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Implementation of Tracker-Assisted Modelling Activity in Online Advanced Physics Experiment Course

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Abstract

Experiment or laboratory-work is an essential part of physics and other science subjects. However, due to COVID-19 pandemic, face-to-face classes must be transformed to remote classes. Access to the laboratory becomes very limited during the remote class. We have to utilize technology to substitute hands-on activity in laboratory based-course. In this paper, we propose implementing modeling activity by using Tracker in the online Advanced Physics Experiment course. The course is mandatory at the Department of Physics Education in an Indonesian private university. The study shows that 20 out of 21 participants have shown an increase in graph interpretation skills. Although the activity could not facilitate students' practicing hands-on skills, this activity can encourage students to practice other science process skill aspects. Moreover, according to the survey, students feel more motivated to learn physics online after exposed to the modeling activity.

Keywords: modeling, physics experiment, graph interpretation, learning motivation, online course.

Introduction

Distance learning has transformed significantly as digital technology develops tremendously. The main problem of distance learning in the past is the lack of interaction between teachers and students. However, with more accessible internet and advance communication technology, that main obstacle can be reduced significantly. Still, distance learning has a significant problem, especially for a science course. The problem is mainly related to bringing laboratory work or experiments in distance learning (Aththibby, Kuswanto, & Mundilarto, 2021).

Laboratory work is an indispensable part of science courses; it facilitates students to inquire, think critically, and practice generating scientific information. Previous studies also show that students' attitudes toward science improve when students are involved in laboratory work. Moreover, it is essential to reveal a meaningful understanding of science concepts (Sadoglu, Durukan, Sadoglu, & Determining, 2018).

COVID-19 pandemic, which started in early 2020, has affected the education system around the world. The schools are forced to close to minimize the spread of the virus. Hence, students and teachers are forced to convert the face-to-face course to remote mode with online learning. In a short period, teachers need to design the online course. For Physics Education Department, the challenge is transforming practical-based courses into online learning. The practical-based course usually is done in a laboratory and requires hands-on activity, but direct access to laboratory is impossible in online learning. Even though it cannot replace hands-on activity, some technologies can be implemented as alternatives (Aththibby et al., 2021; Campari et al., 2021; Pols, 2020).

In this work, we explain the alternative of using Tracker as a video modeling software that students can use for taking data from experiment video, analyzing the data, and helping them in modeling. Instead of students do a hands-on experiment in the lab, the teacher record the experiment and give the video to students. The students then observe the physical phenomena in the video and take quantitative data by using Tracker (Brown & Cox, 2009). Tracker has been widely used in the physics education community to enhance face-to-face physics courses (Castaneda, 2019; Trocaru, Berlic, Miron, & Barna, 2020; Yusuf, 2016). The learning activity implemented in this work is based on modeling. Modeling-based learning encourages students to construct a scientific model or solve particular problems like a real scientist (Cascarosa & Gimeno, 2020). Even though this online activity may not facilitate competencies related to practical things such as using apparatus and laboratory safety, it can also stimulate students to develop other competencies such as data skills and communication skills.

In particular, we investigate how the modeling activity using Tracker affects one aspect of data skill, i.e., graph interpretation skills. A graph is one of the data representations that is widely used in various fields. To anticipate future career paths, students need to get used to interpreting graphs (Ergül, 2018).

Literature Review

Model and Modeling in Physics Learning

Model in physics is a simplified version of a part of the targeted physical world. Based on the representation method, models can be categorized into six types, i.e. concrete models, verbal models, visual models, mathematical models, action models, and a mix of those models (Buckley & Boulter, 2000).

Modeling is a process that scientist uses to construct a scientific model or solve particular problems. Although modeling is initially coming from a process usually done by scientists, it is also adapted in the science learning process (Wang, Jou, Lv, & Huang, 2018). Students can go through the modeling process to develop scientific knowledge. The principle of modeling in learning science is constructing a mental model to understand a phenomenon and using the cognitive model to solve a problem.

There are several learning cycles proposed based on modeling. Hestenes stated that the physics modeling process comprises 3 main parts, i.e., modeling, model analysis, and model validation (Hestenes, 1997). Halloun also developed a learning cycle based on the modeling process; the learning cycle consists of exploration, model adduction, model formulation, model deployment, and paradigmatic synthesis (Halloun, 2007). Meanwhile, Brew proposed five steps: introduction and representation, coordination of representation, application, abstraction and generalization, and continued incremental development (Brewe, 2008). In another study, modeling-based flipped learning has been developed. Flipped learning stages consist of exploration, model adduction, model formulation, and model deployment (Wang et al., 2018). Several studies have indicated the positive impact of model-based learning. The implementation of model-based learning in school can reduce alternative conceptions, clarify disagreement between intuition and physics phenomenon, improve argumentation skill, connect theory and experimental data, improve problem-solving strategies, mediate a new concept with prior knowledge or other disciplines, and help student in understanding the image of nature (Cascarosa & Gimeno, 2020)

Graph Interpretation skill

One of the critical competence in the twenty-first century is working with data, including data analysis (Glazer, 2015). Practicing data analysis is often done in physics class, but data analysis skills are used in various real-life applications. Constructing and interpreting visual data presentation in the form of a graph is included in data analysis skills. In physics, a graph is also a powerful model representation to present the behavior of physical phenomena (Stefanel, 2019). It is also able to reduce the cognitive load and promote cognitive thinking (Pospiech, 2019). Prompt students in interpreting graphs will be useful not only to understand physical concepts but also to train crucial data skills for the future workforce.

E-learning in Physics and Its Challenges

Distance learning has been existing for a long time ago. Following internet and computer technology growth, distance learning has become more facilitated. The concept of electronic-learning or E-learning emerges as the internet becomes more accessible around the world. Nowadays, there is a various e-learning platform that teachers and students can use. The frequency of direct interaction between teacher and students during distance learning was very low in the past. However, with the current communication technology, such as online meeting applications, direct interaction between teacher and students in distance learning become easier (Pratama, Nor, Azman, Kassymova, & Shakizat, 2020).

A learning management system (LMS) also facilitates e-learning well. With LMS, such as Moodle, a teacher can construct interactive and effective material, discussion, and assessment. E-learning is not only used for fully distance learning courses. Teachers can combine a regular face-to-face meeting with e-learning. The combination brought out the concept of blended learning and flipped learning. Shurygin & Sabirova (2017) implement blended learning in teaching physics by using LMS Moodle. It has several positive impacts, such as allowing personalization in education process and motivating students to work independently (Shurygin & Sabirova, 2017).

COVID-19 pandemic forces school closure to minimize human physical contact. Education institutions must change face-to-face classes to remote classes. Some teachers and students have experienced E-learning before; the sudden change has become troublesome for some courses. There is a considerable impact for a practical course such as a physics experiment course. When a hands-on experiment in the laboratory is hard to conduct, teachers need to find other alternative learning methods. Computer and mobile technologies give some alternative activities. It involves computer simulation (Bayrak, 2008; Develaki, 2017; Habibi, Jumadi, & Mundilarto, 2020; Pratidhina, Pujianto, & Sumardi, 2019), simple experiment project with easy to get tools (including smartphone sensor) (Arribas, Escobar, & Suarez, 2015; Pili & Violanda, 2018), pre-recorded video demonstration, live demonstration (Kestin, Miller, Mccarty, Callaghan, & Deslauriers, 2020) and remote laboratory (Hoyer & Girwidz, 2018).

Tracker as a Video modeling tool in physics teaching

Tracker is one of the helpful video modeling tools in physics teaching. It is computer software developed on the Open Source Physics Java code library. Hence, students and teachers can download and use it for free. Tracker provides various features to analyze physics experimental data that has been recorded in a video file. In Tracker, users can track the position, velocity, and acceleration of a particular moving object (Brown, 2020). Moreover, Tracker also has an RGB line profile feature that can be used to analyze spectra (Pratidhina, Wandaru, & Kuswanto, 2020; Rodrigues, Marques, & Sime, 2016). This feature helps get a light intensity distribution graph in light diffraction, interference, or polarization experiment. Some papers have described how to use Tracker in modeling and understanding physics topics in high school and undergraduate levels, such as harmonic motion (Kinchin, 2016), free fall (Wee, Tan, & Leong, 2015), projectile motion (Wee, Chew, Goh, Tan, & Lee, 2012), rotational dynamic (Eadkhong, Rajsadorn, Jannual, & Danworaphong, 2012), electricity and magnetism (Aguilar-Marin, Chaves-Bacilio, & Jáuregui-Rosas, 2018), refraction (Ürek, Özdemir, & Coramik, 2021), and reflection (Rodrigues & Carvalho, 2014). In previous studies, implementing Tracker as a pedagogy tool has shown several advantages, such as improving learning motivation (Wee et al., 2015), increasing conceptual understanding (Amaliah, Darmadi, & Saehana, 2020), and developing conceptual thinking (Hockicko, Krišták, & Miroslav, 2015).

Research Methods

Research Design

This study was intended to investigate the effectiveness and students' view of modeling-based learning activity using Tracker in an undergraduate online physics experiment. The one-group pre-and post-test design was used in the study. Pre- and post-test were given before and after students were exposed to the Tracker assisted modeling activity.

Research Participant

The research was conducted at Physics Education Department in Widya Mandala Catholic University Surabaya, Indonesia. We asked all undergraduate students there who take the Advance Physics Experiment course 2020 to participate in the learning activity. In total, 21 students participate. They consist of 7 male and 14 female students. All students join an online course with a laptop and have considerably good internet access.

Instrument

Instruments used in this research are pre-test, post-test and questionnaire. Pre- and post-test are used to investigate how the learning activity affects graph interpretation skills. There are five questions related to graph interpretation skills given in the pre-and post-test; students need to complete them within 20 minutes. To get the students' feedback on the learning activity, they were asked to fill Likert scale questionnaire.

Data Analysis

To describe the comparison between pre-and post-test, we use normalized gain, $\langle g \rangle$ as an indicator. The formula to calculate normalized-gain is given in equation (1). The criteria of normalized-gain are shown in Table 1.

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre} \qquad (1)$$

where $\%post$ is the pre-test score in percentage, $\%pre$ is the pre-test score in percentage. We calculate both individual normalized-gain and class average normalized-gain.

Table 1. Criteria of the normalized-gain score (Hake, 1998)

Normalized Gain, $\langle g \rangle$	**Criteria**
$\langle g \rangle \geq 0.7$	High
$0.3 \geq \langle g \rangle > 0.7$	Medium
$\langle g \rangle < 0.3$	Low

Result and Discussion

Learning Activity

The participants involved in this study were students who took Advanced Physics Experiment class. This course is mandatory in the Physics Education major. Before students take this course, they took Physics II. The theory of diffraction had been studied in Physics II. Therefore, students who participated in this study had a prior theoretical model of single-slit diffraction. The learning process involved synchronous and asynchronous sessions. The synchronous session was conducted by using Zoom. Meanwhile, asynchronous sessions used the Moodle platform. The learning phases are explained in Table 2.

Table 2. The Learning Activity Phases

Phase	Description	Platform
1.Pre-test	The pre-test was given to students online before they participate in the modeling activity.	Moodle
2.Introduction to Tracker	This phase was conducted asynchronously and synchronously. Before synchronous class, students watched a video explaining how to install and use Tracker to analyze physics experiments. All students had installed Tracker on their computer before the first synchronous class.	Moodle and Zoom
3.Orientation	In the orientation, the lecturer introduced students to the experimental set-up of diffraction with a single slit. The lecturer demonstrated how to do the experiment, and students were asked to observe the diffraction pattern results in the experiment. Students were also asked to hypothesize how the variation of slit width, screen-slit distance, and light wavelength affects the diffraction pattern.	Zoom
4.Exploration	To test the hypothesis, students need to do an investigation. In normal laboratory work, students will do hands-on experiments directly. However, in this online course, instead of students doing a hands-on experiment, the lecturer gave a recorded video about the diffraction experiment with a single slit. The video showed the diffraction pattern when the slit width, screen-slit distance, and light wavelength were varied. Students had to import the video to Tracker and then plot the diffraction pattern's intensity distribution with the Line Profile feature in Tracker (see Figures 1 and 2).	Moodle
5.Model adduction	Students are asked to identify the difference of intensity distribution in diffraction pattern, when the slit width, scree-slit distance and wavelength are varied. They can discuss it in group via Moodle forum.	Moodle
6.Model formulation	After discussing their observation and analysis results, students were asked to make theoretical modeling of diffraction with a single slit. Students also had to relate the experimental result and the light intensity equation yield in the modeling process. To help students connect the theoretical equation and experimental result, they could use Excel to plot the light intensity at each point.	Moodle
7.Reflection	Finally, students reflected on the activities that they had done. They evaluated the limitation of the activity and gave their idea of how to improve the experimental result. After the whole process, students needed to make a report and submit it.	Moodle
8.Post-test	After submitting their task, students did a post-test. The post-test consisted of the same question as the pre-test. Students had to complete it within 20 minutes. After finished the post-test, students were asked to fill a questioner that asks their views on the use of Tracker in the online Advanced Physics Experiment course.	Moodle

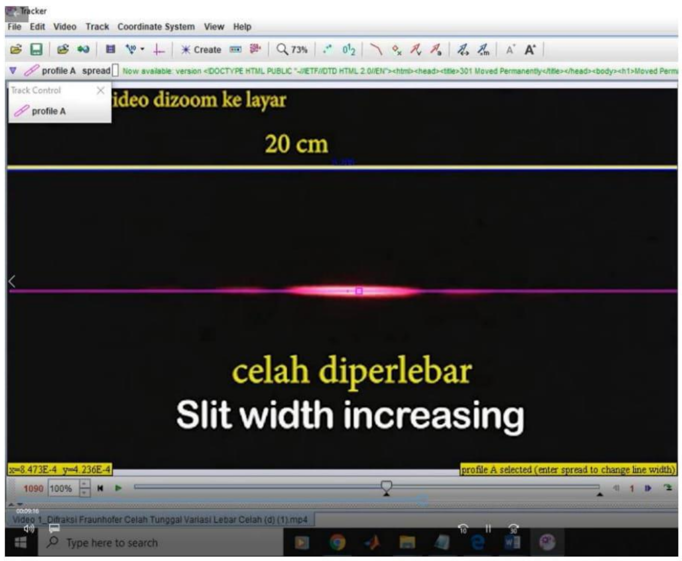

Figure 1. Students performed an investigation of diffraction phenomena by using Tracker.

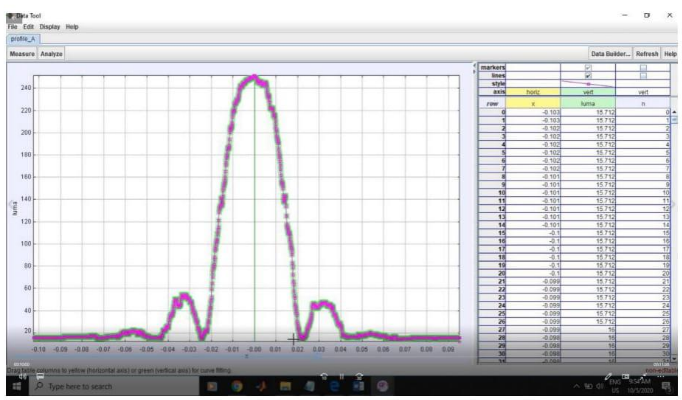

Figure 2. Analysis feature in Tracker can help students to look at the details of the experimental result and perform modeling

Effect of the Learning Activity

In general, this study has shown that using Tracker in modeling activity improves students' graph interpretation skills. Table 3 shows the comparison between pre-and post-test scores. The normalized gain score is calculated according to Eq 1 to compare the pre-and post-test. There is only one student's score that decreases. The other 20 students improved their post-test scores with various normalized-gain. Thirteen students obtain a high normalized-gain, five students receive medium normalized-gain, and one student receives low normalized-gain. The class average of pre-and post-test is shown in Table 4. Based on the average score, the average normalized-gain is calculated to be 0.74, categorized as a high normalized-gain.

Table 3. Comparison between individual pre-test and post-test score

Student	**Final Pre-test Score (max=100)**	**Final Post-test Score (max=100)**	**Individual ⟨*g*⟩**	**Criteria**
S1	0.00	60.00	0.60	medium
S2	60.00	100.00	1.00	high
S3	40.00	60.00	0.33	medium
S4	0.00	100.00	1.00	high
S5	20.00	80.00	0.75	high
S6	40.00	20.00	-0.33	decrease
S7	40.00	100.00	1.00	high
S8	20.00	100.00	1.00	high
S9	40.00	100.00	1.00	high
S10	40.00	100.00	1.00	high
S11	0.00	20.00	0.20	low
S12	20.00	60.00	0.50	medium
S13	0.00	100.00	1.00	high
S14	40.00	100.00	1.00	high
S15	0.00	40.00	0.40	medium
S16	40.00	100.00	1.00	high
S17	20.00	80.00	0.75	high
S18	20.00	100.00	1.00	high
S19	40.00	100.00	1.00	high
S20	20.00	60.00	0.50	medium
S21	0.00	100.00	1.00	high

Table 4. Comparison between class average pre-test and post-test score

Average final pre-test core	**Average final post-test core**	**Average ⟨*g*⟩**	**Criteria**
23.81	80.00	0.74	High

There are 5 questions in the pre-and post-test. All of the questions have indicators related to interpreting graphs. The average scores of each question are given in Table 5. Although students had learned the theory of diffraction in the previous course, the pre-test score is still low. It indicates that students were still not fluent in interpreting graph. In general, the average score of each question in post-test improves. Based on the calculated normalized-gain, score on Q1 and Q3 moderately improve, while scores on Q2, Q4, and Q5 highly improve.

Table 5. Comparison between the average class score of each question on the pre-and post-test score

Question	Indicators	Pre-test Average (max=100)	Post-test Average (max=100)	$\langle g \rangle$	Criteria
Q1	Student can predict the light intensity pattern/graph in single slit diffraction for certain experimental set-up	9.5	71.4	0.68	medium
Q2	Student can guess experimental set-up in single slit diffraction based on the intensity graph interpretation	19.0	81.0	0.76	high
Q3	Student can predict the light intensity pattern/graph when the experiment parameter (slit width) in single slit diffraction is changed	38.1	81.0	0.69	medium
Q4	Student can predict the light intensity pattern/ graph when the experiment parameter (distance between slit and screen) in single slit diffraction is changed	23.8	85.7	0.81	high
Q5	Student can interpret the light wavelength used in the experiment based on the intensity graph	28.6	81.0	0.73	high

Students' View on the Learning Activity

Besides the test about graph interpretation skills, five Likert scale questionnaires were given to students. Out of 21 participants, 15 participants filled and submitted the questionnaires appropriately. The survey aims to collect the students' views on the modeling activity using Tracker in the learning process. The summary of the survey is presented in Table 6. The questionnaire's overall mean score is 4.1, which can be interpreted as high (Ibrahim, Bakar, Asimiran, Mohamed, & Zakaria, 2015).

Based on the survey, 80% of students agreed that modeling activity using Tracker in the Advance Physics Experiment course gave them more opportunity to learn than just observing live demonstrations and analyzing data provided by the lecturer. 93.3% of students also agreed that they could learn data analysis techniques in physics experiments. 93.3% of students thought Tracker and Excel, which were used during the learning activity, helped them interpret experimental results. It is in line with the improvement of graph interpretation skills.

Before this study was conducted, in the online Advanced Physics Experiment course, the lecturer usually did a live demonstration via zoom every week. Students had to make an experiment report based on the lecturer's data. The modeling activity using Tracker was something new for students. According to the survey, 73.3% of students stated that it is easy to understand how to use Tracker. Some of the students may think that it is quite difficult because it is something new for them. However, it has positive effects on students' motivation; 80% of students stated that the activity improves the online physics course motivations and 86.7% of students wanted to explore more physics phenomena with Tracker.

Table 6. Students' View on Modeling Activity using Tracker

No.	Statements	Strongly disagree (1)	Disagree (2)	Don't know (3)	Agree (4)	Strongly agree (5)	Mean score
1	The introduction given in the experiment video gives a clear explanation about Fraunhofer-Diffraction experimental set-up	1 (6.7%)	0 (0%)	1 (6.7%)	3 (20%)	10 (66.7%)	4.4
2	Compare to observing live demonstration and analyze a set of data given by the lecturer, experiment video analysis activity using Tracker gives me more opportunity in learning	0 (0%)	1 (6.7%)	2 (13.3%)	4 (26.7%)	8 (53.3%)	4.3
3	I have an opportunity in learning analysis technique in physics experiment through an activity using Tracker and Excel	0 (0%)	1 (6.7%)	0 (0%)	5 (33.3%)	9 (60%)	4.5
4	Analysis using Tracker and Excel help me to interpret the experimental result	0 (0%)	1 (6.7%)	0 (0%)	7 (46.7%)	7 (46.7%)	4.3
5	I want to explore more physical phenome using Tracker software	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4
6	The learning activity using Tracker improves my motivation in learning physics online	1 (6.7%)	0 (0%)	2 (13.3%)	8 (53.3%)	4 (26.7%)	3.9
7	Understanding how to use Tracker is easy	0 (0%)	1 (6.7%)	3 (20%)	9 (60%)	2 (13.3%)	3.8
8	Activity using Tracker and Excel helps me to connect theoretical models and experimental results.	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4.0
9	Activity using Tracker helps me to interpret the physical meaning of a graph representation.	1 (6.7%)	0 (0%)	1 (6.7%)	7 (46.7%)	6 (40%)	4.1
Overall mean score							4.1

Conclusion

Teaching physics and other science courses during the COVID-19 pandemic is challenging, especially when we need to transform face-to-face laboratory-based courses into online courses. Besides, maintaining students' learning motivation during the online course is also not an easy task. Hence, educators need to implement innovative learning activities during the online course. In this study, we have shown Tracker-assisted modeling activity in the undergraduate Advanced Physics Experiment course. The study shows that the learning activity effectively improves students' data skills especially related to graph interpretation; the normalized-gain is 0.74, which can be categorized as high. This skill is important for preparing the future workforce. Moreover, students also stated that they are more motivated to learn physics online and have more opportunities to learn during the modeling activity by using Tracker. In the future study, Tracker-assisted modeling-activity can also be combined with simple experiment project that can be conducted at home.

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2.	**Bukti hasil review (revision)**	**20 Mei 2021**

Gmail Elisabeth Founda <elisa.founda@gmail.com>

Editorial Decision: Article ID- JEELR/917/2021

Asian Online Journal Publishing Group <editor@asianonlinejournals.com> Thu, May 20, 2021 at 5:50 PM
To: Elisabeth Pratidhina Founda Noviani <elisa.founda@ukwms.ac.id>

Paper for Proofread: 917-JEELR

Dear Elisabeth Pratidhina

We are going to publish your paper in the forthcoming issue of **"JEELR".** Please improve your paper by changing the following:

1. Please check all the section numbers of the article.

2. Your paper abstract should not exceed 240 words

3. You should present from 6 to 10 keywords in the paper.

4. It is necessary to review the English (English must be improved).

5. Please provide the details of missing information in the references.

6. Please send us ORCID profile link of all authors. If you don't have an ORCID profile, please open the given link (www.orcid.org), create a profile and send us a link.

Please send us a revised file within 48 hours by including the above comments. Otherwise, your paper will be pending for publication.

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I look forward to hearing from you.

Sincerely.

Sara Lim
Managing Editor

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On Thu, May 20, 2021 at 12:52 PM Elisabeth Pratidhina Founda Noviani <elisa.founda@ukwms.ac.id> wrote:

> Thank you for your kind response.
>
> Can you inform us of the expected period for publication?
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> Thank you
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2 attachments

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6	Please complete properly the cited references of book review, working paper and conference paper. You will need to properly check the publisher, publisher country name, page no. **List of References** Hestenes, D. (1997). Modeling methodology for physics teachers. *935.*
7	Please check heading and sub heading numbers.

8	Check the grammar and spelling mistake with the words those are highlighted in green color.
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3.	**Bukti submit revisi**	**22 Mei 2021**

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Elisabeth Founda <elisa.founda@gmail.com>

Editorial Decision: Article ID- JEELR/917/2021

Elisabeth Founda <elisa.founda@gmail.com> Sat, May 22, 2021 at 2:53 PM
To: Asian Online Journal Publishing Group <editor@asianonlinejournals.com>

Dear JEELR Editors,

Thank you for sending us an email. We have revised our manuscript according to your advice.

Here is the list of modifications that we have made:

1. We added **Contribution of this paper to the literature:**
"This study contributes to existing literature on modeling theory in physics education, learning technology, and online learning. This paper explains the implementation of modeling approach in an undergraduate online laboratory-based physics course. Tracker is used to facilitate the modeling process of a physics phenomenon in online class. The findings of this study confirm that Tracker-assisted modeling activity can improve students' graph interpretation skill and learning motivation in online class."

2. We wrote 6 keywords
3. In Table 1, we corrected criteria for medium gain to 0.7> <g> >= 0.3
4. We added information sources of Table 1
5. In Table 2, number 5, we corrected typo 'scree-slit' to 'screen-slit'
6. Information in Table 2 is based on the Author's idea of a lesson plan that has been implemented. Hence, we did not add any source.
7. Figure 1 and 2 are Authors' documentation of students' works. Hence, we also did not add any source.
8. Table 3, 4, 5, and 6 are based on our research data. Hence, we also did not add any source
9. We have corrected the following references:
   - Cascarosa., E., Sánchez-Azqueta, C., Gimeno, C., & Aldea, C. (2020). Model-based teaching of physics in higher education: A review of educational strategies and cognitive improvements. *Journal of Applied Research in Higher Education, 13*(1), 33-47.Available at https://doi.org/10.1108/JARHE-11-2019-0287.
   - Hestenes, D. (1997). Modeling methodology for physics teachers. *AIP Conference Proceedings, 399*(935).Available at: https://doi.org/10.1063/1.53196.
   - Trocaru, S., Berlic, C., Miron, C., & Barna, V. (2020). Using tracker as video analysis and augmented reality tool for investigation of the oscillations for coupled pendula. *Romanian Reports in Physics, 72*(902), 1-16.

10. We added a missing reference:
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. Available at: http://dttps://doi.org/10.1119/1.18809

11. The detail information of authors is given in a separate file (authors information)

Note: all corrected parts are highlighted with blue color.
We look forward to hear further feedback from you

Sincerely,

[Quoted text hidden]

With sincere regards,

Elisabeth Pratidhina Founda Noviani

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2 attachments

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Implementation of Tracker-Assisted Modelling Activity in Online Advanced Physics Experiment Course

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Abstract
Experiment or laboratory-work is an essential part of physics and other science subjects. However, due to COVID-19 pandemic, face-to-face classes must be transformed to remote classes. Hence, access to the laboratory becomes very limited during the remote class. Technology has to be utilized to substitute hands-on activity in laboratory based-course. Other than that, maintaining students' motivation in remote class is also challenging. In this paper, we propose implementing modeling activity by using Tracker in the online Advanced Physics Experiment course. We examine the effectiveness of Tracker-assisted modeling activity in improving graph interpretation skills on the topics of Fraunhofer-Diffraction. The study shows that 20 out of 21 participants have shown an increase in graph interpretation skills. The average normalized gain is 0.74, which can be seen as a high improvement. Although the activity could not facilitate students' practicing hands-on skills, this activity can encourage students to practice other science process skill aspects. Moreover, according to the survey, students feel more motivated to learn physics online after exposed to the modeling activity.

Keywords: Modeling, Physics experiment, Graph interpretation, Learning motivation, Online course.

Contribution of this paper to the literature
This study contributes to existing literature on modeling theory in physics education, learning technology, and online learning. This paper explains the implementation of modeling approach in an undergraduate online laboratory-based physics course. Tracker is used to facilitate the modeling process of a physics phenomenon in online class. The finding of this study confirm that Tracker-assisted modeling activity can improve students' graph interpretation skill and learning motivation in online class.

1. Introduction
Distance learning has transformed significantly as digital technology develops tremendously. The main problem of distance learning in the past is the lack of interaction between teachers and students. However, with more accessible internet and advance communication technology, that main obstacle can be reduced significantly. Still, distance learning has a significant problem, especially for a science course. The problem is mainly related to bringing laboratory work or experiments in distance learning (Aththibby, Kuswanto, & Mundilarto, 2021).

Laboratory work is an indispensable part of science courses; it facilitates students to inquire, think critically, and practice generating scientific information. Previous studies also show that students' attitudes toward science improve when students are involved in laboratory work. Moreover, it is essential to reveal a meaningful understanding of science concepts (Sadoglu & Durukan, 2018).

COVID-19 pandemic, which started in early 2020, has affected the education system around the world. The schools are forced to close to minimize the spread of the virus. Hence, students and teachers are forced to convert the face-to-face course to remote mode with online learning. In a short period, teachers need to design the online course. For Physics Education Department, the challenge is transforming practical-based courses into online learning. The practical-based course usually is done in a laboratory and requires hands-on activity, but direct access to laboratory is impossible in online learning. Even though it cannot replace hands-on activity, some technologies can be implemented as alternatives (Aththibby et al., 2021; Campari et al., 2021; Pols, 2020).

In this work, we explain the alternative of using Tracker as a video modeling software that students can use for taking data from experiment video, analyzing the data, and helping them in modeling. Instead of students do a hands-on experiment in the lab, the teacher record the experiment and give the video to students. The students then observe the physical phenomena in the video and take quantitative data by using Tracker (Brown. & Cox, 2009). Tracker has been widely used in the physics education community to enhance face-to-face physics courses (Castaneda, 2019; Eddy, 2016; Trocaru, Berlic, Miron, & Barna, 2020). The learning activity implemented in this work is based on modeling. Modeling-based learning encourages students to construct a scientific model or solve particular problems like a real scientist (Cascarosa., Sánchez-Azqueta, Gimeno, & Aldea, 2020). Even though this online activity may not facilitate competencies related to practical things such as using apparatus and laboratory safety, it can also stimulate students to develop other competencies such as data skills and communication skills.

In particular, we investigate how the modeling activity using Tracker affects one aspect of data skill, i.e., graph interpretation skills. A graph is one of the data representations that is widely used in various fields. To anticipate future career paths, students need to get used to interpreting graphs (Ergül, 2018).

2. Literature Review

2.1. Model and Modeling in Physics Learning

Model in physics is a simplified version of a part of the targeted physical world. Based on the representation method, models can be categorized into six types, i.e. concrete models, verbal models, visual models, mathematical models, action models, and a mix of those models (Buckley & Boulter, 2000).

Modeling is a process that scientist uses to construct a scientific model or solve particular problems. Although modeling is initially coming from a process usually done by scientists, it is also adapted in the science learning process (Wang, Jou, Lv, & Huang, 2018). Students can go through the modeling process to develop scientific knowledge. The principle of modeling in learning science is constructing a mental model to understand a phenomenon and using the cognitive model to solve a problem.

There are several learning cycles proposed based on modeling. Hestenes stated that the physics modeling process comprises 3 main parts, i.e., modeling, model analysis, and model validation (Hestenes, 1997). Halloun (2007) also developed a learning cycle based on the modeling process; the learning cycle consists of exploration, model adduction, model formulation, model deployment, and paradigmatic synthesis (Halloun, 2007). Meanwhile, Brew proposed five steps: introduction and representation, coordination of representation, application, abstraction and generalization, and continued incremental development (Brewe, 2008). In another study, modeling-based flipped learning has been developed. Flipped learning stages consist of exploration, model adduction, model formulation, and model deployment (Wang et al., 2018). Several studies have indicated the positive impact of model-based learning. The implementation of model-based learning in school can reduce alternative conceptions, clarify disagreement between intuition and physics phenomenon, improve argumentation skill, connect theory and experimental data, improve problem-solving strategies, mediate a new concept with prior knowledge or other disciplines, and help student in understanding the image of nature (Cascarosa. et al., 2020).

2.2. Graph Interpretation Skill

One of the critical competence in the twenty-first century is working with data, including data analysis (Glazer, 2015). Practicing data analysis is often done in physics class, but data analysis skills are used in various real-life applications. Constructing and interpreting visual data presentation in the form of a graph is included in data analysis skills. In physics, a graph is also a powerful model representation to present the behavior of physical phenomena (Stefanel, 2019). It is also able to reduce the cognitive load and promote cognitive thinking (Pospiech, 2019). Prompt students in interpreting graphs will be useful not only to understand physical concepts but also to train crucial data skills for the future workforce.

2.3. E-Learning in Physics and Its Challenges

Distance learning has been existing for a long time ago. Following internet and computer technology growth, distance learning has become more facilitated. The concept of electronic-learning or E-learning emerges as the internet becomes more accessible around the world. Nowadays, there is a various e-learning platform that teachers and students can use. The frequency of direct interaction between teacher and students during distance learning was very low in the past. However, with the current communication technology, such as online meeting applications, direct interaction between teacher and students in distance learning become easier (Pratama, Azman, Kassymova, & Duisenbayeva, 2020).

A learning management system (LMS) also facilitates e-learning well. With LMS, such as Moodle, a teacher can construct interactive and effective material, discussion, and assessment. E-learning is not only used for fully distance learning courses. Teachers can combine a regular face-to-face meeting with e-learning. The combination brought out the concept of blended learning and flipped learning. Shurygin and Sabirova (2017) implement blended learning in teaching physics by using LMS Moodle. It has several positive impacts, such as allowing personalization in education process and motivating students to work independently (Shurygin & Sabirova, 2017).

COVID-19 pandemic forces school closure to minimize human physical contact. Education institutions must change face-to-face classes to remote classes. Some teachers and students have experienced E-learning before; the sudden change has become troublesome for some courses. There is a considerable impact for a practical course such as a physics experiment course. When a hands-on experiment in the laboratory is hard to conduct, teachers need to find other alternative learning methods. Computer and mobile technologies give some alternative activities. It involves computer simulation (Bayrak, 2008; Develaki, 2017; Habibi, Jumadi, & Mundilarto, 2020; Pratidhina, Pujianto, & Sumardi, 2019) simple experiment project with easy to get tools (including smartphone sensor)(Arribas, Escobar, & Suarez, 2015; Pili & Violanda, 2018), pre-recorded video demonstration, live demonstration (Kestin, Miller, Mccarty, Callaghan, & Deslauriers, 2020) and remote laboratory (Hoyer & Girwidz, 2018).

2.4. Tracker as a Video Modeling Tool in Physics Teaching

Tracker is one of the helpful video modeling tools in physics teaching. It is computer software developed on the Open Source Physics Java code library. Hence, students and teachers can download and use it for free. Tracker provides various features to analyze physics experimental data that has been recorded in a video file. In Tracker, users can track the position, velocity, and acceleration of a particular moving object (Brown, 2020). Moreover, Tracker also has an RGB line profile feature that can be used to analyze spectra (Pratidhina., Dwandaru, & Kuswanto, 2020; Rodrigues, Marques, & Sime, 2016). This feature helps get a light intensity distribution graph in light diffraction, interference, or polarization experiment. Some papers have described how to use Tracker in modeling and understanding physics topics in high school and undergraduate levels, such as harmonic motion (Kinchin, 2016) free fall (Wee, Tan, & Leong, 2015) projectile motion (Wee., Chew, Goh, Tan, & Lee, 2012) rotational dynamic (Eadkhong, Rajsadorn, Jannual, & Danworaphong, 2012) electricity and magnetism (Aguilar-Marin, Chaves-Bacilio, & Jáuregui-Rosas, 2018) refraction (Ürek, Özdemir, & Coramik, 2021) and reflection(Rodrigues. & Carvalho, 2014). In previous studies, implementing Tracker as a pedagogy tool has shown several advantages, such as improving learning motivation (Wee, Tan, & Leong, 2015) increasing conceptual understanding (Amaliah, Darmadi, & Saehana, 2020) and developing conceptual thinking (Hockicko, Krišták, & Miroslav, 2015).

3. Research Methods

3.1. Research Design

This study was intended to investigate the effectiveness and students' view of modeling-based learning activity using Tracker in an undergraduate online physics experiment. The one-group pre-and post-test design was used in the study. Pre- and post-test were given before and after students were exposed to the Tracker assisted modeling activity.

3.2. Research Participant

The research was conducted at Physics Education Department in Widya Mandala Catholic University Surabaya, Indonesia. We asked all undergraduate students there who take the Advance Physics Experiment course 2020 to participate in the learning activity. In total, 21 students participate. They consist of 7 male and 14 female students. All students join an online course with a laptop and have considerably good internet access.

3.3. Instrument

Instruments used in this research are pre-test, post-test and questionnaire. Pre- and post-test are used to investigate how the learning activity affects graph interpretation skills. There are five questions related to graph interpretation skills given in the pre-and post-test; students need to complete them within 20 minutes. To get the students' feedback on the learning activity, they were asked to fill Likert scale questionnaire.

3.4 Data Analysis

To describe the comparison between pre-and post-test, we use normalized gain, $\langle g \rangle$ as an indicator. The formula to calculate normalized-gain is given in Equation 1. The criteria of normalized-gain are shown in Table 1.

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre} \qquad (1)$$

where $\%post$ is the pre-test score in percentage, $\%pre$ is the pre-test score in percentage. We calculate both individual normalized-gain and class average normalized-gain.

Table-1. Criteria of the normalized-gain score (Hake, 1998).

Normalized Gain, $\langle g \rangle$	Criteria
$\langle g \rangle \geq 0.7$	High
$0.7 > \langle g \rangle \geq 0.3$	Medium
$\langle g \rangle < 0.3$	Low

Source: Criteria adopted from Hake (1998)

4. Result and Discussion

4.1. Learning Activity

The participants involved in this study were students who were taking Advanced Physics Experiment class. This course is mandatory in the Physics Education major. Before students take this course, they took Physics II. The theory of diffraction had been studied in Physics II. Therefore, students who participated in this stud y had a prior theoretical model of single-slit diffraction. The learning process involved synchronous and asynchronous sessions. The synchronous session was conducted by using Zoom. Meanwhile, asynchronous sessions used the Moodle platform. The learning phases are explained in Table 2.

Table-2. The learning activity phases.

Phase	Description	Platform
1. Pre-test	The pre-test was given to students online before they participate in the modeling activity.	Moodle
2. Introduction to Tracker	This phase was conducted asynchronously and synchronously. Before synchronous class, students watched a video explaining how to install and use Tracker to analyze physics experiments. All students had installed Tracker on their computer before the first synchronous class.	Moodle and Zoom
3. Orientation	In the orientation, the lecturer introduced students to the experimental set-up of diffraction with a single slit. The lecturer demonstrated how to do the experiment, and students were asked to observe the diffraction pattern results in the experiment. Students were also asked to hypothesize how the variation of slit width, screen-slit distance, and light wavelength affects the diffraction pattern.	Zoom
4. Exploration	To test the hypothesis, students need to do an investigation. In normal laboratory work, students will do hands-on experiments directly. However, in this online course, instead of students doing a hands-on experiment, the lecturer gave a recorded video about the diffraction experiment with a single slit. The video showed the diffraction pattern when the slit width, screen-slit distance, and light wavelength were varied. Students had to	Moodle

	import the video to Tracker and then plot the diffraction pattern's intensity distribution with the Line Profile feature in Tracker (see Figures 1 and 2).	
5. Model adduction	Students are asked to identify the difference of intensity distribution in diffraction pattern, when the slit width, screen-slit distance and wavelength are varied. They can discuss it in group via Moodle forum.	Moodle
6. Model formulation	After discussing their observation and analysis results, students were asked to make theoretical modeling of diffraction with a single slit. Students also had to relate the experimental result and the light intensity equation yield in the modeling process. To help students connect the theoretical equation and experimental result, they could use Excel to plot the light intensity at each point.	Moodle
7. Reflection	Finally, students reflected on the activities that they had done. They evaluated the limitation of the activity and gave their idea of how to improve the experimental result. After the whole process, students needed to make a report and submit it.	Moodle
8. Post-test	After submitting their task, students did a post-test. The post-test consisted of the same question as the pre-test. Students had to complete it within 20 minutes. After finished the post-test, students were asked to fill a questioner that asks their views on the use of Tracker in the online Advanced Physics Experiment course.	Moodle

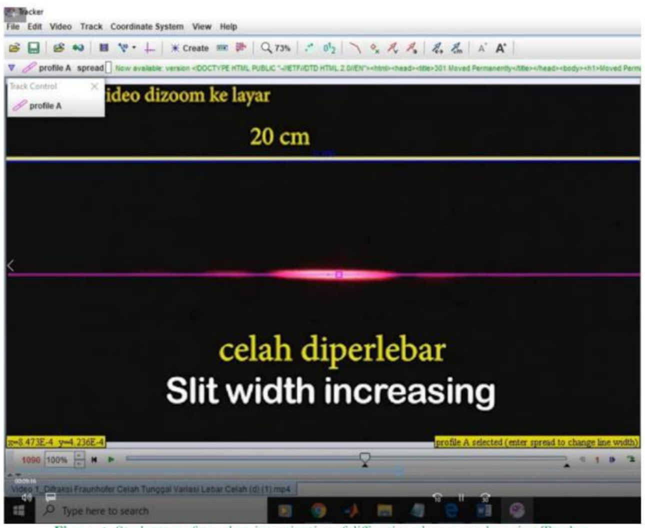

Figure-1. Students performed an investigation of diffraction phenomena by using Tracker.

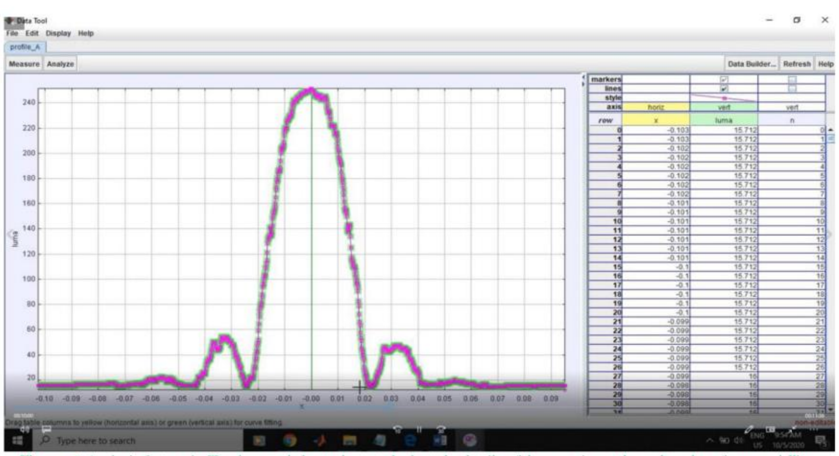

Figure-2. Analysis feature in Tracker can help students to look at the details of the experimental result and perform modelling.

4.2. *Effect of the Learning Activity*

In general, this study has shown that using Tracker in modeling activity improves students' graph interpretation skills. Table 3 shows the comparison between pre-and post-test scores. The normalized gain score is calculated according to Equation 1 to compare the pre-and post-test. There is only one student's score that decreases. The other

20 students improved their post-test scores with various normalized-gain. Thirteen students obtain a high normalized-gain, five students receive medium normalized-gain, and one student receives low normalized-gain. The class average of pre-and post-test is shown in Table 4. Based on the average score, the average normalized-gain is calculated to be 0.74, categorized as a high normalized-gain.

Table-3. Comparison between individual pre-test and post-test score.

Student	Final Pre-test Score (max=100)	Final Post-test Score (max=100)	Individual $\langle g \rangle$	Criteria
S1	0.00	60.00	0.60	medium
S2	60.00	100.00	1.00	high
S3	40.00	60.00	0.33	medium
S4	0.00	100.00	1.00	high
S5	20.00	80.00	0.75	high
S6	40.00	20.00	-0.33	decrease
S7	40.00	100.00	1.00	high
S8	20.00	100.00	1.00	high
S9	40.00	100.00	1.00	high
S10	40.00	100.00	1.00	high
S11	0.00	20.00	0.20	low
S12	20.00	60.00	0.50	medium
S13	0.00	100.00	1.00	high
S14	40.00	100.00	1.00	high
S15	0.00	40.00	0.40	medium
S16	40.00	100.00	1.00	high
S17	20.00	80.00	0.75	high
S18	20.00	100.00	1.00	high
S19	40.00	100.00	1.00	high
S20	20.00	60.00	0.50	medium
S21	0.00	100.00	1.00	high

Table-4. Comparison between class average pre-test and post-test score.

Average final pre-test core	Average final post-test core	Average $\langle g \rangle$	Criteria
23.81	80.00	0.74	High

There are 5 questions in the pre-and post-test. All of the questions have indicators related to interpreting graphs. The average scores of each question are given in Table 5. Although students had learned the theory of diffraction in the previous course, the pre-test score is still low. It indicates that students were still not fluent in interpreting graph. In general, the average score of each question in post-test improves. Based on the calculated normalized-gain, score on Q1 and Q3 moderately improve, while scores on Q2, Q4, and Q5 highly improve.

Table-5. Comparison between the average class score of each question on the pre-and post-test score.

Question	Indicators	Pre-test Average (max=100)	Post-test Average (max=100)	$\langle g \rangle$	Criteria
Q1	Student can predict the light intensity pattern/graph in single slit diffraction for certain experimental set-up	9.5	71.4	0.68	medium
Q2	Student can guess experimental set-up in single slit diffraction based on the intensity graph interpretation	19.0	81.0	0.76	high
Q3	Student can predict the light intensity pattern/graph when the experiment parameter (slit width) in single slit diffraction is changed	38.1	81.0	0.69	medium
Q4	Student can predict the light intensity pattern/ graph when the experiment parameter (distance between slit and screen) in single slit diffraction is changed	23.8	85.7	0.81	high
Q5	Student can interpret the light wavelength used in the experiment based on the intensity graph	28.6	81.0	0.73	high

4.3. Students' View on the Learning Activity

Besides the test about graph interpretation skills, five Likert scale questionnaires were given to students. Out of 21 participants, 15 participants filled and submitted the questionnaires appropriately. The survey aims to collect the students' views on the modeling activity using Tracker in the learning process. The summary of the survey is presented in Table 6. The questionnaire's overall mean score is 4.1, which can be interpreted as high (Ibrahim & Bakar, 2015).

Based on the survey, 80% of students agreed that modeling activity using Tracker in the Advance Physics Experiment course gave them more opportunity to learn than just observing live demonstrations and analyzing data provided by the lecturer. 93.3% of students also agreed that they could learn data analysis techniques in physics experiments. 93.3% of students thought Tracker and Excel, which were used during the learning activity, helped them interpret experimental results. It is in line with the improvement of graph interpretation skills.

Before this study was conducted, in the online Advanced Physics Experiment course, the lecturer usually did a live demonstration via zoom every week. Students had to make an experiment report based on the lecturer's data. The modeling activity using Tracker was something new for students. According to the survey, 73.3% of students stated that it is easy to understand how to use Tracker. Some of the students may think that it is quite difficult because it is something new for them. However, it has positive effects on students' motivation; 80% of students stated that the activity improves the online physics course motivations and 86.7% of students wanted to explore more physics phenomena with Tracker.

Table-6. Students' view on modeling activity using tracker.

No.	Statements	Strongly disagree (1)	Disagree (2)	Don't know (3)	Agree (4)	Strongly agree (5)	Mean score
1	The introduction given in the experiment video gives a clear explanation about Fraunhofer-Diffraction experimental set-up	1 (6.7%)	0 (0%)	1 (6.7%)	3 (20%)	10 (66.7%)	4.4
2	Compare to observing live demonstration and analyze a set of data given by the lecturer, experiment video analysis activity using Tracker gives me more opportunity in learning	0 (0%)	1 (6.7%)	2 (13.3%)	4 (26.7%)	8 (53.3%)	4.3
3	I have an opportunity in learning analysis technique in physics experiment through an activity using Tracker and Excel	0 (0%)	1 (6.7%)	0 (0%)	5 (33.3%)	9 (60%)	4.5
4	Analysis using Tracker and Excel help me to interpret the experimental result	0 (0%)	1 (6.7%)	0 (0%)	7 (46.7%)	7 (46.7%)	4.3
5	I want to explore more physical phenome using Tracker software	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4
6	The learning activity using Tracker improves my motivation in learning physics online	1 (6.7%)	0 (0%)	2 (13.3%)	8 (53.3%)	4 (26.7%)	3.9
7	Understanding how to use Tracker is easy	0 (0%)	1 (6.7%)	3 (20%)	9 (60%)	2 (13.3%)	3.8
8	Activity using Tracker and Excel helps me to connect theoretical models and experimental results.	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4.0
9	Activity using Tracker helps me to interpret the physical meaning of a graph representation.	1 (6.7%)	0 (0%)	1 (6.7%)	7 (46.7%)	6 (40%)	4.1
Overall mean score							4.1

5. Conclusion

Teaching physics and other science courses during the COVID-19 pandemic is challenging, especially when we need to transform face-to-face laboratory-based courses into online courses. Besides, maintaining students' learning motivation during the online course is also not an easy task. Hence, educators need to implement innovative learning activities during the online course. In this study, we have shown Tracker-assisted modeling activity in the undergraduate Advanced Physics Experiment course. The study shows that the learning activity effectively improves students' data skills especially related to graph interpretation; the normalized-gain is 0.74, which can be categorized as high. This skill is important for preparing the future workforce. Moreover, students also stated that they are more motivated to learn physics online and have more opportunities to learn during the modeling activity by using Tracker. In the future study, Tracker-assisted modeling-activity can also be combined with simple experiment project that can be conducted at home.

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Implementation of a Tracker-Assisted Modell~~l~~ing Activity in an Online Advanced Physics Experiment Course

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Abstract

Experiment or laboratory -work is an essential part of physics and other science ~~subjects~~courses. However, due to the COVID-19 pandemic, face-to-face classes ~~must be~~have had to be transformed ~~to~~ into remote classes. ~~Hence~~Because~~,~~ laboratory access ~~to the laboratory becomes~~has become very limited ~~during the remote class.~~, t~~T~~echnology ~~has to~~must be utilized to substitute for hands-on activity in laboratory-~~-~~based-courses. ~~Other than that~~Additionally, maintaining students' motivation ~~in~~ during remote classes is also challenging. In this paper, we ~~propose~~ report on the implementation of ~~implementing~~ modeling activit~~y~~ies ~~by~~ using Tracker in ~~the~~ our online Advanced Physics Experiment course. We examine the effectiveness of Tracker-assisted modeling activity in improving students' graph interpretation skills on the ~~topics~~topic of Fraunhofer-Diffraction. The ~~study~~ results ~~shows~~ show that 20 out of 21 participants ~~have shown~~demonstrated an increase in graph interpretation skills. The average normalized gain is 0.74, which can be seen as a high degree of improvement. Although the activity ~~could~~ did not ~~facilitate~~ allow students to practice~~,~~ ~~practicing~~ hands-on skills, this activity can encourage students to practice other science-related ~~process skill~~skills ~~aspects~~. Moreover, according to the survey, students feel more motivated to learn physics online after being exposed to the modeling activity.

Keywords: Modeling, Physics experiment, Graph interpretation, Learning motivation, Online course.

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Ethical: This study follows all ethical practices during writing.

Contents

Contribution of this paper to the literature
This study contributes to the existing literature on modeling theory in physics education, learning through technology, and online learning. This paper explains the implementation of a modeling approach in an undergraduate online laboratory-based physics course. Tracker is used to facilitate the modeling ~~process~~ of a physics phenomenon in an online class. The ~~finding~~ findings of this study confirm that the Tracker-assisted modeling activity ~~can improve~~improves students' graph interpretation ~~skill~~ skills and their learning motivation in an online class.

1. Introduction

As digital technology has developed rapidly, d~~D~~istance learning has undergone a significant transformation~~transformed significantly as digital technology develops tremendously~~. In the past, t~~T~~he main problem of distance learning ~~in the past is~~was the lack of interaction between teachers and students. However, with ~~more~~ the growing accessibility of the ~~accessible~~ internet and ~~advance~~ advanced communication ~~technology~~technologies, that ~~main~~ obstacle can ~~be reduced significantly~~for the most part be overcome. ~~Still~~However, distance learning ~~has a significant problem~~still poses significant challenges, especially for ~~a~~ science ~~course~~courses. In this case, ~~T~~the problem is mainly related to ~~bringing~~ the incorporation of laboratory work ~~or~~ and experiments in distance learning (Aththibby, Kuswanto, & Mundilarto, 2021).

Laboratory work is an indispensable part of science courses; it ~~facilitates~~ encourages students to inquire independently, think critically, and practice generating scientific information. Previous studies ~~also show~~have also demonstrated that students' attitudes toward science improve when ~~students are involved~~they take part in laboratory work. Moreover, it is an essential component for the creation of ~~to reveal~~ a meaningful understanding of ~~science~~ scientific concepts (Sadoglu & Durukan, 2018).

The COVID-19 pandemic, which started in early 2020, has affected ~~the~~ education ~~system~~ systems around the world. ~~The s~~Schools ~~are~~ have been forced to close to minimize the spread of the virus. Hence, students and teachers ~~are~~ have been forced to ~~convert the~~adapt their face-to-face ~~course~~ courses into a suitable~~to remote~~ mode ~~with~~ for remote online learning. ~~In a short period, t~~Teachers ~~need to~~have been required to design ~~the~~ online ~~course~~courses in a very short period of time. For the Physics Education Department, the main challenge ~~is~~ has been to transform ~~transforming~~ practical-based courses into online learning. The practical-based ~~course~~ courses are usually ~~is done~~conducted in a laboratory and ~~requires~~ require hands-on activity, but direct access to a laboratory is impossible in the case of online learning. However, ~~Even~~ although ~~it~~ they cannot completely replace hands-on activity, ~~some~~ certain technologies can be implemented as alternatives (Aththibby et al., 2021; Campari et al., 2021; Pols, 2020).

In this ~~work~~paper, we ~~explain the alternative~~explore the solution of using the video modeling software Tracker to enable ~~as a video modeling software that~~ students ~~can use for taking~~to collect data from the video of an experiment ~~video~~, analyz~~e~~ing the data, and ~~helping them in modeling~~create models. Instead of students ~~do~~ conducting a hands-on experiment in the lab, the teacher ~~record~~ records the experiment and ~~give the video to~~provides the students with a video. The students then observe the physical phenomena in the video and ~~take~~ collect quantitative data ~~by~~ using Tracker (Brown & Cox, 2009). Over the past years, Tracker has been widely used in the physics education community to enhance face-to-face physics courses (Castaneda, 2019; Eddy, 2016; Trocaru, Berlic, Miron, & Barna, 2020). The learning activity ~~implemented~~ investigated in this ~~work~~ study is based on modeling. Modeling-based learning encourages students to construct a scientific model or solve a particular ~~problems~~ problem like a real scientist (Cascarosa, Sánchez-Azqueta, Gimeno, & Aldea, 2020). ~~Even~~ Although ~~though~~ this online activity may not facilitate practical laboratory competencies, ~~related to practical things~~ such as correctly using apparatus ~~and~~ or laboratory safety, on the other hand it can ~~also~~ stimulate students to develop other competencies, such as data skills and communication skills.

~~In particular~~Specifically, this study explores ~~, we investigate~~ how ~~the~~ practicing modeling activity using Tracker affects one ~~aspect of~~ particular data skill – ~~l, i.e.,~~ graph interpretation ~~skills~~. ~~A graph~~Graphs are method of ~~is one of the~~ data ~~representations~~ visualization that is widely used in various fields. To anticipate their future career paths, students ~~need to get used to~~must become proficient at interpreting graphs (Ergül, 2018).

2. Literature Review

2.1. Models and Modeling in Physics Learning

~~Model i~~In physics, a model is a simplified version of a part of the targeted physical world. Based on the representation method, models can be categorized into six types: ~~, i.e.~~ concrete models, verbal models, visual models, mathematical models, action models, and a mix of those models (Buckley & Boulter, 2000).

Modeling is ~~a~~ the process ~~that scientist uses~~scientists use to construct a scientific model or solve ~~particular problems~~a particular problem. Although modeling ~~is initially coming from a process usually done by~~originated as a process carried out by scientists, it ~~is also~~ has also been adapted ~~in~~ as a part of the science learning process (Wang, Jou, Lv, & Huang, 2018). Students can ~~go through~~use the process of modeling ~~process~~ to develop their scientific knowledge. The principle of modeling in learning science is ~~constructing~~ based on the construction of a mental model to understand a phenomenon and then using ~~the~~ this cognitive model to solve a problem.

~~There are s~~Several learning cycles ~~proposed~~ based on modeling have been proposed. Hestenes ~~stated that~~described the physics modeling process ~~comprises~~ as comprised of ~~3~~ three main parts: ~~, i.e.,~~ modeling, model analysis, and model validation (Hestenes, 1997). Halloun (2007) ~~also~~ developed a learning cycle based on the modeling process, consisting~~; the learning cycle consists~~ of exploration, model adduction, model formulation, model deployment, and paradigmatic synthesis (Halloun, 2007). Meanwhile, Brew proposed five steps of modeling: introduction and representation~~,~~; coordination of representation~~,~~; application~~,~~; abstraction and generalization~~,~~; and continued incremental development (Brewe, 2008). ~~In a~~Another study developed the strategy of~~,~~ modeling-based flipped learning~~ has been developed~~. The ~~F~~flipped learning stages consist of exploration, model adduction, model formulation, and model deployment (Wang et al., 2018). Several studies have ~~indicated~~ demonstrated the positive ~~impact~~ impacts of model-based learning. The implementation of model-based learning in ~~school~~ schools can reduce alternative conceptions, clarify ~~disagreement~~ disagreements between intuition and physics ~~phenomenon~~phenomena, improve students' argumentation ~~skill~~skills, connect theory and experimental data, improve problem-solving strategies, ~~mediate~~ integrate~~a~~ new ~~concept~~ concepts with prior knowledge or other disciplines, and help ~~student in understanding~~students to understand the image of nature (Cascarosa et al., 2020).

2.2. Graph Interpretation Skill

One of the critical ~~competence~~ competences in the twenty-first century is working with data, including data analysis (Glazer, 2015). ~~Practicing d~~Data analysis is often ~~done~~ practiced in physics class, ~~but~~ although data analysis skills are used in various real-life applications. Constructing and interpreting visual data presentation in the form of a graph is ~~included in~~among the data analysis skills. In physics, a graph ~~is also~~can also serve as a powerful model representation to ~~present~~ describe the behavior of physical phenomena (Stefanel, 2019). ~~It is also able to~~They can reduce the cognitive load and promote cognitive thinking (Pospiech, 2019). ~~Prompt~~ If students ~~in~~ are trained in interpreting graphs, it will be useful not only to ~~understand~~ their understanding of physical concepts but will also contribute ~~also~~ to the future workforce's ~~train~~ crucial data skills~~ for the future workforce~~.

2.3. E-Learning in Physics and Its Challenges

Distance learning has ~~been existing for a long time ago~~existed for some time. Following developments in internet and computer technology~~ growth~~, distance learning has become ~~more~~ increasingly facilitated. As the internet has become more accessible around the world, t~~T~~he concept of electronic-learning or ~~E~~e-learning ~~emerges~~has emerged~~ as the internet becomes more accessible around the world~~. Nowadays, there is a ~~various~~ wide variety of e-learning ~~platform~~ platforms ~~that~~ for teachers and students ~~can~~ to use. In the past, ~~T~~the frequency of direct interaction between ~~teacher~~ teachers and students was very low during distance learning~~ was very low in the past~~. However, with the current communication ~~technology~~technologies, such as online meeting applications, direct interaction between ~~teacher~~ teachers and students ~~in~~ during distance learning has become easier (Pratama, Azman, Kassymova, & Duisenbayeva, 2020).

A learning management system (LMS) also ~~facilitates~~ serves to facilitate e-learning~~ well~~. With an LMS, such as Moodle, a teacher can ~~construct~~ design and organize interactive and effective material, discussion, and assessment. E-learning is not only used for courses that are entirely based on ~~fully~~ distance learning~~ courses~~. Teachers can combine ~~a~~ regular face-to-face ~~meeting~~ classroom teaching with e-learning. ~~The~~ This combination has ~~brought out~~led to the ~~concept~~ concepts of blended learning and flipped learning. Shurygin and Sabirova (2017) ~~-~~discuss the implementation of ~~implement~~ blended learning in physics teaching ~~physics by~~through the use of the ~~using~~ LMS Moodle. ~~It has~~They found several positive impacts, such as allowing personalization ~~in~~ of the education process and motivating students to work independently (Shurygin & Sabirova, 2017).

The COVID-19 pandemic ~~forces~~ has forced school ~~closure~~ closures to minimize human physical contact. ~~Education~~ Educational institutions ~~must~~ have had to ~~change~~ redesign face-to-face classes ~~to~~ as remote classes. Although ~~S~~some teachers and students have experienced e~~E~~-learning before,~~;~~ the sudden change has ~~become troublesome~~been challenging for some courses. There ~~is~~ has been a considerable impact ~~for a~~ on practical ~~course~~ courses, such as~~ a~~ physics experiment ~~course~~courses. When ~~a~~ hands-on ~~experiment~~ experiments in the laboratory ~~is hard to conduct~~are no longer an option, teachers need to find ~~other~~ alternative learning methods. Computer and mobile technologies ~~give~~ provide some alternative activities. ~~It~~ These ~~involves~~ include computer simulations (Bayrak, 2008; Develaki, 2017; Habibi, Jumadi, & Mundilarto, 2020; Pratidhina, Pujianto, & Sumardi, 2019) simple ~~experiment~~ experimental ~~project~~ projects with ~~eas~~readily ~~y to get~~available tools (including smartphone sensors) (Arribas, Escobar, & Suarez, 2015; Pili & Violanda, 2018), pre-recorded video ~~demonstration~~demonstrations, live ~~demonstration~~ demonstrations (Kestin, Miller, Mccarty, Callaghan, & Deslauriers, 2020) and remote ~~laboratory~~ laboratories (Hoyer & Girwidz, 2018).

2.4. Tracker as a Video Modeling Tool in Physics Teaching

Tracker is ~~one of the helpful~~a useful video modeling ~~tools~~ tool in physics teaching. ~~It is computer~~The software was developed on the ~~Open Source~~Open-Source Physics Java code library. Hence, students and teachers can download and use it for free. Tracker provides various features ~~to analyze~~for analyzing ~~physics~~ experimental data that has been recorded in a video file. In Tracker, users can track the position, velocity, and acceleration of a ~~particular~~ moving object (Brown, 2020). Moreover, Tracker also has an RGB line profile feature that can be used to analyze spectra (Pratidhina, Dwandaru, & Kuswanto, 2020; Rodrigues, Marques, & Sime, 2016). This feature helps ~~get~~ to generate a light intensity distribution graph in light diffraction, interference, or polarization ~~experiment~~experiments. ~~Some~~ Various papers have described how to use Tracker ~~in~~ for modeling and understanding physics topics in high school and undergraduate ~~levels~~courses, ~~such as~~including harmonic motion (Kinchin, 2016) free fall (Wee, Tan, & Leong, 2015) projectile motion (Wee, Chew, Goh, Tan, & Lee, 2012) rotational dynamic ~~-~~(Eadkhong, Rajsadorn, Jannual, & Danworaphong, 2012) electricity and magnetism (Aguilar-Marin, Chaves-Bacilio, & Jáuregui-Rosas, 2018) refraction (Ürek, Özdemir, & Coramik, 2021) and reflection(Rodrigues. & Carvalho, 2014). In previous studies, ~~implementing~~ the implementation of Tracker as a pedagogy tool has ~~shown~~ revealed several advantages, such as improving learning motivation (Wee et al., 2015) increasing conceptual understanding (Amaliah, Darmadi, & Saehana, 2020) and developing conceptual thinking (Hockicko, Krišták, & Miroslav, 2015).

3. Research Methods

3.1. Research Design

This study ~~was intended to investigate~~investigated the effectiveness and students' ~~view~~ opinion of modeling-based learning ~~activity~~ activities using Tracker ~~in~~ to study an undergraduate online physics experiment. ~~The~~ A one-group pre- and post-test design was used in the study. Pre- and post-tests~~test~~ were ~~given~~ administered before and after students were exposed to the Tracker-assisted modeling activity.

3.2. Research Participants

The research was conducted at the Physics Education Department ~~in~~ of Widya Mandala Catholic University Surabaya, Indonesia. We asked all undergraduate students ~~there who take the~~taking the Advanced Physics Experiment course in 2020 to participate in the learning activity. In total, 21 students ~~participate~~participated. They ~~consist~~ consisted of 7 male and 14 female students. All students ~~join an~~ participated in the online course ~~with~~ using a laptop and ~~have~~ had ~~considerably good~~reasonably reliable internet access.

3.3. Instrument

The i~~I~~nstruments used in this research are pre-test, post-test and questionnaire. The ~~P~~pre- and post-test are used to investigate how the learning activity affects graph interpretation skills. The pre-and post-test consist of ~~There are~~ five questions related to graph interpretation skills ~~given in the pre-and post-test~~; students ~~need to~~are given 20 minutes to complete them ~~within 20 minutes~~. To get the students' feedback on the learning activity, they were asked to fill in a Likert scale questionnaire.

3.4 Data Analysis

To describe the comparison between the pre- and post-test, we use normalized gain, $\langle g \rangle$ as an indicator. The formula to calculate normalized-gain is ~~given~~ provided in Equation 1. The criteria of the normalized-gain score are shown in Table 1.

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre} \quad (1)$$

where $\%post$ is the post~~pre~~-test score in percentage, $\%pre$ is the pre-test score in percentage. ~~We calculate b~~Both individual normalized-gain and class average normalized-gain are calculated.

Table-1. Criteria of the normalized-gain score (Hake, 1998).

Normalized Gain, $\langle g \rangle$	Criteria
$\langle g \rangle \geq 0.7$	High
$0.7 > \langle g \rangle \geq 0.3$	Medium
$\langle g \rangle < 0.3$	Low

Source: Criteria adopted from Hake (1998).

4. Result and Discussion

4.1. Learning Activity

The participants involved in this study were students ~~who were~~ taking an Advanced Physics Experiment class. This course is mandatory in the Physics Education major. Before students take this course, they ~~took~~ complete the course Physics II, in which they study~~. T~~ the theory of diffraction ~~had been studied in Physics II~~. Therefore, the students who participated in this study had a prior theoretical model of single-slit diffraction. The learning process involved synchronous and asynchronous sessions. The synchronous session was conducted ~~by~~ using Zoom. Meanwhile, the asynchronous sessions used the Moodle platform. The learning phases are ~~explained~~ outlined in Table 2.

Table-2. The learning activity phases.

Phase	Description	Platform
1. Pre-test	The pre-test was given to students online before they ~~participate~~ participated in the modeling activity.	Moodle
2. Introduction to Tracker	This phase was conducted both asynchronously and synchronously. Before the synchronous class, students watched a video explaining how to install and use Tracker to analyze physics experiments. All students had ~~installed~~ Tracker installed on their computer before the first synchronous class.	Moodle and Zoom
3. Orientation	In the orientation, the lecturer introduced students to the experimental set-up of diffraction with a single slit. The lecturer demonstrated how to ~~do~~ conduct the experiment, and students were asked to observe the resulting diffraction pattern ~~results in the experiment~~. Students were also asked to hypothesize how ~~the~~ variation of slit width, screen-slit distance, and light wavelength ~~affects~~ would affect the diffraction pattern.	Zoom
4. Exploration	To test their hypothesis, students need to do an investigation. In normal laboratory work, students ~~will~~ would do hands-on experiments directly. However, in this online course, instead of ~~students doing~~ a hands-on experiment, the lecturer ~~gave~~ provided a recorded video ~~about~~ of the diffraction experiment with a single slit. The video showed the diffraction pattern when the slit width, screen-slit distance, and light wavelength were varied. Students had to import the video to Tracker and then plot the diffraction pattern's intensity distribution with the Line Profile feature in Tracker (see Figures 1 and 2).	Moodle
5. Model adduction	Students ~~are~~ were asked to identify the difference of intensity distribution in the diffraction pattern~~,~~ when the slit width, screen-slit distance and wavelength ~~are~~ were varied. They ~~can~~ could discuss it in ~~group~~ groups ~~via~~ using Moodle forum.	Moodle
6. Model formulation	After discussing their observation and analysis results, students were asked to ~~make~~ conduct theoretical modeling of single slit diffraction ~~with a single slit~~. Students also	Moodle

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	had to ~~relate~~ incorporate the experimental results and the light intensity equation yield in the modeling process. To help students connect the theoretical equation ~~and~~ with the experimental result, they could use Excel to plot the light intensity at each point.	
7. Reflection	Finally, students reflected on the activities that they had ~~done~~carried out. They evaluated the limitations of the activity and gave their ideas of how to improve the experimental result. After the whole process, students ~~needed~~ were asked to ~~make~~ write and submit a report ~~and submit it~~.	Moodle
8. Post-test	After submitting their task, students did a post-test. The post-test consisted of the same ~~question~~ questions as the pre-test. Students had to complete it within 20 minutes. After ~~finished~~ finishing the post-test, students were asked to fill in a ~~questioner~~ questionnaire ~~that asks~~asking their views on the use of Tracker in the online Advanced Physics Experiment course.	Moodle

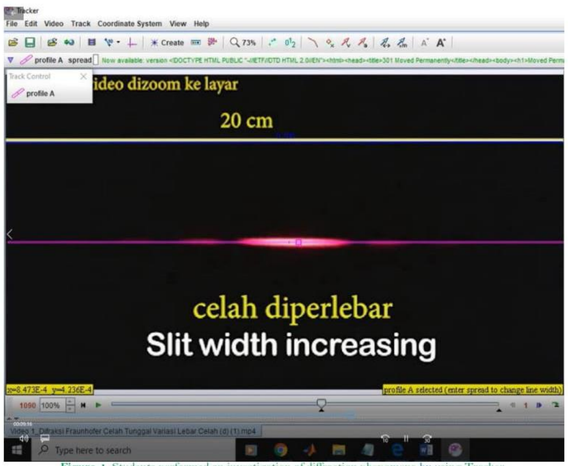

Figure-1. Students performed an investigation of diffraction phenomena ~~by~~ using Tracker.

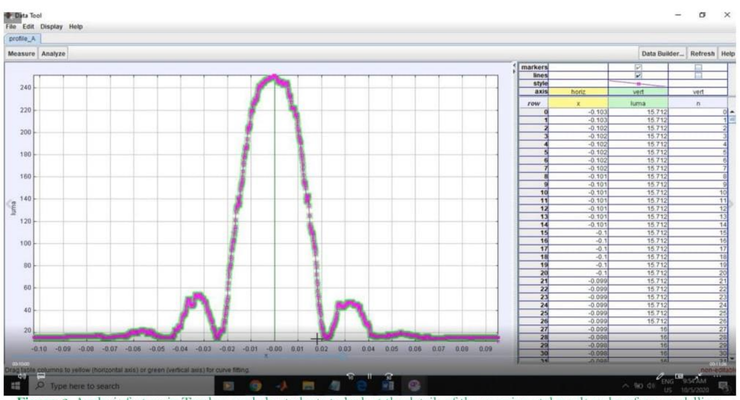

Figure-2. Analysis feature in Tracker can help students to look at the details of the experimental result and perform modelling.

4.2. Effect of the Learning Activity

~~In general~~Overall, the results of this study ~~has shown~~show that using Tracker ~~in~~ to carry out a modeling activity improves students' graph interpretation skills. Table 3 shows the comparison between pre- and post-test scores. The normalized gain score is calculated according to Equation 1 and is used to compare the pre- and post-test. ~~There is o~~Only one student's score ~~that~~ decreases. The other 20 students improved their post-test scores with various normalized -gains. Thirteen students ~~obtain~~ obtained a high normalized -gain, five students ~~receive~~ achieved a medium normalized -gain, and one student ~~receives~~ achieved a low normalized -gain. The class average ~~of~~ for the pre- and post-test is shown in Table 4. Based on the average score, the average normalized -gain is calculated ~~to be~~as 0.74, which is categorized as a high normalized -gain.

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Table-3. Comparison between individual pre-test and post-test ~~score~~scores.

Student	Final Pre-test Score (max=100)	Final Post-test Score (max=100)	Individual ⟨g⟩	Criteria
S1	0.00	60.00	0.60	medium
S2	60.00	100.00	1.00	high
S3	40.00	60.00	0.33	medium
S4	0.00	100.00	1.00	high
S5	20.00	80.00	0.75	high
S6	40.00	20.00	-0.33	decrease
S7	40.00	100.00	1.00	high
S8	20.00	100.00	1.00	high
S9	40.00	100.00	1.00	high
S10	40.00	100.00	1.00	high
S11	0.00	20.00	0.20	low
S12	20.00	60.00	0.50	medium
S13	0.00	100.00	1.00	high
S14	40.00	100.00	1.00	high
S15	0.00	40.00	0.40	medium
S16	40.00	100.00	1.00	high
S17	20.00	80.00	0.75	high
S18	20.00	100.00	1.00	high
S19	40.00	100.00	1.00	high
S20	20.00	60.00	0.50	medium
S21	0.00	100.00	1.00	high

Table-4. Comparison between class average pre-test and post-test ~~score~~scores.

Average final pre-test core	Average final post-test core	Average ⟨g⟩	Criteria
23.81	80.00	0.74	High

~~There are 5 questions in the~~The pre-_and post-test consisted of five questions. All ~~of~~ the questions ~~have included~~ indicators related to interpreting graphs. The average scores ~~of~~ for each question are ~~given~~ presented in Table 5. Although students had learned the theory of diffraction in ~~the~~ a previous course, the pre-test score is still low. ~~It~~ This indicates that students were ~~still~~ not yet ~~fluent~~ proficient in interpreting ~~graph~~graphs. In general, the average score ~~of~~ for each question improves in the post-test ~~improves~~. Based on the calculated normalized -gain, ~~score~~ the scores for ~~on~~ Q1 and Q3 moderately improve, while scores ~~on~~ for Q2, Q4, and Q5 ~~highly~~ greatly improve.

Table-5. Comparison between the average class score ~~of~~for each question on the pre-_and post-test ~~score~~.

Question	Indicators	Pre-test Average (max=100)	Post-test Average (max=100)	⟨g⟩	Criteria
Q1	Student can predict the light intensity pattern/graph in single slit diffraction –for a certain experimental set-up	9.5	71.4	0.68	medium
Q2	Student can guess the experimental set-up in single slit diffraction based on the intensity graph interpretation	19.0	81.0	0.76	high
Q3	Student can predict the light intensity pattern/graph when the experiment parameter (slit width) in single slit diffraction is changed	38.1	81.0	0.69	medium
Q4	Student can predict the light intensity pattern/ graph when the experiment parameter (distance between slit and screen) in single slit diffraction is changed	23.8	85.7	0.81	high
Q5	Student can interpret the light wavelength used in the experiment based on the intensity graph	28.6	81.0	0.73	high

4.3. Students' Views on the Learning Activity

~~Besides~~ In addition to the test ~~about~~ of their graph interpretation skills, a questionnaire of five Likert scale ~~questionnaires~~ questions ~~were~~ was given to students. ~~Out o~~Of the 21 participants, 15 participants filled in and submitted the questionnaires appropriately. The survey aims to collect the students' views on using Tracker for ~~the~~ a modeling activity ~~using Tracker~~ in the learning process. The ~~summary of the survey is presented~~results of the questionnaire are summarized in Table 6. The questionnaire's overall mean score is 4.1, which can be interpreted as high (Ibrahim & Bakar, 2015).

Based on the survey, 80% of students agreed that modeling activity using Tracker in the Advance Physics Experiment course gave them ~~more~~ a greater opportunity to learn than ~~just~~ by simply observing live demonstrations and analyzing data provided by the lecturer. 93.3% of students also agreed that they could learn data analysis techniques ~~in~~ through physics experiments. 93.3% of students thought Tracker and Excel, which were used during the learning activity, helped them interpret the experimental results. ~~It is~~These results are in line with the improvement ~~of~~ in graph interpretation skills.

Before this study was conducted, ~~in~~ the online Advanced Physics Experiment course generally consisted of~~,~~ the lecturer ~~usually did~~giving a live demonstration via Z~~z~~oom every week. Students then had to ~~make~~ write an experiment report based on the lecturer's data. The modeling activity using Tracker was something new ~~for~~ to the students. According to the survey, 73.3% of students ~~stated that it is~~felt that it was easy to understand how to use Tracker. Some of the students may ~~think that it is~~ have found it quite difficult because it ~~is~~ was ~~something~~ new ~~for~~ to them. However, it ~~has~~ did show positive effects on students' motivation; 80% of students stated that the activity ~~improves~~ improved their motivation for the online physics course, ~~motivations~~ and 86.7% of students wanted to explore more physics phenomena ~~with~~ using Tracker.

Table-6. Students' views on modeling activity using T~~t~~racker.

No.	Statements	Strongly disagree (1)	Disagree (2)	Don't know (3)	Agree (4)	Strongly agree (5)	Mean score
1	The introduction given in the experiment video ~~gives~~ provides a clear explanation ~~about~~ of the Fraunhofer-Diffraction experimental set-up	1 (6.7%)	0 (0%)	1 (6.7%)	3 (20%)	10 (66.7%)	4.4
2	~~Compare~~ Compared to observing a live demonstration and analyz~~e~~ing a set of data ~~given~~ provided by the lecturer, the experiment video analysis activity using Tracker ~~gives~~ gave me ~~more~~ a greater opportunity ~~in~~ for learning	0 (0%)	1 (6.7%)	2 (13.3%)	4 (26.7%)	8 (53.3%)	4.3
3	I ~~have an~~had the opportunity ~~in learning~~to learn analysis techniques ~~in~~ for physics experiments through an activity using Tracker and Excel	0 (0%)	1 (6.7%)	0 (0%)	5 (33.3%)	9 (60%)	4.5
4	Analysis using Tracker and Excel helped me to interpret the experimental result	0 (0%)	1 (6.7%)	0 (0%)	7 (46.7%)	7 (46.7%)	4.3
5	I want to explore more physical phenomena using Tracker software	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4
6	The learning activity using Tracker ~~improves~~ improved my motivation ~~in~~ to learn~~ing~~ physics online	1 (6.7%)	0 (0%)	2 (13.3%)	8 (53.3%)	4 (26.7%)	3.9
7	Understanding how to use Tracker is easy	0 (0%)	1 (6.7%)	3 (20%)	9 (60%)	2 (13.3%)	3.8
8	The ~~A~~activity using Tracker and Excel helped~~s~~ me to connect theoretical models ~~and~~ with experimental results~~.~~	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4.0
9	The ~~A~~activity using Tracker helped~~s~~ me to interpret the physical meaning of a graph representation.	1 (6.7%)	0 (0%)	1 (6.7%)	7 (46.7%)	6 (40%)	4.1
Overall mean score							4.1

5. Conclusion

It has been challenging to teach ~~Teaching~~ physics and other science courses during the COVID-19 pandemic ~~is challenging~~, especially when ~~we need to transform~~ face-to-face laboratory-based courses have had to be transformed into online courses. ~~Besides~~In addition, maintaining students' learning motivation during ~~the~~ an online course is ~~also~~ not an easy task. Hence, when teaching online, educators need to implement innovative learning activities ~~during the online course~~. In this study, we have ~~shown~~ demonstrated Tracker-assisted modeling activity, as implemented in the undergraduate Advanced Physics Experiment course. The ~~study~~ results show ~~shows~~ that the learning activity effectively improves students' data skills, especially those related to graph interpretation; the normalized ~~-~~gain is 0.74, which can be categorized as high. This skill is important for preparing the future workforce. Moreover, students also stated that, using Tracker, they ~~are~~ were more motivated to learn physics online and ~~have~~ had more opportunities to learn during the modeling activity ~~by using Tracker~~. In ~~the~~ a future study, Tracker-assisted modeling ~~-~~activity ~~can~~ might also be combined with simple experiment project that ~~can~~ students can conduct ~~be conducted~~ at home.

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Implementation of a Tracker-Assisted Modeling Activity in an Online Advanced Physics Experiment Course

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Abstract

Experiment or laboratory work is an essential part of physics and other science courses. However, due to the COVID-19 pandemic, face-to-face classes have had to be transformed into remote classes. Because laboratory access has become very limited, technology must be utilized to substitute for hands-on activity in laboratory-based courses. Additionally, maintaining students' motivation during remote classes is also challenging. In this paper, we report on the implementation of modeling activities using Tracker in our online Advanced Physics Experiment course. We examine the effectiveness of Tracker-assisted modeling activity in improving students' graph interpretation skills on the topic of Fraunhofer-Diffraction. The results show that 20 out of 21 participants demonstrated an increase in graph interpretation skills. The average normalized gain is 0.74, which can be seen as a high degree of improvement. Although the activity did not allow students to practice hands-on skills, this activity can encourage students to practice other science-related skills. Moreover, according to the survey, students feel more motivated to learn physics online after being exposed to the modeling activity.

Keywords: Modeling, Physics experiment, Graph interpretation, Learning motivation, Online course.

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Contents

Contribution of this paper to the literature
This study contributes to the existing literature on modeling theory in physics education, learning through technology, and online learning. This paper explains the implementation of a modeling approach in an undergraduate online laboratory-based physics course. Tracker is used to facilitate the modeling of a physics phenomenon in an online class. The findings of this study confirm that the Tracker-assisted modeling activity improves students' graph interpretation skills and their learning motivation in an online class.

1. Introduction

As digital technology has developed rapidly, distance learning has undergone a significant transformation. In the past, the main problem of distance learning was the lack of interaction between teachers and students. However, with the growing accessibility of the internet and advanced communication technologies, that obstacle can for the most part be overcome. However, distance learning still poses significant challenges, especially for science courses. In this case, the problem is mainly related to the incorporation of laboratory work and experiments in distance learning (Aththibby, Kuswanto, & Mundilarto, 2021).

Laboratory work is an indispensable part of science courses; it encourages students to inquire independently, think critically, and practice generating scientific information. Previous studies have also demonstrated that students' attitudes toward science improve when they take part in laboratory work. Moreover, it is an essential component for the creation of a meaningful understanding of scientific concepts (Sadoglu & Durukan, 2018).

The COVID-19 pandemic, which started in early 2020, has affected education systems around the world. Schools have been forced to close to minimize the spread of the virus. Hence, students and teachers have been forced to adapt their face-to-face courses into a suitable mode for remote online learning. Teachers have been required to design online courses in a very short period of time. For the Physics Education Department, the main challenge has been to transform practical-based courses into online learning. The practical-based courses are usually conducted in a laboratory and require hands-on activity, but direct access to a laboratory is impossible in the case of online learning. However, although they cannot completely replace hands-on activity, certain technologies can be implemented as alternatives (Aththibby et al., 2021; Campari et al., 2021; Pols, 2020).

In this paper, we explore the solution of using the video modeling software Tracker to enable students to collect data from the video of an experiment, analyze the data, and create models. Instead of students conducting a hands-on experiment in the lab, the teacher records the experiment and provides the students with a video. The students then observe the physical phenomena in the video and collect quantitative data using Tracker (Brown & Cox, 2009). Over the past years, Tracker has been widely used in the physics education community to enhance face-to-face physics courses (Castaneda, 2019; Eddy, 2016; Trocaru, Berlic, Miron, & Barna, 2020). The learning activity investigated in this study is based on modeling. Modeling-based learning encourages students to construct a scientific model or solve a particular problem like a real scientist (Cascarosa, Sánchez-Azqueta, Gimeno, & Aldea, 2020). Although this online activity may not facilitate practical laboratory competencies, such as correctly using apparatus or laboratory safety, on the other hand it can stimulate students to develop other competencies, such as data skills and communication skills.

Specifically, this study explores how practicing modeling activity using Tracker affects one particular data skill – graph interpretation. Graphs are method of data visualization that is widely used in various fields. To anticipate their future career paths, students must become proficient at interpreting graphs (Ergül, 2018).

2. Literature Review

2.1. Models and Modeling in Physics Learning

In physics, a model is a simplified version of a part of the targeted physical world. Based on the representation method, models can be categorized into six types: concrete models, verbal models, visual models, mathematical models, action models, and a mix of those models (Buckley & Boulter, 2000).

Modeling is the process scientists use to construct a scientific model or solve a particular problem. Although modeling originated as a process carried out by scientists, it has also been adapted as a part of the science learning process (Wang, Jou, Lv, & Huang, 2018). Students can use the process of modeling to develop their scientific knowledge. The principle of modeling in learning science is based on the construction of a mental model to understand a phenomenon and then using this cognitive model to solve a problem.

Several learning cycles based on modeling have been proposed. Hestenes described the physics modeling process as comprised of three main parts: modeling, model analysis, and model validation (Hestenes, 1997). Halloun (2007) developed a learning cycle based on the modeling process, consisting of exploration, model adduction, model formulation, model deployment, and paradigmatic synthesis (Halloun, 2007). Meanwhile, Brew proposed five steps of modeling: introduction and representation; coordination of representation; application; abstraction and generalization; and continued incremental development (Brewe, 2008). Another study developed the strategy of modeling-based flipped learning. The flipped learning stages consist of exploration, model adduction, model formulation, and model deployment (Wang et al., 2018). Several studies have demonstrated the positive impacts of model-based learning. The implementation of model-based learning in schools can reduce alternative conceptions, clarify disagreements between intuition and physics phenomena, improve students' argumentation skills, connect theory and experimental data, improve problem-solving strategies, integrate new concepts with prior knowledge or other disciplines, and help students to understand the image of nature (Cascarosa et al., 2020).

2.2. Graph Interpretation Skill

One of the critical competences in the twenty-first century is working with data, including data analysis (Glazer, 2015). Data analysis is often practiced in physics class, although data analysis skills are used in various real-life applications. Constructing and interpreting visual data presentation in the form of a graph is among the data analysis skills. In physics, a graph can also serve as a powerful model representation to describe the behavior of physical phenomena (Stefanel, 2019). They can reduce the cognitive load and promote cognitive thinking

(Pospiech, 2019). If students are trained in interpreting graphs, it will be useful not only to their understanding of physical concepts but will also contribute to the future workforce's crucial data skills.

2.3. E-Learning in Physics and Its Challenges

Distance learning has existed for some time. Following developments in internet and computer technology, distance learning has become increasingly facilitated. As the internet has become more accessible around the world, the concept of electronic-learning or e-learning has emerged. Nowadays, there is a wide variety of e-learning platforms for teachers and students to use. In the past, the frequency of direct interaction between teachers and students was very low during distance learning. However, with the current communication technologies, such as online meeting applications, direct interaction between teachers and students during distance learning has become easier (Pratama, Azman, Kassymova, & Duisenbayeva, 2020).

A learning management system (LMS) also serves to facilitate e-learning. With an LMS, such as Moodle, a teacher can design and organize interactive and effective material, discussion, and assessment. E-learning is not only used for courses that are entirely based on distance learning. Teachers can combine regular face-to-face classroom teaching with e-learning. This combination has led to the concepts of blended learning and flipped learning. Shurygin and Sabirova (2017) discuss the implementation of blended learning in physics teaching through the use of the LMS Moodle. They found several positive impacts, such as allowing personalization of the education process and motivating students to work independently (Shurygin & Sabirova, 2017).

The COVID-19 pandemic has forced school closures to minimize human physical contact. Educational institutions have had to redesign face-to-face classes as remote classes. Although some teachers and students have experienced e-learning before, the sudden change has been challenging for some courses. There has been a considerable impact on practical courses, such as physics experiment courses. When hands-on experiments in the laboratory are no longer an option, teachers need to find alternative learning methods. Computer and mobile technologies provide some alternative activities. These include computer simulations (Bayrak, 2008; Develaki, 2017; Habibi, Jumadi, & Mundilarto, 2020; Pratidhina, Pujianto, & Sumardi, 2019) simple experimental projects with readily available tools (including smartphone sensors) (Arribas, Escobar, & Suarez, 2015; Pili & Violanda, 2018), pre-recorded video demonstrations, live demonstrations (Kestin, Miller, Mccarty, Callaghan, & Deslauriers, 2020) and remote laboratories (Hoyer & Girwidz, 2018).

2.4. Tracker as a Video Modeling Tool in Physics Teaching

Tracker is a useful video modeling tool in physics teaching. The software was developed on the Open-Source Physics Java code library. Hence, students and teachers can download and use it for free. Tracker provides various features for analyzing experimental data that has been recorded in a video file. In Tracker, users can track the position, velocity, and acceleration of a moving object (Brown, 2020). Moreover, Tracker also has an RGB line profile feature that can be used to analyze spectra (Pratidhina, Dwandaru, & Kuswanto, 2020; Rodrigues, Marques, & Sime, 2016). This feature helps to generate a light intensity distribution graph in light diffraction, interference, or polarization experiments. Various papers have described how to use Tracker for modeling and understanding physics topics in high school and undergraduate courses, including harmonic motion (Kinchin, 2016) free fall (Wee, Tan, & Leong, 2015) projectile motion (Wee, Chew, Goh, Tan, & Lee, 2012) rotational dynamic (Eadkhong, Rajsadorn, Jannual, & Danworaphong, 2012) electricity and magnetism (Aguilar-Marin, Chaves-Bacilio, & Jáuregui-Rosas, 2018) refraction (Ürek, Özdemir, & Coramik, 2021) and reflection(Rodrigues. & Carvalho, 2014). In previous studies, the implementation of Tracker as a pedagogy tool has revealed several advantages, such as improving learning motivation (Wee et al., 2015) increasing conceptual understanding (Amaliah, Darmadi, & Saehana, 2020) and developing conceptual thinking (Hockicko, Krišták, & Miroslav, 2015).

3. Research Methods

3.1. Research Design

This study investigated the effectiveness and students' opinion of modeling-based learning activities using Tracker to study an undergraduate online physics experiment. A one-group pre- and post-test design was used in the study. Pre- and post-tests were administered before and after students were exposed to the Tracker-assisted modeling activity.

3.2. Research Participants

The research was conducted at the Physics Education Department of Widya Mandala Catholic University Surabaya, Indonesia. We asked all undergraduate students taking the Advanced Physics Experiment course in 2020 to participate in the learning activity. In total, 21 students participated. They consisted of 7 male and 14 female students. All students participated in the online course using a laptop and had reasonably reliable internet access.

3.3. Instrument

The instruments used in this research are pre-test, post-test and questionnaire. The pre- and post-test are used to investigate how the learning activity affects graph interpretation skills. The pre-and post-test consist of five questions related to graph interpretation skills; students are given 20 minutes to complete them. To get the students' feedback on the learning activity, they were asked to fill in a Likert scale questionnaire.

3.4 Data Analysis

To describe the comparison between the pre- and post-test, we use normalized gain, $\langle g \rangle$ as an indicator. The formula to calculate normalized gain is provided in Equation 1. The criteria of the normalized gain score are shown in Table 1.

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre} \quad (1)$$

where $\%post$ is the post-test score in percentage, $\%pre$ is the pre-test score in percentage. Both individual normalized gain and class average normalized gain are calculated.

Table-1. Criteria of the normalized gain score (Hake, 1998).

Normalized Gain, $\langle g \rangle$	Criteria
$\langle g \rangle \geq 0.7$	High
$0.7 > \langle g \rangle \geq 0.3$	Medium
$\langle g \rangle < 0.3$	Low

Source: Criteria adopted from Hake (1998).

4. Result and Discussion

4.1. Learning Activity

The participants involved in this study were students taking an Advanced Physics Experiment class. This course is mandatory in the Physics Education major. Before students take this course, they complete the course Physics II, in which they study the theory of diffraction. Therefore, the students who participated in this study had a prior theoretical model of single-slit diffraction. The learning process involved synchronous and asynchronous sessions. The synchronous session was conducted using Zoom. Meanwhile, the asynchronous sessions used the Moodle platform. The learning phases are outlined in Table 2.

Table-2. The learning activity phases.

Phase	Description	Platform
1. Pre-test	The pre-test was given to students online before they participated in the modeling activity.	Moodle
2. Introduction to Tracker	This phase was conducted both asynchronously and synchronously. Before the synchronous class, students watched a video explaining how to install and use Tracker to analyze physics experiments. All students had Tracker installed on their computer before the first synchronous class.	Moodle and Zoom
3. Orientation	In the orientation, the lecturer introduced students to the experimental set-up of diffraction with a single slit. The lecturer demonstrated how to conduct the experiment, and students were asked to observe the resulting diffraction pattern. Students were also asked to hypothesize how variation of slit width, screen-slit distance, and light wavelength would affect the diffraction pattern.	Zoom
4. Exploration	To test their hypothesis, students need to do an investigation. In normal laboratory work, students would do hands-on experiments directly. However, in this online course, instead of a hands-on experiment, the lecturer provided a recorded video of the diffraction experiment with a single slit. The video showed the diffraction pattern when the slit width, screen-slit distance, and light wavelength were varied. Students had to import the video to Tracker and then plot the diffraction pattern's intensity distribution with the Line Profile feature in Tracker (see Figures 1 and 2).	Moodle
5. Model adduction	Students were asked to identify the difference of intensity distribution in the diffraction pattern when the slit width, screen-slit distance and wavelength were varied. They could discuss it in groups using Moodle forum.	Moodle
6. Model formulation	After discussing their observation and analysis results, students were asked to conduct theoretical modeling of single slit diffraction. Students also had to incorporate the experimental results and the light intensity equation yield in the modeling process. To help students connect the theoretical equation with the experimental result, they could use Excel to plot the light intensity at each point.	Moodle
7. Reflection	Finally, students reflected on the activities that they had carried out. They evaluated the limitations of the activity and gave their ideas of how to improve the experimental result. After the whole process, students were asked to write and submit a report.	Moodle
8. Post-test	After submitting their task, students did a post-test. The post-test consisted of the same questions as the pre-test. Students had to complete it within 20 minutes. After finishing the post-test, students were asked to fill in a questionnaire asking their views on the use of Tracker in the online Advanced Physics Experiment course.	Moodle

4.2. Effect of the Learning Activity

Overall, the results of this study show that using Tracker to carry out a modeling activity improves students' graph interpretation skills. Table 3 shows the comparison between pre- and post-test scores. The normalized gain score is calculated according to Equation 1 and is used to compare the pre- and post-test. Only one student's score decreases. The other 20 students improved their post-test scores with various normalized gains. Thirteen students obtained a high normalized gain, five students achieved a medium normalized gain, and one student achieved a low normalized gain. The class average for the pre- and post-test is shown in Table 4. Based on the average score, the average normalized gain is calculated as 0.74, which is categorized as a high normalized gain.

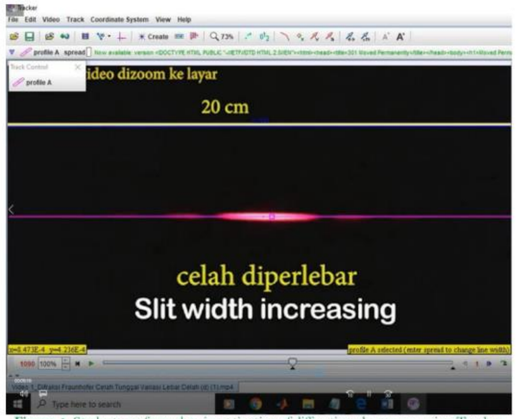

Figure-1. Students performed an investigation of diffraction phenomena using Tracker.

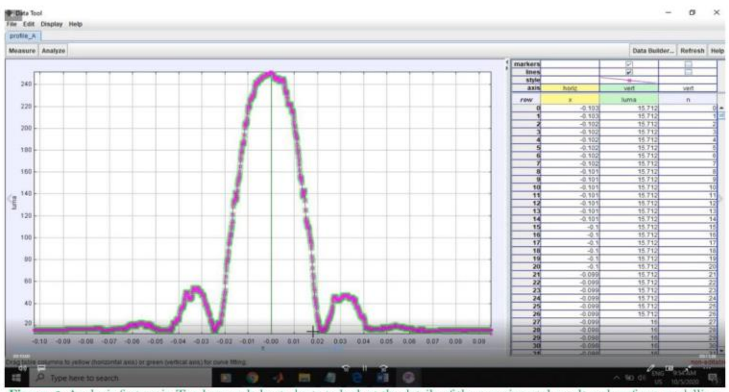

Figure-2. Analysis feature in Tracker can help students to look at the details of the experimental result and perform modelling.

Table-3. Comparison between individual pre-test and post-test scores.

Student	Final Pre-test Score (max=100)	Final Post-test Score (max=100)	Individual ⟨g⟩	Criteria
S1	0.00	60.00	0.60	medium
S2	60.00	100.00	1.00	high
S3	40.00	60.00	0.33	medium
S4	0.00	100.00	1.00	high
S5	20.00	80.00	0.75	high
S6	40.00	20.00	-0.33	decrease
S7	40.00	100.00	1.00	high
S8	20.00	100.00	1.00	high
S9	40.00	100.00	1.00	high
S10	40.00	100.00	1.00	high
S11	0.00	20.00	0.20	low
S12	20.00	60.00	0.50	medium
S13	0.00	100.00	1.00	high
S14	40.00	100.00	1.00	high
S15	0.00	40.00	0.40	medium
S16	40.00	100.00	1.00	high
S17	20.00	80.00	0.75	high
S18	20.00	100.00	1.00	high
S19	40.00	100.00	1.00	high
S20	20.00	60.00	0.50	medium
S21	0.00	100.00	1.00	high

Table-4. Comparison between class average pre-test and post-test scores.

Average final pre-test core	Average final post-test core	Average ⟨g⟩	Criteria
23.81	80.00	0.74	High

The pre- and post-test consisted of five questions. All the questions included indicators related to interpreting graphs. The average scores for each question are presented in Table 5. Although students had learned the theory of diffraction in a previous course, the pre-test score is still low. This indicates that students were not yet proficient in interpreting graphs. In general, the average score for each question improves in the post-test. Based on the calculated normalized gain, the scores for Q1 and Q3 moderately improve, while scores for Q2, Q4, and Q5 greatly improve.

Table-5. Comparison between the average class score for each question on the pre- and post-test.

Question	Indicators	Pre-test Average (max=100)	Post-test Average (max=100)	⟨g⟩	Criteria
Q1	Student can predict the light intensity pattern/graph in single slit diffraction for a certain experimental set-up	9.5	71.4	0.68	medium
Q2	Student can guess the experimental set-up in single slit diffraction based on the intensity graph interpretation	19.0	81.0	0.76	high
Q3	Student can predict the light intensity pattern/graph when the experiment parameter (slit width) in single slit diffraction is changed	38.1	81.0	0.69	medium
Q4	Student can predict the light intensity pattern/ graph when the experiment parameter (distance between slit and screen) in single slit diffraction is changed	23.8	85.7	0.81	high
Q5	Student can interpret the light wavelength used in the experiment based on the intensity graph	28.6	81.0	0.73	high

4.3. Students' Views on the Learning Activity

In addition to the test of their graph interpretation skills, a questionnaire of five Likert scale questions was given to students. Of the 21 participants, 15 participants filled in and submitted the questionnaires appropriately. The survey aims to collect the students' views on using Tracker for a modeling activity in the learning process. The results of the questionnaire are summarized in Table 6. The questionnaire's overall mean score is 4.1, which can be interpreted as high (Ibrahim & Bakar, 2015).

Table-6. Students' views on modeling activity using Tracker.

No.	Statements	Strongly disagree (1)	Disagree (2)	Don't know (3)	Agree (4)	Strongly agree (5)	Mean score
1	The introduction given in the experiment video provides a clear explanation of the Fraunhofer-Diffraction experimental set-up	1 (6.7%)	0 (0%)	1 (6.7%)	3 (20%)	10 (66.7%)	4.4
2	Compared to observing a live demonstration and analyzing a set of data provided by the lecturer, the experiment video analysis activity using Tracker gave me a greater opportunity for learning	0 (0%)	1 (6.7%)	2 (13.3%)	4 (26.7%)	8 (53.3%)	4.3
3	I had the opportunity to learn analysis techniques for physics experiments through an activity using Tracker and Excel	0 (0%)	1 (6.7%)	0 (0%)	5 (33.3%)	9 (60%)	4.5
4	Analysis using Tracker and Excel helped me to interpret the experimental result	0 (0%)	1 (6.7%)	0 (0%)	7 (46.7%)	7 (46.7%)	4.3
5	I want to explore more physical phenomena using Tracker software	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4
6	The learning activity using Tracker improved my motivation to learn physics online	1 (6.7%)	0 (0%)	2 (13.3%)	8 (53.3%)	4 (26.7%)	3.9
7	Understanding how to use Tracker is easy	0 (0%)	1 (6.7%)	3 (20%)	9 (60%)	2 (13.3%)	3.8
8	The activity using Tracker and Excel helped me to connect theoretical models with experimental results	1 (6.7%)	0 (0%)	1 (6.7%)	9 (60%)	4 (26.7%)	4.0
9	The activity using Tracker helped me to interpret the physical meaning of a graph representation.	1 (6.7%)	0 (0%)	1 (6.7%)	7 (46.7%)	6 (40%)	4.1
	Overall mean score						4.1

Based on the survey, 80% of students agreed that modeling activity using Tracker in the Advance Physics Experiment course gave them a greater opportunity to learn than by simply observing live demonstrations and analyzing data provided by the lecturer. 93.3% of students also agreed that they could learn data analysis techniques through physics experiments. 93.3% of students thought Tracker and Excel, which were used during the learning activity, helped them interpret the experimental results. These results are in line with the improvement in graph interpretation skills.

Before this study was conducted, the online Advanced Physics Experiment course generally consisted of the lecturer giving a live demonstration via Zoom every week. Students then had to write an experiment report based on the lecturer's data. The modeling activity using Tracker was something new to the students. According to the survey, 73.3% of students felt that it was easy to understand how to use Tracker. Some of the students may have found it quite difficult because it was new to them. However, it did show positive effects on students' motivation; 80% of students stated that the activity improved their motivation for the online physics course, and 86.7% of students wanted to explore more physics phenomena using Tracker.

5. Conclusion

It has been challenging to teach physics and other science courses during the COVID-19 pandemic, especially when face-to-face laboratory-based courses have had to be transformed into online courses. In addition, maintaining students' learning motivation during an online course is not an easy task. Hence, when teaching online, educators need to implement innovative learning activities. In this study, we have demonstrated Tracker-assisted modeling activity, as implemented in the undergraduate Advanced Physics Experiment course. The results show that the learning activity effectively improves students' data skills, especially those related to graph interpretation; the normalized gain is 0.74, which can be categorized as high. This skill is important for preparing the future workforce. Moreover, students also stated that, using Tracker, they were more motivated to learn physics online and had more opportunities to learn during the modeling activity. In a future study, Tracker-assisted modeling activity might also be combined with simple experiment project that students can conduct at home.

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Section
Articles

Implementation of a Tracker-Assisted Modeling Activity in an Online Advanced Physics Experiment Course

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