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(Projectile Motion) Props Assisted by Tracker Video Analysis to Increase Students' Interest in Learning Parabolic Motion Material

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Abstract. Learning physics is considered difficult and unpleasant for students. This is a challenge for educators to develop an interesting lesson for students. The non-virtual practicum can be one of the media that can attract students' attention. Many physics materials require practicum to support students' understanding. Therefore, the authors developed a Promot (Projectile Motion) teaching aid assisted by a video analysis tracker software to increase student interest in parabolic motion material. The type of research used is ADDIE development research. This development has 5 stages, namely Analyze, Design, Development, Implementation, and Evaluation. Based on these stages the author has succeeded in making Promot props that are suitable for use because the data generated is by the theory of parabolic motion material. Through these teaching aids, the author has also created a mini manual that contains practicum guidelines, how to use the video analysis tracker software, and how to analyze data. Through the g-form questionnaire which contains a video about Promot props, it can be seen that this teaching aid can be applied to learning physics on parabolic motion material. In addition, the application of this teaching aid has an impact on increasing student learning interest in parabolic motion material.

1. Introduction

Physics is one branch of science (Natural Science) that develops through scientific methods such as observation, problem discovery, hypothesis preparation, experimental implementation, conclusion drawing, and concept discovery (melde). Physics is a science that studies objects and phenomena related to these objects where to describe the state of an object or a phenomenon that occurs in objects, various physical quantities are defined [1]. Physics also requires understanding complex concepts to be able to understand matter and content in physics. Physics, in school learning, is often considered a difficult and unpleasant subject for students [2]. This is the challenge for physics educators in schools to be able to bring physics lessons to be interesting. According to Hoelwartt, 2015, classroom learning emphasizes mastery of concepts rather than students' physics problem-solving abilities [3]. The process of learning physics can be done and made as interesting as possible so it will cause a situation where the student will become interested in studying physics. An interest in learning is very important in making physics an easy and fun lesson. Interest is a concentration that contains elements of feelings, pleasure, involuntary inclinations of the heart, and involuntary desires that are active in nature to receive something from outside (the environment) [4]. Learning interest also affects learning achievement where if the learning material is not to student interests, students will not learn well. The increase in student interest in learning can be seen through the indicators, in Hendriana's opinion the indicators of interest in learning are 1) feelings of pleasure, 2) interest in learning, 3) showing attention while learning, 4) involvement in learning [5].

The material in physics lessons is very diverse, for example, parabolic motion material. The motion of a bullet is a motion that forms a certain angle concerning the horizontal plane [6]. Two-dimensional motion that combines two axes, namely the horizontal axis (x-axis) and the vertical axis (y-axis) is the definition of parabolic motion. The parabolic motion requires complex understanding to be able to understand it. Students often consider one part of this straight-motion mechanics to be complex material. Parabolic motion is a combination of regular straight motion (GLB) and regular changing straight motion (GLBB). The contextual application of parabolic motion in the daily life of these students is quite a lot, for example, movements in playing basketball, movements in *golf*, and the movement of bullets fired from cannons. The assumption that is widely used in parabolic motion is that air friction is ignored even though in reality air friction plays a role in reducing the motion energy of objects which will eventually reduce the size of the projectile trajectory [7]. The principle of parabolic motion applies to the motion of objects if: the earth is homogeneous, the height of the object is fixed, the air pressure is small or the object moves slowly, and occurs at the north pole or south pole [8]. This contextual application in everyday life can be used by teachers in arousing students' interest in learning physics. In addition, teachers can also invite students to practicum parabolic motion material to attract students' interest in learning. Practicum activities invite students to explore the meaning of the physical concept of parabolic motion itself.

Practicum learning requires tools to support the learning outcomes to be achieved, for example, the concept of parabolic motion. Practicum activities in today's digital era can be carried out using technology, for example, parabolic motion practicum can be done virtually using the Phet website. This virtual practicum does tend to get more accurate results and less uncertainty and *errors* during practicum activities. However, virtual practicum activities also lack interest from students because students only use devices in carrying out their practicum and lack collaboration with other friends [9]. Non-virtual *practicum activities* using teaching aids are more appropriate in making students collaborate in finding physics concepts, but *non-virtual* teaching aids are found more errors and uncertainties, allowing students to find concept errors.

In this article, the author examines combining digital software-assisted manual props (*Tracker Video Analysis*) in increasing students' learning interest in parabolic motion physics material. According to Wee, 2015 and Brown, 2009 *tracker* is a video analyzer and modeling tool built on open-source physics with Java framework [10]. *Tracker video analysis* allows students to record videos of life events and analyze them easily using this software [11]. Video tracker analysis provides several opportunities to discuss limitations and refine measurements students find, e.g. student B holding the camera in a fixed position and orientation [12]. The author makes props from simple materials such as wood and then takes videos during the process of practicum activities. Videos of practicum activities are processed using *Tracker Video Analysis* to obtain components that cannot be obtained manually using props made such as speed. The results of the experiment using teaching aids assisted by *tracker software* will then be continued by using a response questionnaire to determine students' learning interest in parabolic motion physics material.

2. Method

The type of research used is a type of ADDIE development research *(Analyze, Design, Development, Implementation, Evaluation)*. At the *Analyze* stage, using the article review method so that researchers can find compatibility between physical material and the concept of teaching aids design to be developed. After going to the *Design* stage, the concept of teaching aids designs into the stage of designing sketch drawings which will be consulted with the supervisor of the physics laboratory course for advice. At the *development* stage, the process of preparing the tools and materials needed in developing teaching aids by the design that has been consulted and at this stage also developing a guidebook for the use of teaching aids. The implementation stage is carried out by testing teaching aids independently by researchers which are then documented in videos. The video is used to fill out interest questionnaires through *G-form* by students. The last stage is to evaluate the results of self-trials of the tool with the results of interest questionnaires that have been distributed to student participants. The stages of the ADDIE research scheme can be described as follows

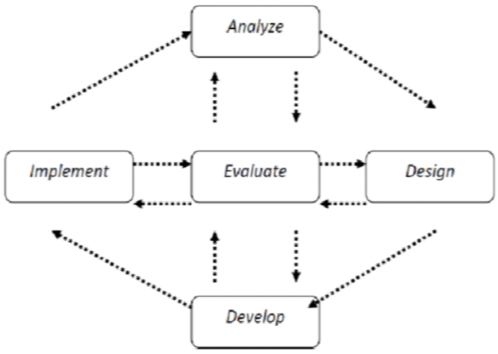

Figure 1. Schematic of the ADDIE stages (Soegiyono, 2011)

3. Result and Discussion

The R&D (Research and Development) research model used by researchers to develop the Promot (Projectile Motion) parabolic motion prop is none other than ADDIE which was listed in the previous section, namely the method. In the first stage, namely the Analyze stage, researchers carried out an analysis by reviewing several national and international journals with the aim of looking for physics material that was difficult and less popular with students due to the lack of appropriate learning media to represent physics concepts. After reviewing several literatures, the researcher chose parabolic motion material as material for developing the media used. In the second stage, namely the Design stage, the researcher designed sketches and basic materials for parabolic motion media in the form of projectile motion props with the aim of making the concept of parabolic motion easy for students to understand. Apart from that, researchers also integrate technology in this Promot teaching aid as a renewal of development. The technology chosen by the researcher is video analysis tracker software. Another reason the researcher used this tracker technology is that the tracker can also project components in the direction of the x-axis and y-axis which are the basis for the motion of the parabola. At the design stage, the researcher also designed a practical tool book. props to make it easier for props users to work. In the third stage, namely the Development stage, the researcher developed sketches of props using wood as the basic material. The development of the structure of the teaching aids also adjusts the variables contained in the practical teaching aids manual, bearing in mind that the media developed by researchers is practical teaching aids media because physics is related to proof-of-concept experiments.

In the fourth stage, namely the Implementation stage, the researcher tried to carry out personal exploration using Promot props that had been developed and took an exploratory video aimed at integrating it with a video tracker to determine the motion components of the parabola. At this stage the researcher also made a video of the activities for developing teaching aids that were used to provide research to high school students and physics education students as prospective physics teachers. This was done in order to find out the response to the teaching aids that had been developed by the researcher. In the final stage, namely the evaluation stage, the researcher distributed a g-form response questionnaire containing a questionnaire and also a video of activities for making Promot teaching aids that integrated video tracker technology to determine the evaluation of the suitability of Promot teaching aids in increasing students' interest in studying physics regarding parabolic motion.

Development of parabolic motion props or *Promot* (*Projectile Motion)* tools, which uses wood-based materials. The reason for the author to design teaching aids using wood-based materials is to make them sturdier when used for practicum and durable. This *Promot* prop requires additional supporting materials such as bolts and nuts to unite the wood parts that have been cut according to the design that has been made. This *Promot* prop has two main parts, namely the ejector and the rail section, the ejector part is a part of the prop that has an important function as an elevation angle regulator as a condition for motion that travels a parabolic trajectory because there is an arc and a lead suction as an object thrower. The second part, namely the rail section is an additional part to place the props thrower. The rail section is used so that the props can be changed in height according to the user's wishes. The principle of this *Promot* prop is designed as well as the working principle of a cannon. Cannon is a large tubular weapon of war used to fire weapons made of gunpowder to the enemy. The cannon serves as a means of shooting enemies who are at a considerable distance because throwing using bare hands alone will not provide enough range. This gun can be adjusted the angle of elevation so that the range of fire can be estimated the same as how the promot prop works which can be adjusted the angle of elevation to estimate the range of position of the object being fired. The *Promot* prop developed by this author is combined with the help of *tracker analysis software* which is used to see the speed of objects fired both in the direction of the x-axis and y-axis. In addition to developing Promot props, the author also developed a mini practicum guidebook using "*Projectile Motion"* props with contents such as practicum guides, how to use *tracker analysis software,* and parabolic motion component data analysis that users can explore using *this* Promot props.

The mini practicum guidebook using "*Projectile Motion"* props is designed to maximize user needs in using the props made so that it can explore all components and variables that exist in parabolic motion and can illustrate clearly the concept of parabolic motion material both in each sub-component, namely variables on the x-axis and variables on the y-axis. The following is the design of the mini practicum guidebook developed.

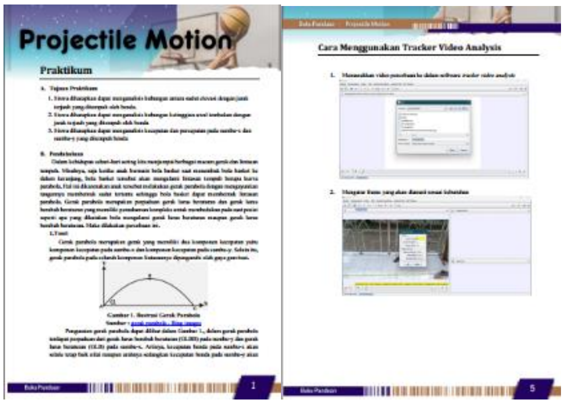

Figure 2. An overview of the Practicum Mini Guidebook using Teaching Aids Projectile Motion (Personal Documentation)

The guidebook is designed like a regular book with pages at the bottom left. The difference between guidebooks developed and guidebooks is usually significant in size. The guidebook is usually A4 size while the guidebook developed is A5 size or half of the guidebook in general. That's because the guidebook developed is a mini practicum guidebook that only contains a practicum section that contains practicum objectives and an introduction that has sub-chapters, namely theories and methods or practicum steps with explanations of how to use teaching aids, and how to use *video analysis tracker software* due to *Promot* props This is technology-aided to manage parabolic motion components such as x-axis and y-axis velocities. In addition to size, another difference is in the cover, the cover of the mini guidebook that was developed is made into one with the content so that there is no stand-alone cover (without material). Just like the guidebook in general, the title used is the title of practicum, namely practicum about parabolic motion or *projectile motion*. The guidebook uses colors with one component that is the same as the colors in the video design to create harmony. This guidebook also contains results and analysis data contains tables of experimental data results used and graphs that can make it easier to analyze relationships between related variables. This results section is intended to make it easier for users to analyze and understand each component resulting from experiments using probability props.

Researchers have explored the use of *these Promot props* personally on two occasions. The first exploration is the exploration of the influence of the height of the ejector device with parabolic motion components. In the first exploration, the manipulation variable is the height of the ejector, the control variable is the angle of elevation, mass and type of object ejected, and the initial speed of the object so that the response of the parabolic motion component is obtained, namely the farthest distance traveled by experiment or calculation, travel time, x-axis speed and y-axis. The following is the result of one of the first explorations and results of *tracker video analysis* by researchers with a height manipulation of 0.60 m.

Figure 3. The first exploration of the manipulation of the ejector height (Personal Documentation)

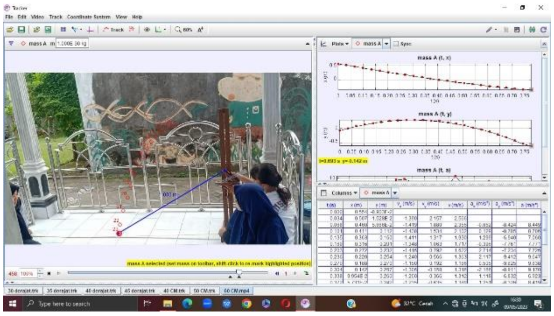

Figure 2. The results of the first exploratory tracker manipulation of the ejection height (Personal Documentation)

The results of exploration when manipulating the height of the ejector device will form a half-parabolic trajectory proven by using a *video analysis tracker* application on the bottom graph will form a half-parabolic trajectory starting from a certain height until it reaches the lowest point.
The second exploration is the exploration of the influence of the elevation angle of the ejector device with the parabolic motion component. In the exploration of the two manipulation variables are the angle of elevation of the ejector, the control variables are the height of the ejector device, the mass and type of object ejected, and the initial speed of the object so that the response of the parabolic motion component is obtained the farthest distance traveled by experiment or calculation, x-axis speed, and y-axis. Here are the results of one of the first explorations and results of *tracker video analysis* by researchers with 30^{o} elevation angle manipulation.

Figure 5. The second exploration of elevation angle manipulation (Personal Documentation)

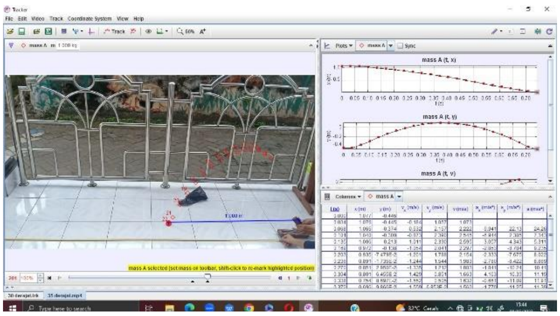

Figure 4. The results of the first exploratory tracker manipulation of the ejection height (Personal Documentation)

The results of exploration when manipulating the elevation angle will form a complete parabolic trajectory as evidenced by using the *video analysis tracker application on the* bottom graph will form a whole parabolic trajectory different from the first exploration because the motion of objects on the ejector device does not have a certain height or zero meters. The motion of objects begins with a certain speed when it reaches the peak point it will be influenced only by the acceleration of the earth's gravity while in the first exploration, the motion of objects will be directly located at the peak height with a short time then the motion of objects is only influenced by the acceleration of the earth's gravity. The following is the data of the first and second exploration tables conducted by researchers

Table 1. The First Exploration[1]

Height (m)	Maximum Height Exploration (m)	Maximum Height Calculation (m)	Time (s)	X-axis Velocity (ms^{-1})	Y-axis Velocity (ms^{-1})
0.40	*122*	*123.0*	*0.91*	*6,567*	*-7,567*
0.50	*114*	*116.0*	*0.92*	*6,723*	*-7,897*
0.60	*110*	*108.5*	*0.94*	*7,573*	*-8,765*
0.70	*108*	*109.0*	*0.99*	*8,775*	*-9,123*
0.80	*107*	*106.5*	*1.22*	*9,234*	*-9,875*

[1]*earth's gravity (g)* = 9.8 ms^{-2}; *mass (m)* = 28.6 gr; angle (α) = 60°; initial velocity (V_0) = 8.645 ms^{-1}

Table 2. Second Exploration[2]

Angle (°)	Maximum Height Exploration (m)	Maximum Height Calculation (m)	X-axis Velocity (ms^{-1})	Y-axis Velocity (ms^{-1})
25	*120*	*121.0*	*2,567*	*-3,567*
30	*105*	*107.0*	*5,723*	*-7,457*
35	*87*	*86.5*	*6,573*	*-7,897*
40	*53*	*51.0*	*7,775*	*-8,235*
45	*20*	*19.5*	*7,875*	*-8,954*

[2]*earth's gravity (g)* = 9.8 ms^{-2}; *mass (m)* = 28.6 gr; angle (α) = 60°; initial velocity (V_0) = 8.645 ms^{-1}

Based on the results of the first exploration by manipulating the height of the ejection device, the parabolic motion component is obtained which is X_{max} or the farthest point of the object by experiment and calculation, Maximum Height travel time, speed on the x-axis, and speed on the y-axis. Maximum Height is experimentally obtained by measurement directly with a meter while Maximum Height is calculated using the Maximum Height formula = $v_o \cos\alpha\, t$ while travel time is also obtained by calculation through t equation $y = v_o \sin\alpha\, t - \frac{1}{2}gt^2$ [13]. The x-axis speed and y-axis speed are obtained through *a video analysis tracker* application. The results of the second exploration by manipulating the angle of elevation obtained the components of parabolic motion, namely Maximum Height or the farthest point of the object experimentally and Maximum Height by calculation, as well as the speed on the x-axis, and the velocity on the y-axis. As in the first exploration, Maximum Height is experimentally obtained by measuring directly with a meter while Maximum Height is calculated using the Maximum Height formula = $\frac{v_o{}^2 \sin 2\alpha}{g}$. While the x-axis speed and y-axis speed are obtained through the *video analysis tracker application*. Through the first exploration data, a relationship was obtained between height and the maximum mileage of the object, which is inversely proportional where when the height of the ejector has a greater value, the value of the distance traveled will be smaller and vice versa. In the Maximum Height data experimentally and the comparison calculation is not too far away, namely in the range of 0.98 while the speed value on the x-axis component is always smaller in value with the y-axis speed. The speed of the y-axis is negative because the speed is against the direction of the acceleration of gravity. Through the second exploration data, the relationship between the elevation angle and the maximum mileage of the object can be reviewed inversely, where when the elevation angle has a greater value, the value of the mileage will be smaller and vice versa. In Maximum Height data experimentally and the comparison calculation is not too far in the range of 0.75 while the value of velocity in the x-axis component is always smaller in value with the speed of the y-axis. The speed of the y-axis is negative because the speed is against the direction of the acceleration of gravity. Exploration data by researchers can be said that Propet's props can produce data that are by the theory of parabolic motion.

The learning process using this *Promot* teaching aid uses a guided inquiry learning model. The inquiry learning model allows students to find and investigate a problem systematically, logically, and analytically which is carried out independently, while teachers or educators are only facilitators in charge of determining topics, and questions, and preparing supporting materials. This learning model aims to improve students' understanding of concepts, science process skills, and critical thinking. The guided inquiry model emphasizes students can carry out the process of seeking knowledge compared to knowledge transfer [14]. The guided inquiry learning model has several steps or syntax, including: 1) the teacher provides initial questions or problems that interest students, 2) students formulate hypotheses or temporary conjectures to answer the question or problem, 3) students design experiments or activities to test their hypotheses with the help of the teacher if needed, 4) students carry out experiments or activities according to their design and collect relevant data, 5) students analyze the data obtained and conclude the results, 6) students present the results of experiments or activities to classmates or teachers and discuss them, 7) teachers provide feedback and assessment of student learning processes and outcomes. The inquiry learning model is by the independent curriculum by implementing a *student center* and applying the concept of critical thinking competencies that are being used. The independent curriculum is the curriculum that is being used today. Learning in the independent curriculum is much more relevant and interactive through project activities providing opportunities for students to more actively explore real-world problems such as the environment, health, and others to support the development of personality and skills of Pancasila student profiles and aims to strengthen students' abilities in literacy and numeracy as well as their knowledge [15]. Parabolic motion enters phase F with parabolic motion kinematics vector material so this *Promot* prop is suitable to be applied in physics learning with an independent curriculum, especially using the trimming inquiry learning model in classroom learning.

At the implementation stage, researchers also distributed questionnaires through *g-form* containing videos of the process of making *Promot* props, exploring parabolic movements using Probe props, and *tracking* data from exploration. The purpose of distributing this *g-form* questionnaire is to find out the response of respondents to suggestions and criticisms of this *Promot props*. In addition, also know the response to their interest if physics learning is done with the help of these teaching aids. G-form respondents the composition of 60% high school students and 40% physics education students. Respondents gave a "Yes" opinion on the statement that *Promot props* are appropriate and appropriate to be applied with parabolic motion material in physics learning with a percentage of 100%

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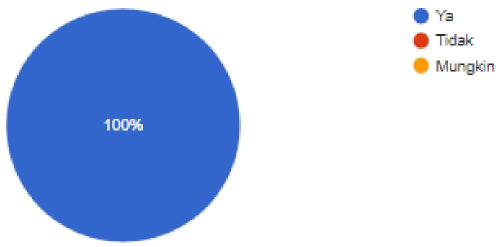

Figure 6. The results of the response to the suitability of the props in the parabolic motion material (Personal Documentation)

Furthermore, respondents also gave "agree" and "strongly agree" answers to the statement that the application of teaching aids in physics learning will make it easier for teachers to deliver parabolic motion material. The statement, This teaching aid can integrate students with technology in physics learning and also provides "agree" and "strongly agree" answers with the same amount, can be illustrated through the following graph.

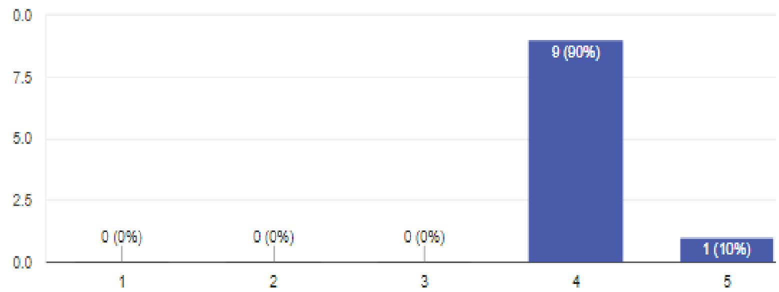

Figure 7. The results of the response to this teaching aid integrate learning in technology (Personal Documentation)

In addition, the author also received a response to the increase in student interest in learning physics through this promot prop. An indicator of increased interest is an increase in students' curiosity about learning parabolic movements, as many as 70% answered in agreement and 30% answered strongly in agreement.

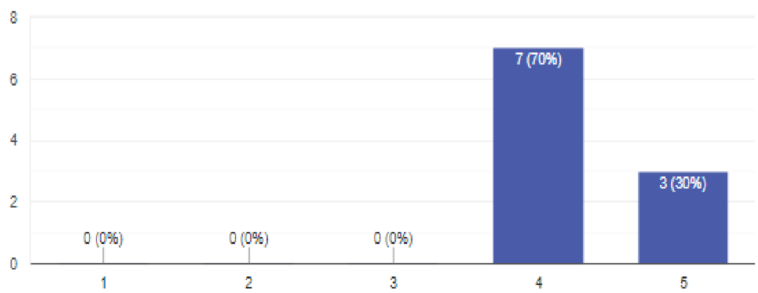

Figure 8. Response results to indicators of increased interest (Personal Documentation)

The next indicator of increasing student interest is that this teaching aid can invite students to play an active role during learning parabolic motion material as many as 50% answered in agreement and 50% answered strongly agree.

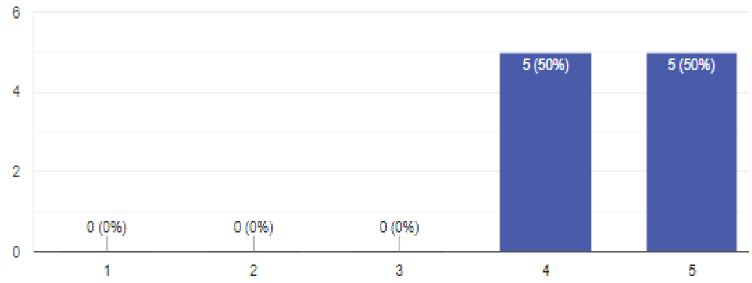

Figure 9. Response results to indicators of increased interest (Personal Documentation)

The next indicator of increasing student interest is that this teaching aid can increase student focus on learning parabolic movements through practicum activities as much as 90% answered in the affirmative and 10% answered strongly in the affirmative.

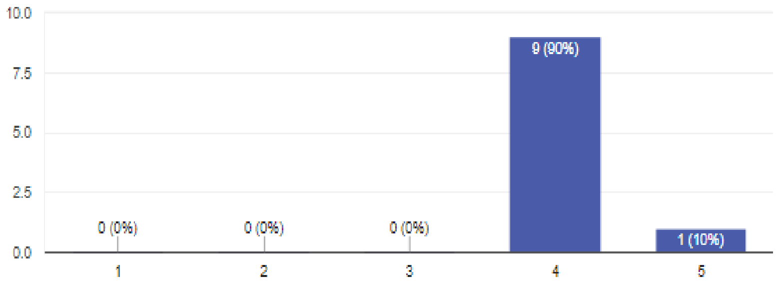

Figure 10. Results of responses to indicators of increased interest (Personal Documentation)

The next indicator of increasing student interest is that these teaching aids increase students' interest and pleasure in learning parabolic motion through practicum as many as 70% answered affirmatively and 30% answered strongly agree.

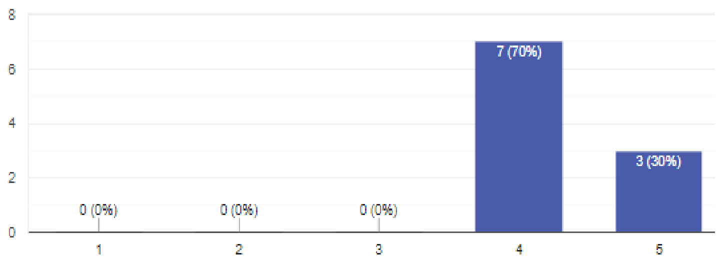

Figure 11. Results of responses to indicators of increased interest (Personal Documentation)

Overall, the results of the questionnaire showed positive support for this *Promot prop* applied to learning the physics of parabolic motion matter. In addition, this teaching aids application has an impact on increasing students' interest in learning parabolic motion material. This teaching tool can also create technology-assisted physics learning in the form of *tracker video analysis*.

4. Conclusion

To increase students' interest in parabolic motion material, the author has developed Promot *(Projectile Motion) props*. The results of the analysis of these props are then analyzed using the help of *Tracker Video Analysis software*. The author has done a simple exploration to test these *Promot* props. From the exploration, it was found that the relationship between the angle of elevation and the maximum mileage of objects is inversely proportional to each other where when the angle of elevation has a greater value, the value of the mileage will be smaller and vice versa. In addition, it is also known that the relationship between height and the maximum mileage of objects is inversely proportional where when the height of the ejector has a greater value, the value of the distance traveled will be smaller and vice versa. So through the exploration data that has been done by the author, it can be said that Propet's props can produce data that is by the theory of parabolic motion.

In this study, the author also made a mini guidebook containing practicum guidelines, how to use *tracker analysis software*, and data analysis of parabolic motion components that users can explore using this prop. The author also distributed the questionnaire through *a g-form* containing videos about Probe props. From the responses given by high school students and Physics Education students, it shows positive support for this *Promot teaching aid* applied to learning the physics of parabolic motion materials. In addition, this teaching aids application has an impact on increasing students' interest in learning parabolic motion material. This teaching tool can also create technology-assisted physics learning in the form of *tracker video analysis*.

Reference

[1] Satriawan M 2012 *Fisika Dasar* 2012.
[2] Hasbi M A 2015 *J Penelit Pendidik IPA* **1** 57.
[3] Sujarwanto A H W E 2014 *J. Pendidikan IPA Indonesia (JPII)* **3** 65.
[4] Slameto 2013 *Belajar dan FaktorFaktor yang Mempengaruhinya* (Jakarta: PT Bina Aksara).
[5] Rojabiyah A B 2019 *J. Educ.* **1** 458.
[6] Riskawati N 2017 *Fisika Dasar I* (Makassar: LPP Unismuh Makassar).
[7] Purwadi I 2014 *JRKPF UAD* **1** 1.
[8] A. P 2015 *Fisika Dasar* (Jakarta: Graha Ilmu).
[9] Agustiani D 2015 *Prosiding Seminar Nasional Fisika* **4** 45.
[10] Asrizal Y Z K 2018 *J. Eksakta Pendidikan (JEP)* **2** 41.
[11] Firdaus T 2017 International Conference on Mathematics and Science Education (ICMScE)," *IOP Conf. Series: Journal of Physics*.
[12] Zwickl 2015 Model-Based Reasoning in the Upper-Division PhysicsLaboratory: Framework and Initial Results, Rochester: School of Physics and Astronomy. Rochester Institute of Technology.
[13] Soegiyono 2011 Metode Penelitian Kuantitatif, Kualitatif dan R and D.
[14] A M 2016 *Besaran-Besaran Gerak, Fisika Dasar 1* 81.
[15] Haryono *J. Pendidikan Dasar* **7**, no. 1, pp. 1-13, 2016.
[16] Rahmadayanti A H D 2022 *J. BASICEDU* **6** 7174.
[17] Hayyuningtias Y P R 2022 *JIPFRI (J. Inovasi Pendidikan Fisika dan Riset Ilmiah)* **6** 51.
[18] Nomleni F T 2018 *Scholaria: Jurnal Pendidikan dan Kebudayaan* **8** 219.
[19] Swandi S 2021 *JRPF (J. Riset Pendidikan Fisika)* **6** 75.
[20] Situmorang A S 2022 *SEPREN: J. Mathematics Education and Applied* **2** 30.
[21] Irbah A A 2019 *Pillar of Physics* **12** 9.
[22] Prastyo H I S 2020 *J. Phenomenon* **10** 22.
[23] Fauziah Y D A 2019 *Pillar of Physics Education* **12** 73.
[24] Hamdi C K R 2019 *J. Sains Riset (JSR)* **9** 68.
[25] Huda H K N 2019 *J. Pijar MIPA* **14** 62.
[26] Widyastuti N N S 2021 *Integrated Lab Journal* **9** 124.
[27] Kurniawati I 2021 *J. Teknodik* **25** 107.