P-ISSN: 1693-1246
E-ISSN: 2355-3812
June 2025

Jurnal Pendidikan Fisika Indonesia 21 (1) (2025) 97-108
DOI: 10.15294/jpfi.v21i1.3364

http://journal.unnes.ac.id/journals/jpfi

Tracker Software Assisted Guided Inquiry Learning Model to Improve High School Students' Graphical Representation Ability

Ananda Aprilia[1]*, Pipit Wijayanti[2], Insih Wilujeng[3], Ichwan Aryono[5], Wipsar Sunu Brams Dwandaru[4]

[1,2,3,4]Faculty of Mathematics and Natural Sciences,
Universitas Negeri Yogyakarta, Indonesia

[5]SMA Negeri 3 Yogyakarta, Indonesia
*Corresponding Author: anandaaprilia.2024@student.uny.ac.id

Received: 22 January 2025. Accepted: 26 March 2025. Published: 12 June 2025

Abstract

This research aimed to improve students' graphical representation using the guided inquiry learning model assisted by the Tracker software. The method used in this research was a pre-experimental study with a one-group pretest-posttest design. The data collection techniques used were observation, interview, and tests. The sample for this research was students of science class X at Public Senior High School. The analysis techniques were carried out using Wilcoxon and N-Gain test calculations. The results of the research showed that the Wilcoxon test produced a significance, which means that there were differences in the guided inquiry learning model assisted by Tracker software to improve the graphical representation abilities of high school students on the Work and Energy topic. The N-Gain test indicated that more than half of the students achieved a high category, while only a small number obtained the low category. Moreover, the N-Gain results for the two-question item indicators showed that most students were in the medium and high categories. Thus, students' graphical representation abilities can be improved using the guided inquiry learning model assisted by the Tracker software.

Keywords: graphical representation ability, guided inquiry learning model, tracker software, work and energy topic.

INTRODUCTION

Physics is an important compulsory subject in high school. This is because physics is related to the application of various scientific concepts that can be found in everyday life. Physics is a science subject integrated with natural phenomena that occur in the environment and people’s behavior (Uralovich et al., 2023; Wardani & Sarjan, 2024). Therefore, it is important to provide physics topics to students. Studying physics is important for developing thinking skills and providing students with knowledge and understanding (Sengul, 2024; Assem, Nartley, & Aidoo, 2023; Sudiartha, 2022). However, physics is still difficult for high school students (Wangchuk, Wangdi, Tshomo, & Zangmo, 2023; Vicovaro, 2021). This is because physics requires persistence, precision, and much practice (Black, Matz, Mills, & Evrard, 2023; Kholilah, Pratiwi, Wahyuni, Yolviansyah, & Wicaksono, 2021). Physics also contains complex formulas and calculations (Baran-Bulut & Yuskel, 2024; Algiranto, 2022). Studying physics without understanding the concepts and their application in life makes physics topics difficult to understand (Azzahra et al., 2022; Hu, 2024). In this case, one of the fundamental problems is the lack of development of teaching materials (Michael, Uwaechia, Omowumi, Chinenye, & Temitope, 2024; Wenno, Limba, & Silahoy, 2022). Apart from teaching materials, it is also necessary to use and develop appropriate learning models. Based on our literature study, it was found that some students had difficulties in learning physics (Liang, Zou, Xie, & Wang, 2023). Therefore, teaching materials and learning models are needed to make students interested and understand physics concepts (Hong & Lin-Siegler, 2012).

The learning model applied is one factor influencing the learning process. (Ernita, Muin, Verawati, Prayogi, 2021; Anwar, Yuliani, & Fatmawati, 2018). The learning models teachers use greatly influence the quality of learning from the aspect of student activity. The quality of learning depends upon activeness, enthusiasm, motivation, self-confidence, and learning outcome. (Regidor, Vesmanos, & Deguito, 2024; Telaumbanua, 2022). One learning model that is appropriate to be used in learning is guided inquiry. This is because the learning process requires students to carry out investigations directly. (Najwa, Gunawan, Sahidu, & Harjono, 2022). The guided inquiry learning model can train students' scientific processes through experimental activities. Based on research by Seprianingsih, Jufri, & Jamaluddin (2017). It is stated that the guided inquiry learning model is more effective in training and guiding students to discover a concrete concept and building a high mindset. Thus, this model is suitable for physics learning applications, focusing on experimental activities. (Wang, Guo, & Jou, 2015). Furthermore, learning models that involve technology can contribute to the learning process. (Guentulle, Munoz, Nussbaum, & Madariaga, 2024; Heswari & Patri, 2021). This is because education currently focuses on analyzing educational concepts influenced by the Industrial Revolution 4.0 (Azzahra et al., 2022; Sharma, Suri, Sijariya, & Jindal, 2023). Education in the era of Industrial Revolution 4.0 utilizes digital technology in the learning process. (Sarker, Wu, Cao, Alam, & Li, 2019). The development of digital technology in the education sector has created easy access to teaching and learning activities. (Alieto, Abequibel-Encarnacion, Estigoy, Balasa, Eijansantos, & Torres-Toukoumidis, 2024; Wahab, Sari, Zuana, Luturmas, & Kuncoro, 2022). One digital technology in the education sector that is appropriate to use is Tracker software. (Aprilia & Dwandaru, 2023; Chiriacescu, Chiriacescu, Miron, Berlic, & Barna, 2020).

Tracker software is an application for analyzing graphs. In simple terms, the Tracker software can track the movement of an object so that various information can be obtained, hence the object's motion can be analyzed. (Oktaviani, Wahyudi, & Abdurrahman, 2020). The tracking process of the object is done by recording the object's movement via video. The recording results can then be processed using the Tracker application. The results are graphs that automatically appear. This way, the various data displayed can be interpreted, making it easier for students to analyze the motion phenomena and produce graphs. Tracker software is suitable for physics learning and experiments. However, physics experiments in laboratories have been carried out conventionally or still use manual data collection methods. Carrying out experiments can be used to develop students' abilities in applying knowledge theoretically and practically. (Kurbanbekov et al., 2016). The Tracker software has been used for distance learning in advanced physics experimental subjects. (Pratidhina, Rosana, & Kuswanto, 2021). One phenomenon that can be observed using the Tracker software is the motion of an object on an inclined plane in the physics topics of Work and Energy.

Work and Energy are physics topics that are important for students to understand because their applications are related to everyday life. The Work and Energy topics are physics materials considered difficult for students to understand (Ibrahim & Yusuf, 2019). Based on the results of observations in the field, it was found that physics learning about Work and Energy focuses more on equations or formulas. This indicates that students do not understand mathematical representations in physics material. Thus, a solution is needed to implement other representations, including a graphical representation. The graphical representation is used to help students better understand and interpret data. On the other hand, graphical representation in the Work and Energy topics is still low, with the percentage of students who do not understand graphical representation at 89.9%, and is still rarely applied in learning (Dienyati, Werdhiana, & Wahyono, 2020; Jatmika, Jumadi, Pujianto, & Rahmatullah, 2021; Pramadanti & Wahyuni, 2021; Purba & Werdhiana, 2021). This also aligns with a study by Safitri & Zainuddin (2024) that shows students' graphical representation abilities in the Work and Energy topics are in the low category. Students are not used to reading and describing graphs, so they cannot represent them in other representations (Silaen, Sudjito, & Sudarmi, 2019). Based on this study, the graphical representation indicators used in this research are 1) interpreting graphs regarding the relationship between variables and 2) making graphs comparisons. Thus, this research aims to analyze students' graphical representation improvement using the guided inquiry learning model assisted by the Tracker software.

METHOD

The method used in this research was a pre-experimental design. The pre-experimental design was an experimental design that only included one group or class that was given a pretest and a posttest. (Sugiyono, 2014). The research design was a one-group pretest-posttest design, an experiment carried out on one group without a comparison group. (Sugiyono, 2013). This research was conducted at Public Senior High School 3 Yogyakarta on students of science class X. This research used one class as a sample, namely science class X Science 4, with a cluster random sampling technique of 24 students. This research began with a pretest and ended with a posttest to observe the improvement of students' graphical representation abilities. The design scheme can be observed in Table 1.

Table 1. Pre-experimental design scheme.

Pre-test	Treatment	Post-test
T1	X	T2

Note: T1 is the pretest before the treatment; X is the treatment using the guided inquiry learning model assisted by the Tracker software; and T2 is the posttest given after the treatment.

The data collection techniques utilized were observation, interview, and tests. Moreover, the data processing and analysis techniques used in this research included the normality, difference, and N-Gain tests. A non-parametric difference test was used, namely the Wilcoxon test. (Rosyidah, Kusairi, & Taufiq, 2021). The difference test was supported by the N-Gain test, which was carried out to understand the magnitude of differences in students' graphical representation abilities. The N-Gain test was analyzed using the Hake (1998) The equation is as follows

$$\langle g \rangle = \frac{\langle x_{posttest} \rangle - \langle x_{pretest} \rangle}{x_{max} - \langle x_{pretest} \rangle}, \qquad (1)$$

where $\langle x_{posttest} \rangle$, $\langle x_{pretest} \rangle$, and x_{max} represented the average posttest, average pretest, and the maximum scores, respectively, the N-Gain test results were categorized according to Table 2.

Table 2. N-Gain interpretation value (Hake, 1998).

N-Gain Value	Interpretation
-1.00 < $\langle g \rangle$ < 0.00	A decrease occurs
$\langle g \rangle$ = 0.00	No increase
0.00 < $\langle g \rangle$ ≤ 0.30	Low
0.30 < $\langle g \rangle$≤ 0.70	Medium
0.70 < $\langle g \rangle$ ≤ 1.00	High

RESULTS AND DISCUSSION

The difference test is determined by first carrying out the normality test. The results of the normality test can be observed in Table 3. Based on the aforementioned table, it is obtained that the data are not normally distributed. This is because the test results have a significance value of < 0.05. Thus, the data in this study cannot be analyzed using the parametric tests. Thus, the difference test is carried out using the Wilcoxon test. The Wilcoxon test results can be seen in Table 4.

Table 3. Normality test results.

Normality test	Sig.	Category
Pretest	0.029	Not normal
Posttest	0.001	

Table 4. Wilcoxon test results.

	Posttest-pretest
Z	-4.299
Asymp Sig. (2-tailed)	.000

Based on Table 4, the results of the Wilcoxon test analysis show that the significance value is < 0.05 according to the test criteria if Asymp Sig. (2-tailed) is smaller than 0.05. Thus, this analysis means that the guided inquiry learning model assisted by Tracker software makes a difference to students' graphical representation abilities on the Work and Energy topics. Next, analysis of the difference in scores between the pretest and posttest to support the difference test can be observed from the N-Gain value. The N-Gain results can be given in Figure 1. The N-Gain criteria are obtained from Table 2 according to Hake (1998). Every student who takes the pretest and posttest is classified into one of these categories, namely high, medium, and low. Most students fall into the high N-Gain category, with a percentage of 58%. Meanwhile, students in the medium and low categories have 38% and 4%, respectively.

Finally, the average posttest score of 82.9 is higher than the pretest average score of 41.7. The results of the pretest and posttest scores can be observed in Table 5.

Table 5. Pretest and posttest results.

Parameter	Pretest	Posttest
Lowest value	10.0	60.0
Highest value	80.0	100.0
Average value	**41.7**	**82.9**

Learning observation in the class shows that students initially do not understand the Tracker software. Hence, an explanation and example of how to use the Tracker software are provided. In a relatively short time, the students can master and operate the Tracker software. This happens to most students, and only a few still do not understand the Tracker software. This fact supports the N-Gain results: around 58% of students obtain the high category, and only 4% obtain the low category. This is according to a study by Nurjannah, Nyeneng, & Wahyudi (2021) That practical online learning using Tracker software on the Elastic Collision topic, partly based on guided inquiry, can improve graphical interpretation and increase the N-Gain value of 0.39 in the medium category.

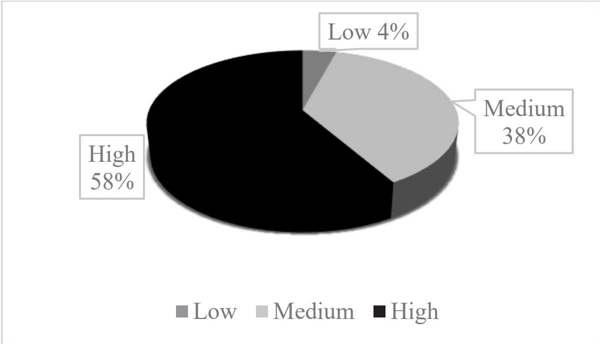


Figure 1. Students' N-Gain results.

Two graphical representation indicators are used in this research, namely 1) interpreting graphs related to the relationship between variables, and 2) making comparisons of a graph. Analysis of the graphical representation indicators is carried out using the N-Gain test. Every student who answers the questions on the first and second indicators falls into one of the categories, namely: high, medium, no increase, and decrease. The first indicator of students is categorized into four categories: decrease, no increase, moderate, and high, with percentages of 13%, 13%, 54%, and 21%, respectively. Meanwhile, the second indicator of students is categorized into three categories: no increase, medium, and high, with percentages of 4%, 13%, and 83%, respectively. Thus, most students fall into the moderate N-Gain category in the first indicator, with a percentage of 54%. Meanwhile, in the second indicator, most students fall into the high N-Gain category, with a percentage of 83%. This can be observed in Figure 2.

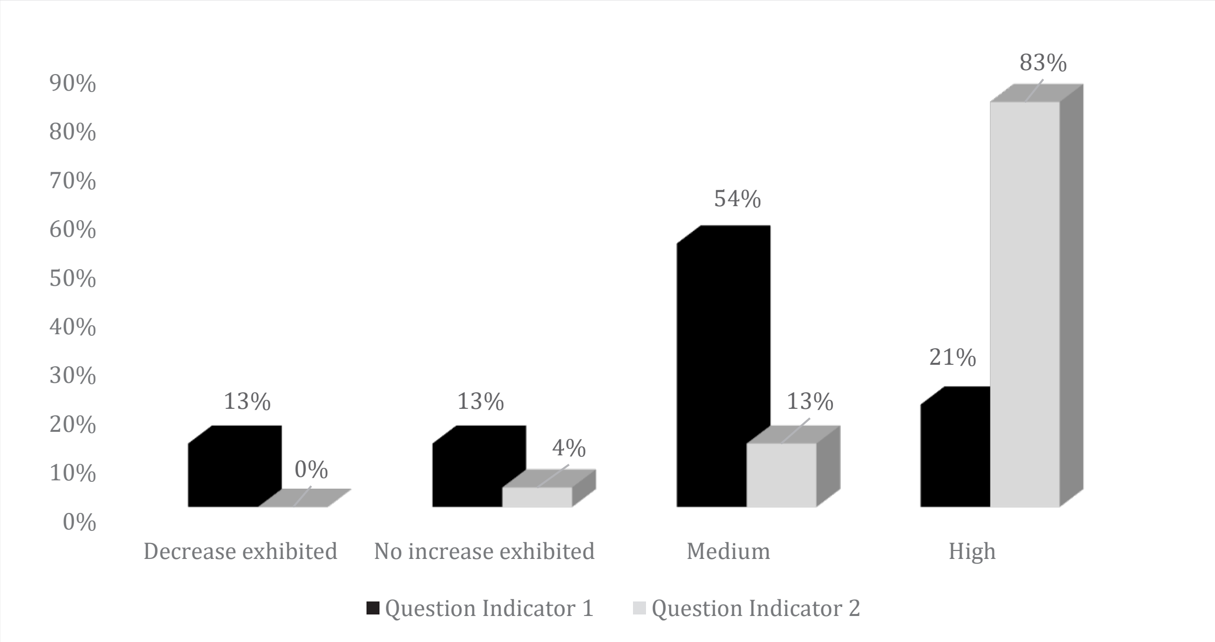
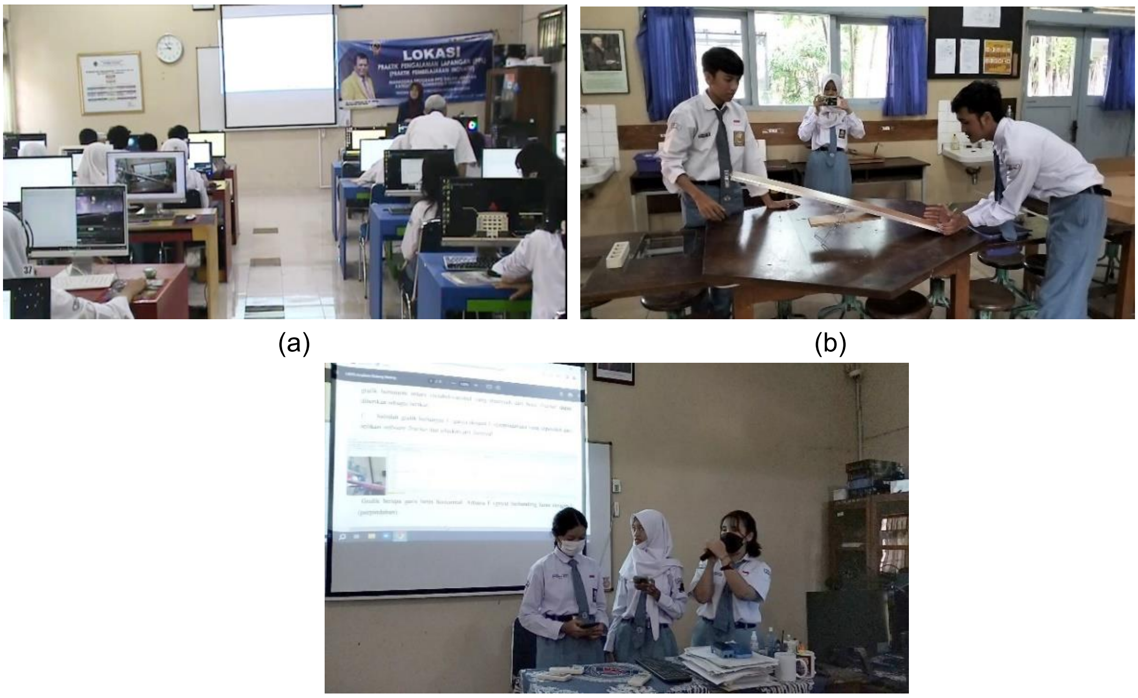


Figure 2. N-Gain results for each indicator.

Based on Figure 2, the N-Gain results are obtained for each question item indicator. It may be observed that the second indicator experiences a higher increase compared to the first indicator. Some students fall into the category of decrease, and no increase, with a percentage of 13%. This indicates that the first indicator item, namely, interpreting graphs related to the relationship between variables, still needs to be improved. Moreover, the high category of the question indicator 2 compared to the moderate category of question indicator one indicates that comparing graphs is easier than interpreting graphs. This means that students can compare graphs rather than interpret them. Higher thinking skills are needed in interpreting graphs rather than comparing them.

The results of the Wilcoxon and N-Gain tests are also supported by various documents on learning implementation, which can be observed in Figure 3. Figure 3(a) shows the enthusiasm and attitude of students in following the explanation about the Tracker software (Aprilia, Kuswanto, & Dwandaru, 2023). The video used in operating the Tracker software is obtained from the practicum process, which can be observed in Figure 3(b). This video data collection occurs briefly, so the video data is obtained within a few seconds. Besides these documentations, the interview results with the students further support the above analysis, e.g., "*We are very amazed and happy that nowadays there is technology as fast and sophisticated as this (Tracker software). We become more efficient at observing and searching for components of motion. We can search for the necessary graphs and components by entering the video and formula. We are delighted with this technology*."



(a) (b)

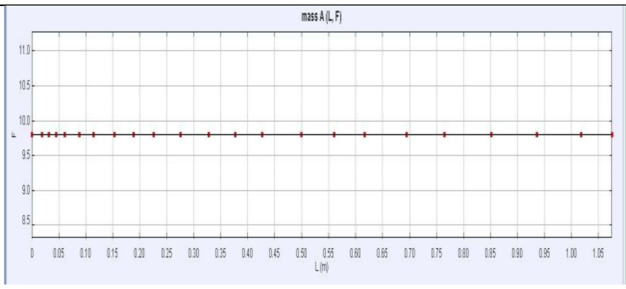
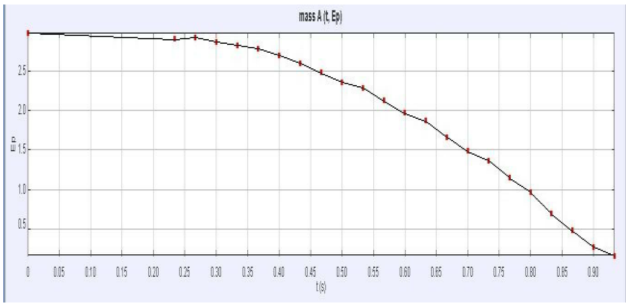
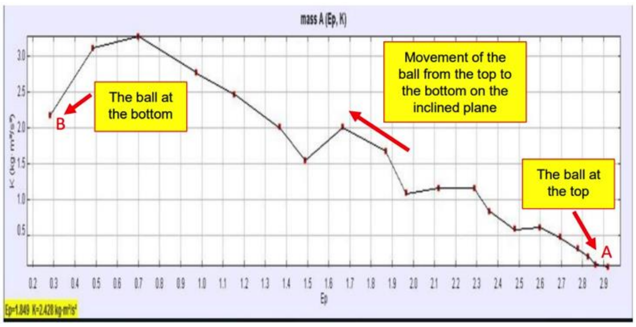
(c)

Figure 3. Documentation of learning activities: (a) Tracker software explanation, (b) inclined plane practicum experiment, and (c) presentation of the practicum results.

The video is analyzed using the Tracker software, and the data are then obtained in the form of various graphs, i.e., force (*F*), potential energy (E_p), kinetic energy (*K*), mechanical energy, and power (*P*). The results of students' analysis using the Tracker software can be seen in Table 6. The students' analysis results are in the form of graphs with various variable relationships. Students produce five graphs using the Tracker software, i.e., *F* vs length (*L*); E_p vs time (*t*); *K* vs *t*; *K* vs E_p; and *P* vs *t*. All the graphs students obtain are based on the physical properties of an object moving on an inclined plane. In this case, students can produce the graphs utilizing the Tracker software. However, it is still a challenge for students to interpret the graphs. Finally, students write a practicum report in groups by explaining the meaning of the graphs obtained and then presenting the report's results as observed in Figure 3(c). Based on the output results from the Tracker software, students can be trained to have the ability to represent mathematical equations in graphical forms, which are then discussed verbally.

The previous explanation of the Wilcoxon and N-Gain tests shows differences in the pretest and posttest comparison results of students' graphical representation abilities on Work and Energy topics using the guided inquiry learning model assisted by the Tracker software. This is also supported by an example of written pretest and posttest answers for each question item, which can be observed in Table 7. Based on Table 7, it may be observed that the pretest answers tend to be short and shallow, e.g., "*changes irregularly*"; "*x and y change together regularly*"; and "*graph a is stable while graph b is unstable*". Hence, students are initially unable to interpret and compare graphs. On the other hand, the posttest answers are longer and show the student's effort in interpreting and comparing graphs, e.g.: "*The graph increases and forms a curve, meaning that as the value of x increases, the value of y increases with the ratio of x and y changing*"; and "*The graph of the results of* *the practicum (b) is fluctuating compared to the graph of the theoretical results (a) caused by several factors during the practicum such as inefficiency or accuracy of the tools and implementation of the practicum. However, overall, the graph of the practicum results tends to increase and is similar to the graph in theory (ideal results)*. Therefore, students can interpret and compare graphs through the guided inquiry learning model assisted by the Tracker software. This is by a study conducted by Matuk et al. (2019), where authentic inquiry learning supports students' understanding of graphical representations.

Table 6. Analysis results using Tracker software.

Variable relationships	Graphic Image	Results
F vs *L*		*L* does not affect the *force* of the ball. This is because *the force of the ball is constant as it rolls downwards (it is a type of free-fall* movement).
E_p vs *t*		As the object moves downward, the *EP* decreases (according to the law of conservation of mechanical energy). So, with the increase in *t*, the E_p decreases.
K vs *t*		As the object moves downward, *K* increases. So, with the increase in *t*, the *K* increases.
K vs E_p		E_p and *K* are related to each other. As the object moves downward, the ratio of *K* vs E_p increases from A to B. As *K* increases, E_p decreases; hence, *K* vs E_p increases.

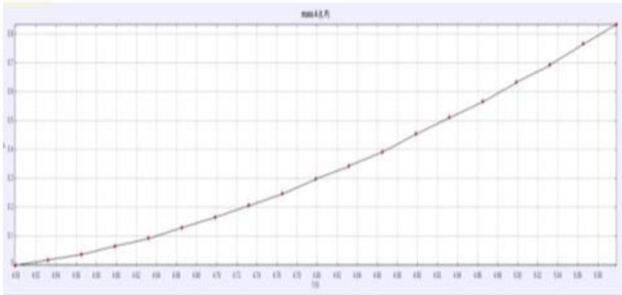
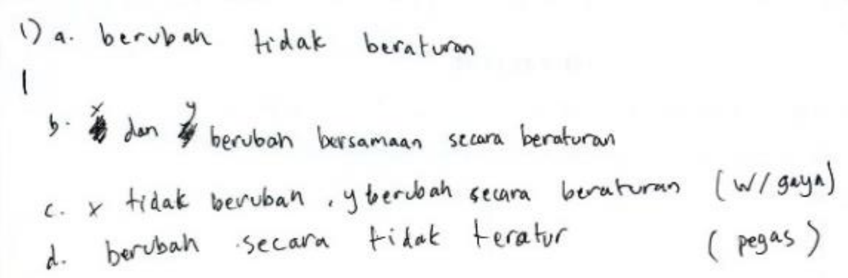
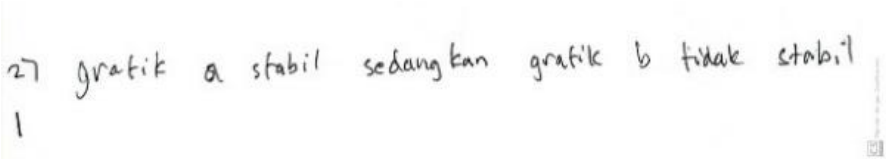
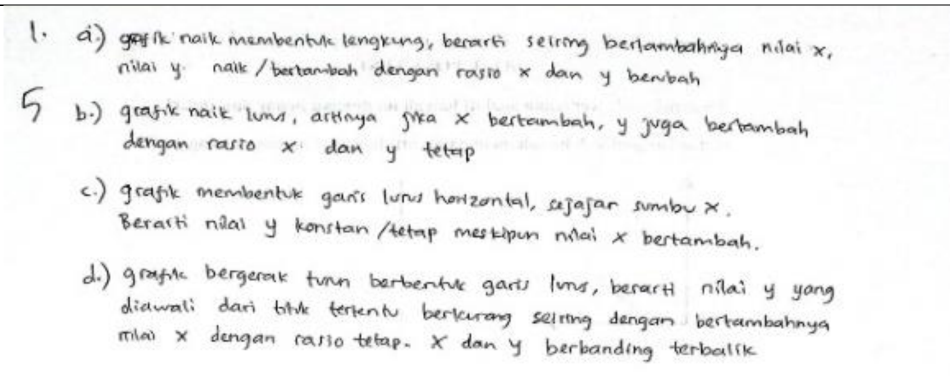
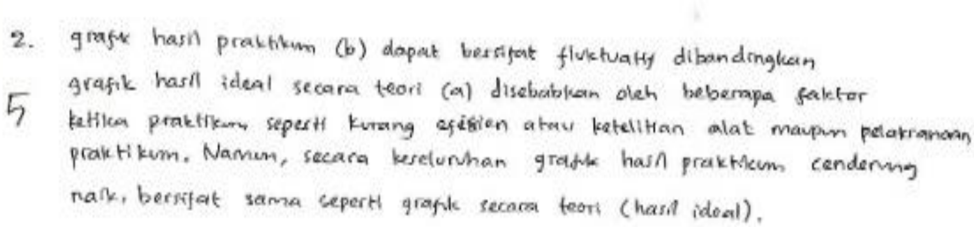
Variable relationships	Graphic Image	Results
Power (P) vs t		As the object moves downward, the more P is used. This means that as t increases, P also increases.

Table 7. Pretest and posttest comparison results.

Question	Pretest
1	 1) a. berubah tidak beraturan 1 b. x dan y berubah bersamaan secara beraturan c. x tidak berubah, y berubah secara beraturan (w/ gaya) d. berubah secara tidak teratur (pegas)
2	 2) grafik a stabil sedangkan grafik b tidak stabil 1
	Posttest
1	 1. a.) grafik naik membentuk lengkung, berarti seiring bertambahnya nilai x, nilai y naik / bertambah dengan rasio x dan y berubah 5 b.) grafik naik lurus, artinya jika x bertambah, y juga bertambah dengan rasio x dan y tetap c.) grafik membentuk garis lurus horizontal, sejajar sumbu x. Berarti nilai y konstan / tetap meskipun nilai x bertambah. d.) grafik bergerak turun berbentuk garis lurus, berarti nilai y yang diawali dari titik tertentu berkurang seiring dengan bertambahnya nilai x dengan rasio tetap. x dan y berbanding terbalik
2	 2. grafik hasil praktikum (b) dapat bersifat fluktuatif dibandingkan grafik hasil ideal secara teori (a) disebabkan oleh beberapa faktor ketika praktikum seperti kurang efisien atau ketelitian alat maupun pelaksanaan praktikum. Namun, secara keseluruhan grafik hasil praktikum cenderung naik, bersifat sama seperti grafik secara teori (hasil ideal). 5

CONCLUSION

It can be concluded that the guided inquiry learning method assisted by Tracker software on the Work and Energy topics can improve students' graphical representation skills. The result of the Wilcoxon test shows a significance value of < 0.05, which means that there are differences in the guided inquiry learning model assisted by Tracker software to improve graphical representation skills of senior high school students on Work and Energy topics. Meanwhile, the results of the N-Gain tests show that there are three categories achieved by students, namely high, medium, and low, with percentages of 58%, 38%, and 4%, respectively. In addition, the results of the N-Gain analysis on the first and second indicators produce the highest percentages, with 54% of students in the medium category and 83% of students in the high category, respectively. Through this learning model, students look enthusiastic in learning the Tracker software, doing inclined plane practicum, and presenting the practicum results in front of the class. For further study, it is necessary to do research by adding a comparison (control) class to ensure the results obtained come from the variables studied and to determine the study's effectiveness.

REFERENCES

Algiranto, A. (2022). Pengembangan Modul Pembelajaran Fisika Berbasis Discovery Learning untuk Siswa SMA. *Jurnal Perspektif Pendidikan*, *16*(1), 34–43. https://doi.org/10.31540/jpp.v16i1.1565.

Alieto, E., Abequibel-Encarnacion, B., Estigoy, E., Balasa, K., Eijansantos, A., & Torres-Toukoumidis, A. (2024). Teaching Inside a Digital Classroom: A Quantitative Analysis of Attitude, Technological Competence and Access Among Teachers Across Subject Disciplines. *Heliyon*, *10*(2), e24282. https://doi.org/10.1016/j.heliyon.2024.e24282

Anwar, M., Yuliani, H., & Fatmawati, S. (2018). Perbandingan Model Pembelajaran Kooperatif Tipe Jigsaw dan Tipe Two Stay Two Stray terhadap Kemampuan Berpikir Kritis Siswa pada Materi Elastisitas. *Jurnal Riset Fisika Edukasi dan Sains*, *5*(2), 47–56. https://doi.org/10.22202/jrfes.2018.v5i2.2750.

Aprilia, A., & Dwandaru, W. S. B. (2023). Study of Tracker Software-assisted Spring Coupled Pendulum Oscillation. *Indonesian Review of Physics*, *6*(2), 63–74. https://doi.org/10.12928/irip.v6i2.7423.

Aprilia, A., Kuswanto, H., & Dwandaru, W. S. B. (2023). Attitudes and Beliefs toward Physics: A Mini Review. *Revista Mexicana de Física E*, *20*(2), 1-8. https://doi.org/10.31349/RevMexFisE.20.020212.

Azzahra, S., Khasanah, N. I., Kurniawan, D. A., Maison, M., Wibisono, G., Sari, D. P., & Nasution, O. S. M. (2022). Analisis Minat Belajar Peserta Didik dalam Pembelajaran Fisika Menggunakan Website sebagai Media Pembelajaran di SMAN 8 Tanjung Jabung Barat. *Jurnal Pendidikan MIPA*, *12*(2), 192–197. https://doi.org/10.37630/jpm.v12i2.557.

Baran-Bulut, D., & Yuskel, T. (2024). Interdisciplinary Teaching: Solving Real-life Physics Problems through Mathematical Modelling. *Electronic Journal for Research in Science and Mathematical Education*, *27*(4), 118–140.

Black, W. K., Matz, R. L., Mills, M., & Evrard, A. E. (2023). Quantifying Grade Benefits of Study: Practice Makes Perfect. *Physical Review Physics Education Research*, *19*(1), 010139. https://doi.org/10.1103/PhysRevPhysEducRes.19.010139.

Chiriacescu, B., Chiriacescu, F. S., Miron, C., Berlic, C., & Barna, V. (2020). Arduino and Tracker Video - Didactic Tools for Study of the Kater Pendulum Physical Experiment. *Romanian Reports in Physics*, *72*(901), 1-14.

Dienyati, N. H., Werdhiana, I. K., & Wahyono, U. (2020). Analisis Pemahaman Konsep Siswa berdasarkan Multirepresentasi pada Materi Usaha dan Energi Kelas XI SMAN 1 Banawa Tengah. *Jurnal Kreatif Online*, *1816*(1), 74–84.

Ernita, N., Muin, A., Verawati, N. N. S. P., & Prayogi, S. (2021). The Effect of Inquiry

Learning Model based on Laboratory and Achievement Motivation toward Students' Physics Learning Outcomes. *Journal of Physics: Conference Series*, *1816*(1), 012090. https://doi.org/10.1088/1742-6596/1816/1/012090.

Guentulle, V., Muñoz, R., Nussbaum, M., & Madariaga, L. (2024). How Multiple Representations using Cyber–Physical Systems to Teach Rectilinear Motion Improves Learning and Creativity. *Education Sciences*, *14*(3), 293. https://doi.org/10.3390/educsci14030293.

Hake, R. R. (1998). Interactive-engagement Versus Traditional Methods: A Six-thousand-student Survey of Mechanics Test Data for Introductory Physics Courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809.

Heswari, S., & Patri, S. (2021). Pengembangan Media Pembelajaran Matematika Berbasis Android untuk Mengoptimalkan Kemampuan Berpikir Kreatif Siswa. *Jurnal Inovasi Penelitian*, *2*(8), 2715–2722.

Hong, H. -Y., & Lin-Sigeler, X. (2012). How Learning about Scientists' Struggles Influences Students' Interest and Learning in Physics. *Journal of Educational Psychology*, *104*(2), 469-484. https://doi.org/10.1037/a0026224

Hu, S. (2024). Study on Teaching Strategies in Secondary School Physics from the Perspective of Core Literacy. *International Journal of Education and Humanities*, *12*(3), 139–142. https://doi.org/10.54097/cfjhad29.

Ibrahim, E., & Yusuf, M. (2019). Implementasi Modul Pembelajaran Fisika dengan Menggunakan Model REACT Berbasis Kontekstual pada Konsep Usaha dan Energi. *Jambura Physics Journal*, *1*(1), 1–13. https://doi.org/10.34312/jpj.v1i1.2281.

Jatmika, S., Jumadi, Pujianto, & Rahmatullah, R. (2021). Analisis Penyebab Kesalahan Pemahaman Siswa pada Materi Usaha dan Energi. *Indonesian Journal of Applied Science and Technology*, *2*(3), 97-105. https://www.journal.publication-center.com/index.php/ijast/article/view/1228.

Kholilah, K., Pratiwi, M. R., Wahyuni, S., Yolviansyah, F., & Wicaksono, L. (2021). Analisis Karakter Kerja Keras terhadap Mata Pelajaran Fisika di SMA NEGERI 1 Kota JAMBI. *Jurnal Sains dan Pendidikan Fisika*, *17*(1), 11. https://doi.org/10.35580/jspf.v17i1.15528.

Kurbanbekov, B. A., Turmambekov, T. A., Baizak, U. A., Saidakhmetov, P. A., Abdraimov, R. T., Bekayeva, A. E., & Orazbayeva, K. O. (2016). Students' Experimental Research Competences in the Study of Physics. *Journal of Environmental and Science Education*, *11*(18), 13069–13078.

Liang, Y., Zou, D., Xie, H., & Wang, F. L. (2023). Exploring the Potential of Using ChatGPT in Physics Education. *Smart Learning Evironments*, *10*(52), 1-19. https://doi.org/10.1186/s40561-023-00273-7.

Matuk, C., Zhang, J., Uk, I., & Linn, M. C. (2019). Qualitative Graphing in an Authentic Inquiry Context: How Construction and Critique Help Middle School Students to Reason about Cancer. *Journal of Research in Science Teaching*, *56*(7), 905-936. https://doi.org/10.1002/tea.21533.

Michael, F. B., Uwaechia, F. C., Omowumi, O. E., Chinenye, E. C., & Temitope, O. F. (2024). Impact of Inadequate Instructional Materials on the Effective Teaching and Learning of Physics In the Bwari Area Council of Nigeria, Federal Capital, Abuja: Implications for Preparing Future Engineers. *International Journal of Humanities, Social Science and Management*, *4*(3), 1511–1518.

Najwa, N., Gunawan, G., Sahidu, H., & Harjono, A. (2022). Pengembangan Perangkat Pembelajaran Model Inkuiri Terbimbing untuk Meningkatkan Hasil Belajar Fisika Peserta Didik. *Jurnal Pendidikan Fisika dan Teknologi*, *8* (Special Issue), 31–37. https://doi.org/10.29303/jpft.v8iSpecialIssue.3420.

Nurjannah, A., Nyeneng, I. D. P., & Wahyudi, I. (2021). Pengaruh Pembelajaran Daring Berpraktikum Menggunakan Media Tracker berbasis Inkuiri Terbimbing terhadap Peningkatan Kemampuan Interpretasi Grafik.

Jurnal Inovasi dan Pembelajaran Fisika, *8*(2), 198–207.

Oktaviani, Y., Wahyudi, I., & Abdurrahman, A. (2020). Pengaruh Software Tracker pada Pembelajaran Koefisien Restitusi Berbasis Inkuiri Terbimbing terhadap Kemampuan Multi-Reperentasi Siswa. *Kappa Journal*, *4*(1), 48–56. https://doi.org/10.29408/kpj.v4i1.1992.

Pramadanti, H. D., & Wahyuni, I. (2021). Analisis Kemampuan Interpretasi Data Siswa dalam Belajar Materi Usaha dan Energi. *Jurnal Ikatan Alumni Fisika*, *7*(2), 12. https://doi.org/10.24114/jiaf.v7i2.25664.

Pratidhina, E., Rosana, D., & Kuswanto, H. (2021). Implementation of a Tracker-assisted Modeling Activity in an Online Advanced Physics Experiment Course. *Journal of Education and E-Learning Research*, *8*(2), 222–229. https://doi.org/10.20448/journal.509.2021.82.222.229.

Purba, D. T., & Werdhiana, I. K. (2021). Deskripsi Pemahaman Siswa SMA tentang Grafik Usaha dan Energi. *Jurnal Pendidikan Fisika Tadulako Online*, *9*(2), 13–17.

Regidor, A. R., Vesmanos, A. T., & Deguito, P. O. (2024). The Impact of Supportive Learning Environment on Student Learning Motivation of Senior High School Students. *Asian Journal of Education and Social Studies*, *50*(7), 558–571. https://doi.org/10.9734/ajess/2024/v50i71487

Rosyidah, N. D., Kusairi, S., & Taufiq, A. (2021). Kemampuan Berpikir Kritis Siswa melalui Model STEM PjBL disertai Penilaian Otentik pada Materi Fluida Statis. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *5*(10), 1422. https://doi.org/10.17977/jptpp.v5i10.14107.

Safitri, R. A., & Zainuddin A. (2024). Analisis Kemampuan Multirepresentasi Peserta Didik dalam Menyelesaikan Masalah pada Materi Usaha dan Energi. *Jurnal Arjuna: Publikasi Ilmu Pendidikan, Bahasa dan Matematika*, *2*(2), 47–58. https://doi.org/10.61132/arjuna.v2i2.603.

Sarker, M. N. I., Wu, M., Cao, Q., Alam, G. M., & Li, D. (2019). Leveraging Digital Technology for Better Learning and Education: A Systematic Literature Review. *International Journal of Information and Education Technology*, *9*(7), 453–461. https://doi.org/10.18178/ijiet.2019.9.7.1246.

Sengul, O. (2024). Learning to Become a Physics Teacher: A Case Study of Experienced Teachers. *Education Sciences*, *14*(2), 195. https://doi.org/10.3390/educsci14020195.

Seprianingsih, D., Jufri, W., & Jamaluddin. (2017). Pengembangan Perangkat Pembelajaran Biologi Berbasis Inkuiri Terbimbing (PPBIT) dalam Meningkatkan Kemampuan Berargumen Siswa. *Jurnal Penelitian Pendidikan IPA*, *3*(2). https://doi.org/10.29303/jppipa.v3i2.86.

Sharma, Y., Suri, A., Sijariya, R., & Jindal, L. (2023). Role of Education 4.0 in Innovative Curriculum Practices and Digital Literacy – A Bibliometric Approach. *E-Learning and Digital Media*, *22*(1), 1-32. https://doi.org/10.1177/20427530231221073.

Silaen, S. S., Sudjito, D. N., & Sudarmi, M. (2019). Pengembangan Tes Diagnostik Multi Representasi Eksternal (MRE) untuk Mengetahui Profil Kemampuan Representasi Konsep. *Publikasi Pendidikan*, *9*(2), 98–103. Retrieved from http://ojs.unm.ac.id/index.php/pubpend.

Sugiyono. (2013). *Statistika untuk Penelitian*. Bandung: Alfabeta.

Sugiyono. (2014). *Metode Penelitian Bisnis*. Bandung: Alfabeta.

Uralovich, K. S., Toshmamatovich, T. U., Kubayevich, K. F., Sapaev, I. B., Saylaubaevna, S. S., Beknazarova, Z. F., & Khurramov, A. (2023). A Primary Factor in Sustainable Development and Environmental Sustainability is Environmental Education. *Caspian Journal of Environmental Sciences*, *21*(4), 965–975. https://doi.org/10.22124/cjes.2023.7155.

Vicovaro, M. (2021). Intuitive Physics and Cognitive Algebra: A Review. *European Review of Applied Psychology*, *71*(5), 1–19. https://doi.org/10.1016/j.erap.2020.100610.

Wahab, A., Sari, A. R., Zuana, M. M. M., Luturmas, Y., & Kuncoro, B. (2022). Penguatan Pendidikan Karakter melalui Literasi Digital sebagai Strategi dalam Menuju Pembelajaran Imersif Era 4.0. *Jurnal Pendidikan dan Konseling*, *4*(5), 4644–4653.

Wang, J., Guo, D., & Jou, M. (2015). A study on the Effects of Model-based Inquiry Pedagogy on Students' Inquiry Skills in a Virtual Physics Lab. *Computers in Human Behavior*, *49*, 658–669. https://doi.org/10.1016/j.chb.2015.01.043.

Wangchuk, D., Wangdi, D., Tshomo, S., & Zangmo, J. (2023). Exploring Students' Perceived Difficulties of Learning Physics. *Educational Innovation and Practice*, *6*. https://doi.org/10.17102/eip.6.2023.03.

Wardani, I. K., & Sarjan, M. (2024). Etnosains dan Kearifan Lokal Pemanfaatan Ampas Minyak Kelapa terhadap Pembelajaran Berdiferensiasi dalam Perspektif Progresivisme pada Mata Pelajaran IPA. *Journal Transformation of Mandalika*, *5*(1), 122–129. Retrieved from https://ojs.cahayamandalika.com/index.php/jtm/article/view/2667.

Wenno, I. H., Limba, A., & Silahoy, Y. G. M. (2022). The Development of Physics Learning Tools to Improve Critical Thinking Skills. *International Journal of Evaluation and Research in Education*, *11*(2), 862. https://doi.org/10.11591/ijere.v11i2.21621.