on the car will tend to be longer since the rubber takes longer to detach from the vehicle.

In a handmade rubber car, the car is powered by the rubber band, which provides the

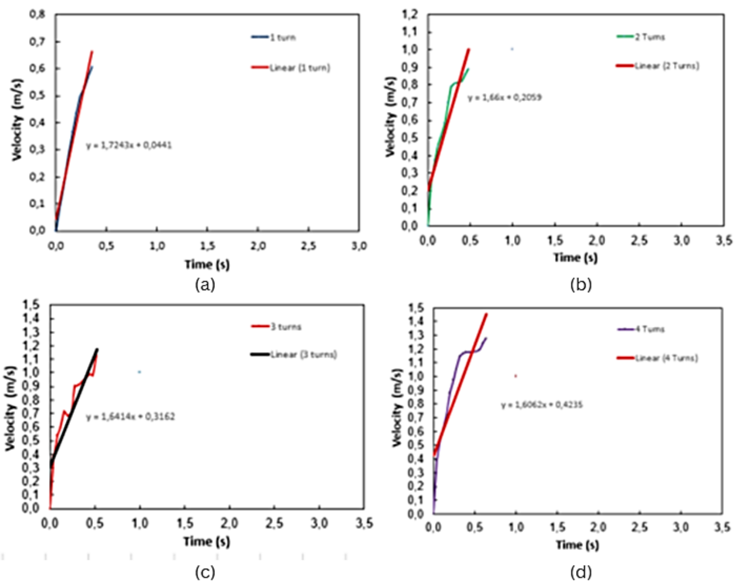


Figure 14. Acceleration in (a) one turn, (b) two turns, (c) three turns, and (d) four turns

Figure 15. Experiment implementation

force as the elastic potential energy stored in the rubber band when it is wound up. The potential energy is converted to kinetic energy as the car is propelled forward (Feinberg, 2011). The more rubber is turned, the longer potential energy acts on the vehicle. Consequently, the force acting on the vehicle will also work longer as the number of rubber turns increases. However, the force of the rubber band is not constant. As the rubber unwinds, it loses potential energy and becomes less stretched, so the force decreases as the car moves. The car eventually stops when the rubber band is fully unwound, and the force becomes zero. When the rubber detaches, the speed remains constant, I was following the law of inertia.

Moreover, this study successfully analyzed the kinematics aspects, including acceleration, deceleration, force, position, and time, from the handmade rubber car using Tracker Video Analysis. Based on the result, the accuracy and the precision of the calculation and measurement are relatively good since the result shows a consistent result when the car has received a different number of rubber turned. However, to enhance and support the accuracy and precision of the measurement, the camera should be of high quality to record the car's motion.

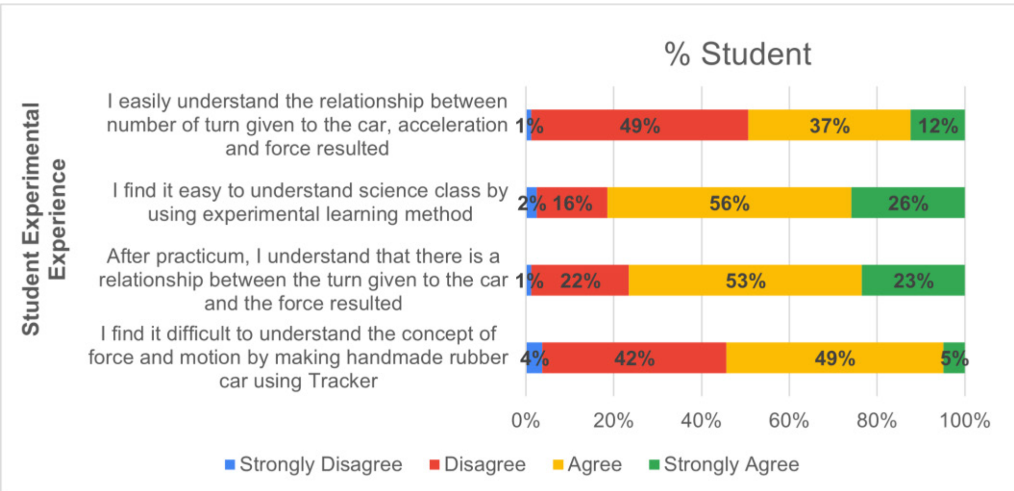


Figure 16. Students' responses about the significance of practicum

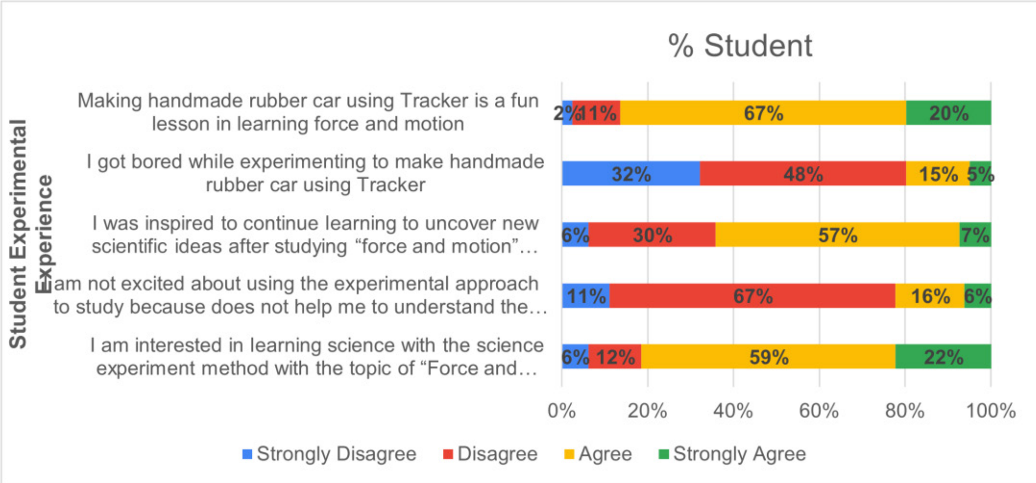


Figure 17. Students' responses about the learning motivation

Student response to the experiment design

The experimental design of a handmade rubber car using Tracking has been implemented in four seventh-grade classes, each divided into four groups. A total of 81 students filled out a questionnaire, and 81 students completed it after the trial. The four sub-variables from the student response questionnaire were expanded into seventeen modified statements. A high category was identified based on examining student responses to a questionnaire regarding the experimental design of building a handmade rubber car utilizing Tracker, which yielded an overall average percentage of 71.63%. This happened because, during the learning implementation, the students tended to participate actively and enjoy the experiment process. Students also felt challenged by the project given to create and analyze the handmade rubber car that had been made. So that even if they encounter difficulties, they can overcome them well. The time given to students is long, so students can improve and analyze the results without rushing. Table 9 demonstrates that the practicum has met four sub-variables: practicum significance, learning motivation, and practicum. usefulness, and product creation skills.

There were 69.14% of students responded favorably to the practicum's significance, placing

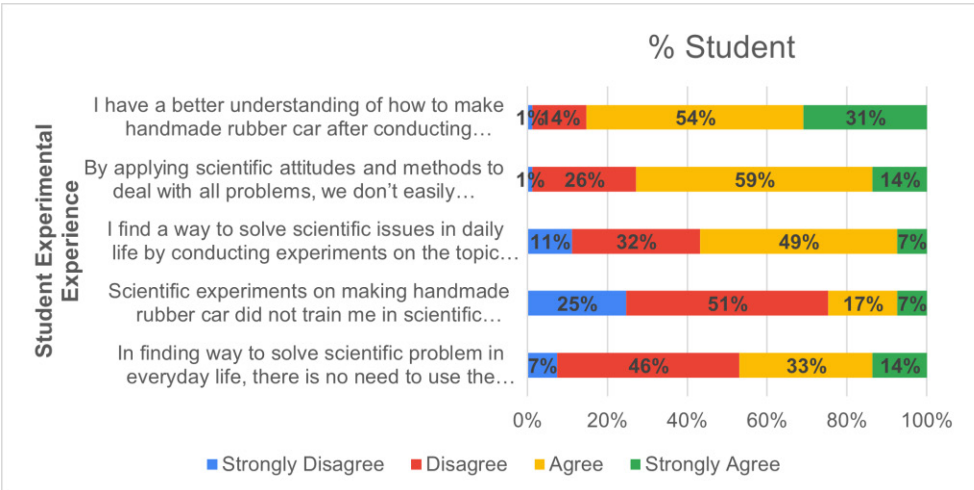


Figure 18. Students' responses about practical usefulness

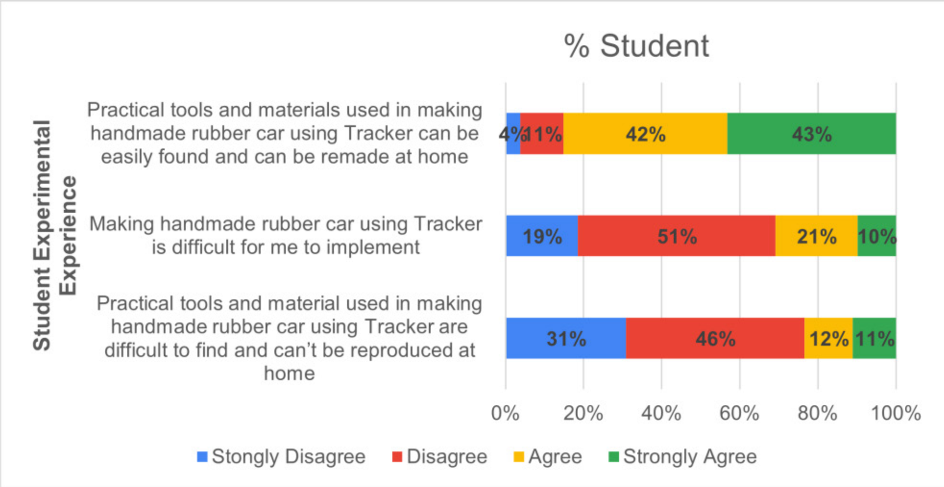


Figure 19. Students' responses about product creation skills

them in the high group. This suggests that the students' experimental activity, which involved building a handmade rubber car using a tracker, simplified the concept of force and motion and gave the lecture a deeper meaning. Figure 16 displays the specifics of the statements made by the students regarding the importance of the practicum. Students' learning activity is improved, and their process skills are strengthened by direct experience gained through practicum. This helps students grasp concepts or materials with a lengthy shelf life (Jumarni, Jalmo, & Yolida, 2014). By applying what they have, students can attain learning success by using experimental methods and developing a scientific mindset that supports their process of acquiring knowledge (scientific product). They can also attain learning success by doing and experiencing what they have learned for themselves (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2020).

The second sub-variable is learning motivation. The average response of students in learning motivation is 72.84%, which is categorized as a high category. This demonstrates how the hands-on, experimental activity of building a handmade rubber car with a tracker may encourage and excite children to learn new things and uncover ideas that have real-world applications. Students' motivation is a psychosocial factor that propels them to design educational activities. Students motivated to learn are prodded to engage in activities intended to modify their behavior due to their enhanced cognitive, emotional, and psychomotor skills due to pertinent learning experiences. Pupils show themselves by actively participating in their education (Bahriah & Abadi, 2016). Figure 17 displays the statements made by students regarding their motivation to learn.

The third sub-variables analyze the students' opinions about the usefulness of the practicum. This study shows that the sub-average variables' percentage is 69.63%, categorized as a high category. This suggests that the tracker-based experimentation on creating a handmade rubber car is evident, especially when grasping the idea of force and motion. Students who apply the scientific method also show an increased concern for the environment. When utilized effectively, media may greatly simplify and captivate students' learning tasks, raising their motivation to comprehend the material (Primasari et al., 2015). Figure 18 displays the statements made by students regarding the practicum's value.

The last sub-variables analyze the students' response towards product creation skills. The average percentage is 74.90% in the high category. It suggests that utilizing Tracker to create a handmade rubber car experiment will help students become more adept at applying the concepts of force and motion in everyday situations. A benefit of the practicum is that it allows students to draw new conclusions from their investigations and enhances their ability to conduct creative and innovative experiments. It also inspires and motivates learning science subjects, particularly regarding substances and their changes (Zahara, Datta, Boonkorkaew, & Mishra, 2017). Figure 19 displays the student responses statement regarding their product creation skills.

Overall, the student's response to the experimental activity of making a handmade rubber car using Tracker is included in the high category. This demonstrates how well kids respond to the practice. The student's answers to each question in the sub-variable demonstrate this, showing how effectively the practicum is applied to the subject of substances and their variations. In addition, utilizing a tracker to create a handmade rubber car helps increase kids' awareness of how force and motion are applied in their environment. However, when implementing, the students need careful guidance, mainly when doing experiments and analyzing data, to prevent students' misconceptions.

CONCLUSION

The Kinematics aspects of handmade rubber cars have been successfully analyzed by utilizing Tracker Video Analysis—however, the results were obtained against the initial proposed hypothesis. The results show that the acceleration and force decrease as more turns are given to the car. Meanwhile, the car still travels longer when the number of rubbers turned is higher. This happened because the car took longer to reach maximum speed, and the rubber band detached when more turns of rubber were given to the car. Moreover, based on the analysis, this study has explained the relation between the number of turns given to the car and the acceleration and force, which relates to Newton's second law concept. Using the Tracker Video Analysis, the kinematics aspect of the handmade rubber car was analyzed accurately and precisely, as seen in the graph and the data shown in the discussion. The accuracy and the precision of the calculation and measurement are relatively good since they show a consistent result when the car has received a different number of rubber turned. The experimental activity of making a handmade rubber car using Tracker was well received by students, as seen from the response questionnaire scores, which averaged 71.63% in the high category. Thus, the students and teacher can implement the experimental design in this study in learning force and motion topics. To have an accurate result, several things need to be addressed, including the quality of the camera used in recording the experiment should be high quality, the guidance to the students when doing the experiments, analyzing data, and making the car extra to prevent misconception as well as to get good results, and the materials used and calculation in making the car should be considered. Future studies can apply different independent variables such as mass, using the frictional surface and moving the car on a sloping surface.

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