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Dear JEELR Editorial Board,

We wish to submit our manuscript, entitled "**Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class**" by Herwinarso, E. Pratidhina, P. Adam, H. Kuswanto, A. D. Rahmat for your consideration of publication in JEELR.

Computational thinking and science process skills development are part of high school physics course objectives. This paper explains the adaptation of modeling activity in physics class. The pilot study indicates modeling activity may stimulate students' CT dispositions, science process skills, and conceptual understanding.

As our project contributes to educational theory, we think our manuscript will be suitable for publication in JEELR. Finally, please send all correspondence regarding the manuscript to Herwinarso.

With sincere regards,

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Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

CT skills are essential in the era when technology develops tremendously. To cultivate CT skills, growing CT dispositions among students are also necessary. High school physics class has the potency to stimulate CT dispositions. On the other hand, science process skill is also emphasized in high school physics class. This study aims to design and implement collaborative modeling-based learning for high school physics classes. Students are stimulated to gain new scientific concepts by modeling physics phenomena, like scientists always do. According to the pilot study, students who participated in collaborative modeling-based learning had excellent science process skills and gained theoretical understandings. Moreover, based on the self-report checklist, students had good CT dispositions and stated they were likely to use CT aspects during the learning process.

Keywords: CT disposition, modeling-based learning, high school physics, science process skills.

A. Introduction

In recent years, a massive transformation of technology has changed people's lifestyles. This fact encourages educational institutions to prepare students for the more dynamic life and demands for job transformation. One of the crucial skills that students must possess is computational thinking (CT) skills (Esteve-Mon et al., 2020; Hsu et al., 2018).

CT has been described as an analytic approach to problem-solving that adapts the process on the computer (Sengupta & Kinnebrew, 2013). CT has become one of the fundamental skills, along with writing, reading, and arithmetic (Barr et al., 2011). CT is a problem-solving process that consists of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon et al., 2022; Yin et al., 2020). CT has become essential to science, technology, engineering, and mathematics (STEM). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Next Generation Science Standards (NGSS) have included computational thinking as a part of core scientific practices (NGSS, 2013). Developing CT skills in science courses, such as high school physics, has become necessary. CT and physics are closely related to each other. Physicists often employ CT skills when they do their job. Students may develop ideas relevant to computational thinking by engaging in experiments, problem-solving, and discussions during physics class.

Several studies have been conducted to explore how to integrate CT with science effectively. For example, Yin et al. (2019) try to integrate CT with physics and engineering learning through maker activities they have designed. Sengupta et al. (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). To develop CT skills, students' tendency to apply CT is an important thing. The attitudinal tendency to CT is called CT disposition. High school physics class has a crucial role in making CT disposition grow.

High school physics curriculum also emphasizes science process skills (Susilawati et al., 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge

(Gunawan et al., 2019). To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning. Typically, science processes and CT skills are always used by physicists in understanding physical phenomena. Physicists always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist to acquire new knowledge about natural phenomena. The modeling process may be incorporated in high school physics classes to train science process skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning, which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell et al., 2015; Louca & Zacharia, 2012).

This study has objectives such as:

(1) Design learning material based on collaborative modeling-based learning

(2) Implement collaborative modeling-based learning in a high school physics class

(3) Investigate the students' CT disposition and science process skills.

B. Literature Review

Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore et al., 2014). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon, and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa et al., 2020).

Some types of physical models are categorized based on the representation, 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 of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

Modeling-based learning

The modeling process that physicists usually do can be adapted to the learning process. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence, and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. By involving students in modeling, students can develop their main conceptual view of science (Campbell et al., 2015; Dukerich, 2015). Students also can build their understanding of the nature of science.

According to Hestenes (2007), the modeling process comprises three main parts, i.e., modeling, model analysis, and validation. The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning cycles proposed.

Brew (2008), proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation; (3) application; (4) abstraction and generalization; (5) continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning cycle that consists of (1) exploration, (2) model adduction,(4) model formulation, (5) model deployment, and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang et al., 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science (Cascarosa et al., 2020).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is a pedagogical approach in physics based on conceptual model development and testing (Brewe, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow et al., 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation, and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. After that, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they constructed. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other 21st-century skills like problem-solving, creativity, and critical thinking (Yadav et al., 2016). CT can be regarded as thinking skills which aim to solve the problem effectively by adapting the process that occurs in a computer (Lee et al., 2020; Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking, and pattern generalization (Psycharis & Kotzampasaki, 2019; Yin et al., 2020). CT development for students has been attracting much attention, from early childhood to university (Bilbao et al., 2021; Kafai & Proctor, 2022; Papadakis, 2020). In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.

Thinking process needs not only knowledge and skills but also dispositions. Dispositions are internal motivation and a combination of attitudes, values, ad beliefs (Sovey et al., 2022). CT disposition can also be considered confident in dealing with complexity (Jong et al., 2020). CT dispositions are the value, motivations, feelings, and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency to CT (Tsai et al., 2021). CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively (Barr & Stephenson, 2011).

When people are engaged in CT, they have a CT disposition. CT dispositions are essential since it is a motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition in a learning process is also necessary to design and evaluate a specific intervention in the learning process.

Science Process Skills

Scientists use Science process skills to construct knowledge for solving problems and formulating results (Özgelen, 2012). Science process skills are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills include observing, classifying, communicating, measuring, concluding, and predicting (Darmaji et al., 2019; Mulyeni et al., 2019). Meanwhile, integrated science process skills consist of controlling variables, defining operational definitions, identifying and controlling variables, formulating hypotheses, experimenting, and interpreting data (Elfeky et al., 2020).

C. Method

Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing science process skills is one of the primary purposes of physics courses. Students' Science process skills are also assessed based on students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement, respectively. The

CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-test design was implemented in the study. Pre- and post-test were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

Research Participants

The pilot study was conducted in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

Instrument

The research instruments employed in the study are pre-test, post-test, CT dispositions checklist, and science process skills rubrics. The pre-and post-test consists of 5 essay problems about elasticity. A checklist to assess students' CT disposition is given at the end of the learning process. The checklist consists of several statements about CT disposition with a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

Data Analysis

The score of the pre-and post-test is compared, and the normalized gain score is calculated. The formula to calculate the normalized gain score, $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score, and $\%post$ is the percentage of the post-test score. The criteria of the normalized gain score are presented in Table 1.

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

Criteria are adopted from (Hake, 1998)

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into quantitative data such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, and "strongly agree" = 4. The data is then analyzed by using descriptive statistics. The mean CT disposition score is interpreted using criteria as shown in Table 2. The category is constructed using the ideal mean Score (X_i) and ideal standard deviation (*SDi*) as a basis (Widoyoko, 2016; Wirjawan et al., 2020)

Table 2. Classification of the actual average Score of students' responses.

No	Score interval formula	Score interval	Criteria
1	$\bar{X} > \bar{X}_i + 1.8SDi$	$\bar{X} > 3.4$	Very good
2	$\bar{X}_i + 0.6SDi < \bar{X} \leq \bar{X}_i + 1.8SDi$	$2.8 < \bar{X} \leq 3.4$	Good
3	$\bar{X}_i - 0.6SDi < \bar{X} \leq \bar{X}_i + 0.6SDi$	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$\bar{X}_i - 1.8SDi < \bar{X} \leq \bar{X}_i - 0.6SDi$	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq \bar{X}_i - 1.8SDi$	$\bar{X} \leq 1.6$	Very poor

D. Result and Discussions

Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation, and post-experiment discussion. Meanwhile, model deployment comprises model application and problem exercise. A detailed explanation of each stage is provided in Table 3.

Table 3. The stages of collaborative-modeling-based learning

Stages	Activity Explanation
Pre-experiment	In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed. This activity aims to engage students at the beginning of the class. Students are also stimulated for questioning and constructing hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement.

	They plan experiments, arrange the apparatus, observe the phenomena, collect the data, and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide, along with the worksheet, is provided.
Post-experiment Discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Based on the data, students are asked to construct a model. A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.
Reflection	Students are asked to make a reflection on the learning activity.

Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding, and communicating. Figure 1 shows the average score of each aspect in percentage during the first learning cycle and second learning cycles. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the observing and formulating hypothesis can be categorized as fair. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding, and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process, hence their science process skills improve. The aspects of formulating a hypothesis in the learning cycle improve and can be categorized as good. Meanwhile, the others change significantly to be excellent.

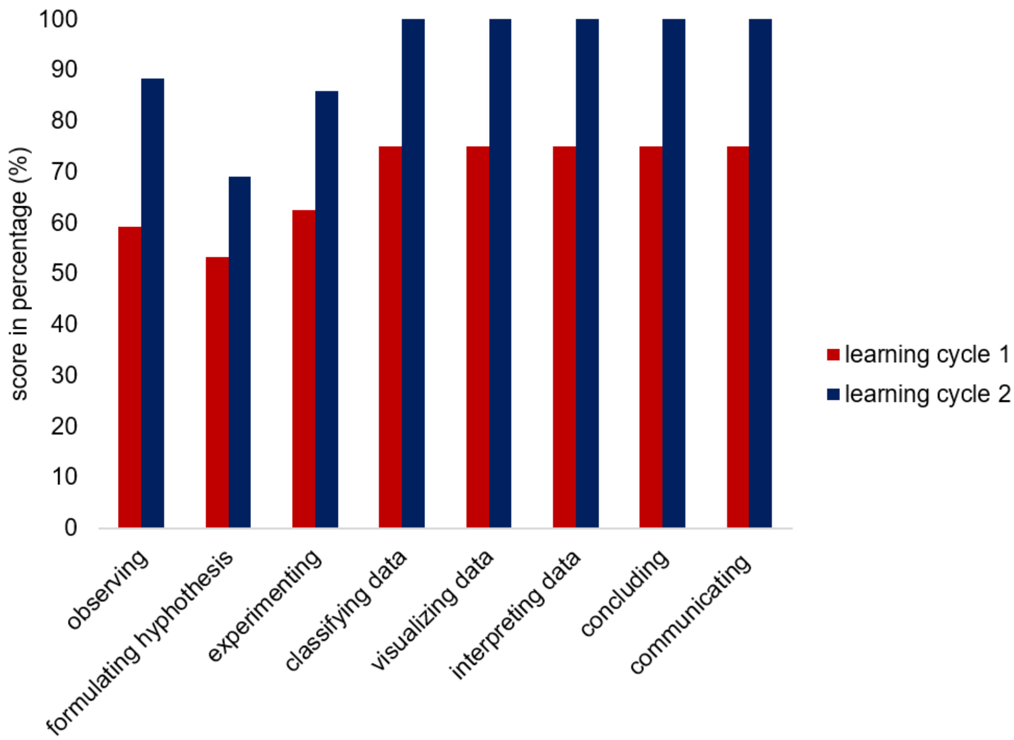

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2

The improvement of science process skills aspects indicates that students have been familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation, and revision.

This study's finding is in accordance with other studies (Zorlu & Sezek, 2020). Ogan-Bekiroğlu & Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçalı & Selvi, 2022).

Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the modeling-based learning with the topics of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 4 shows the comparison between pre-and post-test scores. There are significant improvements in students' theoretical understanding with a normalized gain of 0.77, which can be categorized as a high gain. The average pre-test score of 89 students participating in this study is 21.3.

Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students in acquiring process skills but also theoretical understanding.

The modeling process support students in acquiring cognitive domains since, during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue et al., 2022).

Table 4. Comparison between the average of pre-test and post-test

Number of participants	Average pre-test score	Average post-test score	Average of N-gain	Criteria
89	21.3	81.7	0.77	High

Computational Thinking Disposition

The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal.

Each CT disposition is described in some statements in the questionnaires, such as in Table 5. Based on the self-report checklist, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00). However, students seem still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00), which is only categorized as acceptable.

Table 5. Score of CT dispositions

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when dealing with complex problems.	2.63	3.00	Good
		I can solve complex problems if I continuously try.	3.23		
		I can solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best and my mind in working on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to spend extra time and effort when solving complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Ability to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 6. Frequency of using CT

No	Statements	Average score	Criteria
1	I try to break down complex problems into simpler parts to make them easy to understand and solve.	3.06	Good
2	When facing complex problems, I gather general characteristics and filter out specific information that is unnecessary to solve the problem.	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution.	3.08	Good
4	I reduce complexity and look for main ideas through modes.	2.83	Good
5	To solve many problems, I have developed a step-by-step solution that can be followed.	3.16	Good
6	After solving a problem, I evaluate how the solution can be improved.	3.05	Good
7	After finding a solution to a problem, I determine whether the answer is truly correct and efficient.	3.11	Good
8	I compared the advantages and disadvantages of various alternative solutions to the problem and took the best one.	3.11	Good
Average		**3.06**	**Good**

According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects. Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills.

E. Conclusions

In this study, we designed collaborative modeling-based learning for high school physics classes to improve students' theoretical understanding and science process skills. After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills.

There is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

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Contribution of this paper to literature

This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activity in physics class. The pilot study indicates modeling activity may stimulate students' CT dispositions, science process skills, and conceptual understanding.

Competing Interests:

The authors declare that they have no conflict of interest.

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2. First Review Result: August 16, 2023

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Asian Online Journal Publishing Group <editor@asianonlinejournals.com> Wed, Aug 16, 2023 at 1:57 PM
To: Kaprodi Fisika <hod-physics@ukwms.ac.id>

Editorial Decision: Article ID- 2040/JEELR

Title: Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class.

Journal: Journal of Education and e-Learning Research.

Dear Herwinarso

Reviewers have now commented on your paper. You will see that there are several issues that need to be addressed before the paper can be accepted for publication by Journal of Education and e-Learning Research. Please find in attachment referees' comments.

We ask that you give the comments raised by the referees your careful consideration and that you submit a revised version of your manuscript as well as an itemized reply to each of the reviewers' comments. Please make sure to mark all changes in a different color. You have one week to submit your revised file.

If you decide to revise the work, please submit a list of changes or a rebuttal against each point which is being raised when you submit the revised manuscript.

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2 attachments

Reviewer's comments 2040-JEELR.pdf
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25%- Investigation of Science Process Skills and Computational Thinking.pdf
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2. First Review Result: August 16, 2023

Journal of Education and e-Learning Research
[E] ISSN: 2410-9991
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Title: Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modelling-Based Learning in High School Physics Class

Article. No. 2040

Reviewers Comments

- This study aims to design and implement collaborative modelling-based learning for high school physics classes. Students are stimulated to gain new scientific concepts by modelling physics phenomena, like scientists always do.
- According to the pilot study, students who participated in collaborative modelling-based learning had excellent science process skills and gained theoretical understandings. Moreover, based on the self-report checklist, students had good CT dispositions and stated they were likely to use CT aspects during the learning process.

1. The abstract would benefit from the inclusion of more information pertaining to the research design, methodologies employed, people involved, and instruments utilised.
2. The introduction is effectively composed and provides comprehensive elaboration.
3. Kindly add a section that discusses the significance of the study.
4. The literature review should comprehensively examine recent studies conducted within the past four years.
5. The methodology is thoroughly explained in every one of its components.
6. Discussion is thorough however aligning your discussion with other contemporary studies to improve the quality of it.
7. Please provide a more detailed explanation of the primary discoveries in the concluding section.
8. Include a distinct segment dedicated to the examination of consequences and prospective recommendations.

It is advisable to make minor modifications before publication.

Editorial Comments

1. Please state the following: Funding, Conflicts of Interest, Institutional Review Board Statement, and Data Availability Statement.
2. The references need to meet the APA style of referencing.
3. Rewriting is necessary due to the high similarity index in comparison to the journal's policy. The acceptable rate for the similarity index is 19%.

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Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

CT skills are essential in the era when technology develops tremendously. To cultivate CT skills, growing CT dispositions among students are also necessary. High school physics class has the potency to stimulate CT dispositions. On the other hand, science process skill is also emphasized in high school physics class. This study aims to design and implement collaborative modeling-based learning for high school physics classes. Students are stimulated to gain new scientific concepts by modeling physics phenomena, like scientists always do. According to the pilot study, students who participated in collaborative modeling-based learning had excellent science process skills and gained theoretical understandings. Moreover, based on the self-report checklist, students had good CT dispositions and stated they were likely to use CT aspects during the learning process.

Keywords: CT disposition, modeling-based learning, high school physics, science process skills.

A. Introduction

In recent years, a massive transformation of technology has changed people's lifestyles. This fact encourages educational institutions to prepare students for the more dynamic life and demands for job transformation. One of the crucial skills that students must possess is computational thinking (CT) skills (Esteve-Mon et al., 2020; Hsu et al., 2018).

CT has been described as an analytic approach to problem-solving that adapts the process on the computer (Sengupta & Kinnebrew, 2013). CT has become one of the fundamental skills, along with writing, reading, and arithmetic (Barr et al., 2011). CT is a problem-solving process that consists of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon et al., 2022; Yin et al., 2020). CT has become essential to science, technology, engineering, and mathematics (STEM). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Next Generation Science Standards (NGSS) have included computational thinking as a part of core scientific practices (NGSS, 2013). Developing CT skills in science courses, such as high school physics, has become necessary. CT and physics are closely related to each other. Physicists often employ CT skills when they do their job. Students may develop ideas relevant to computational thinking by engaging in experiments, problem-solving, and discussions during physics class.

Several studies have been conducted to explore how to integrate CT with science effectively. For example, Yin et al. (2019) try to integrate CT with physics and engineering learning through maker activities they have designed. Sengupta et al. (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). To develop CT skills, students' tendency to apply CT is an important thing. The attitudinal tendency to CT is called CT disposition. High school physics class has a crucial role in making CT disposition grow.

High school physics curriculum also emphasizes science process skills (Susilawati et al., 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge

(Gunawan et al., 2019). To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning. Typically, science processes and CT skills are always used by physicists in understanding physical phenomena. Physicists always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist to acquire new knowledge about natural phenomena. The modeling process may be incorporated in high school physics classes to train science process skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning, which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell et al., 2015; Louca & Zacharia, 2012).

This study has objectives such as:

(1) Design learning material based on collaborative modeling-based learning

(2) Implement collaborative modeling-based learning in a high school physics class

(3) Investigate the students' CT disposition and science process skills.

B. Literature Review

Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore et al., 2014). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon, and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa et al., 2020).

Some types of physical models are categorized based on the representation, 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 of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

Modeling-based learning

The modeling process that physicists usually do can be adapted to the learning process. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence, and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. By involving students in modeling, students can develop their main conceptual view of science (Campbell et al., 2015; Dukerich, 2015). Students also can build their understanding of the nature of science.

According to Hestenes (2007), the modeling process comprises three main parts, i.e., modeling, model analysis, and validation. The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning cycles proposed.

Brew (2008), proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation; (3) application; (4) abstraction and generalization; (5) continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning cycle that consists of (1) exploration, (2) model adduction,(4) model formulation, (5) model deployment, and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang et al., 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science (Cascarosa et al., 2020).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is a pedagogical approach in physics based on conceptual model development and testing (Brewe, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow et al., 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation, and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. After that, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they constructed. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other 21st-century skills like problem-solving, creativity, and critical thinking (Yadav et al., 2016). CT can be regarded as thinking skills which aim to solve the problem effectively by adapting the process that occurs in a computer (Lee et al., 2020; Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking, and pattern generalization (Psycharis & Kotzampasaki, 2019; Yin et al., 2020). CT development for students has been attracting much attention, from early childhood to university (Bilbao et al., 2021; Kafai & Proctor, 2022; Papadakis, 2020). In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.

Thinking process needs not only knowledge and skills but also dispositions. Dispositions are internal motivation and a combination of attitudes, values, ad beliefs (Sovey et al., 2022). CT disposition can also be considered confident in dealing with complexity (Jong et al., 2020). CT dispositions are the value, motivations, feelings, and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency to CT (Tsai et al., 2021). CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively (Barr & Stephenson, 2011).

When people are engaged in CT, they have a CT disposition. CT dispositions are essential since it is a motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition in a learning process is also necessary to design and evaluate a specific intervention in the learning process.

Science Process Skills

Scientists use Science process skills to construct knowledge for solving problems and formulating results (Özgelen, 2012). Science process skills are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills include observing, classifying, communicating, measuring, concluding, and predicting (Darmaji et al., 2019; Mulyeni et al., 2019). Meanwhile, integrated science process skills consist of controlling variables, defining operational definitions, identifying and controlling variables, formulating hypotheses, experimenting, and interpreting data (Elfeky et al., 2020).

C. Method

Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing science process skills is one of the primary purposes of physics courses. Students' Science process skills are also assessed based on students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement, respectively. The

CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-test design was implemented in the study. Pre- and post-test were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

Research Participants

The pilot study was conducted in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

Instrument

The research instruments employed in the study are pre-test, post-test, CT dispositions checklist, and science process skills rubrics. The pre-and post-test consists of 5 essay problems about elasticity. A checklist to assess students' CT disposition is given at the end of the learning process. The checklist consists of several statements about CT disposition with a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

Data Analysis

The score of the pre-and post-test is compared, and the normalized gain score is calculated. The formula to calculate the normalized gain score, $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score, and $\%post$ is the percentage of the post-test score. The criteria of the normalized gain score are presented in Table 1.

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

Criteria are adopted from (Hake, 1998)

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into quantitative data such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, and "strongly agree" = 4. The data is then analyzed by using descriptive statistics. The mean CT disposition score is interpreted using criteria as shown in Table 2. The category is constructed using the ideal mean Score (X_i) and ideal standard deviation (*SDi*) as a basis (Widoyoko, 2016; Wirjawan et al., 2020)

Table 2. Classification of the actual average Score of students' responses.

No	Score interval formula	Score interval	Criteria
1	$\bar{X} > \bar{X}_i + 1.8SDi$	$\bar{X} > 3.4$	Very good
2	$\bar{X}_i + 0.6SDi < \bar{X} \leq \bar{X}_i + 1.8SDi$	$2.8 < \bar{X} \leq 3.4$	Good
3	$\bar{X}_i - 0.6SDi < \bar{X} \leq \bar{X}_i + 0.6SDi$	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$\bar{X}_i - 1.8SDi < \bar{X} \leq \bar{X}_i - 0.6SDi$	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq \bar{X}_i - 1.8SDi$	$\bar{X} \leq 1.6$	Very poor

D. Result and Discussions

Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation, and post-experiment discussion. Meanwhile, model deployment comprises model application and problem exercise. A detailed explanation of each stage is provided in Table 3.

Table 3. The stages of collaborative-modeling-based learning

Stages	Activity Explanation
Pre-experiment	In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed. This activity aims to engage students at the beginning of the class. Students are also stimulated for questioning and constructing hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement.

	They plan experiments, arrange the apparatus, observe the phenomena, collect the data, and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide, along with the worksheet, is provided.
Post-experiment Discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Based on the data, students are asked to construct a model. A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.
Reflection	Students are asked to make a reflection on the learning activity.

Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding, and communicating. Figure 1 shows the average score of each aspect in percentage during the first learning cycle and second learning cycles. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the observing and formulating hypothesis can be categorized as fair. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding, and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process, hence their science process skills improve. The aspects of formulating a hypothesis in the learning cycle improve and can be categorized as good. Meanwhile, the others change significantly to be excellent.

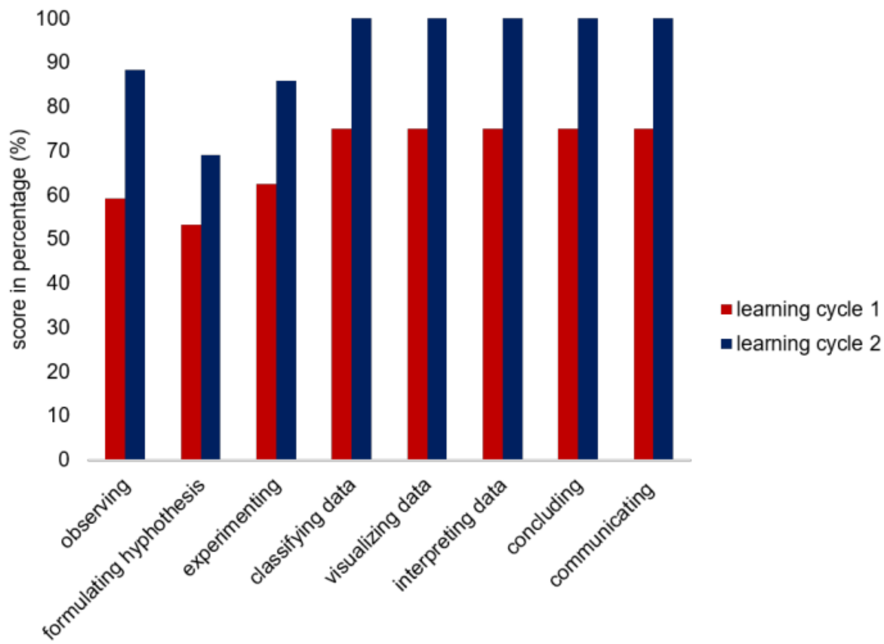

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2

The improvement of science process skills aspects indicates that students have been familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation, and revision.

This study's finding is in accordance with other studies (Zorlu & Sezek, 2020). Ogan-Bekiroğlu & Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçalı & Selvi, 2022).

Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the modeling-based learning with the topics of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 4 shows the comparison between pre-and post-test scores. There are significant improvements in students' theoretical understanding with a normalized gain of 0.77, which can be categorized as a high gain. The average pre-test score of 89 students participating in this study is 21.3.

Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students in acquiring process skills but also theoretical understanding.

The modeling process support students in acquiring cognitive domains since, during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue et al., 2022).

Table 4. Comparison between the average of pre-test and post-test

Number of participants	Average pre-test score	Average post-test score	Average of N-gain	Criteria
89	21.3	81.7	0.77	High

Computational Thinking Disposition

The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal.

Each CT disposition is described in some statements in the questionnaires, such as in Table 5. Based on the self-report checklist, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00). However, students seem still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00), which is only categorized as acceptable.

Table 5. Score of CT dispositions

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when dealing with complex problems.	2.63	3.00	Good
		I can solve complex problems if I continuously try.	3.23		
		I can solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best and my mind in working on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to spend extra time and effort when solving complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Ability to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 6. Frequency of using CT

No	Statements	Average score	Criteria
1	I try to break down complex problems into simpler parts to make them easy to understand and solve.	3.06	Good
2	When facing complex problems, I gather general characteristics and filter out specific information that is unnecessary to solve the problem.	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution.	3.08	Good
4	I reduce complexity and look for main ideas through modes.	2.83	Good
5	To solve many problems, I have developed a step-by-step solution that can be followed.	3.16	Good
6	After solving a problem, I evaluate how the solution can be improved.	3.05	Good
7	After finding a solution to a problem, I determine whether the answer is truly correct and efficient.	3.11	Good
8	I compared the advantages and disadvantages of various alternative solutions to the problem and took the best one.	3.11	Good
Average		**3.06**	**Good**

According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects. Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills.

E. Conclusions

In this study, we designed collaborative modeling-based learning for high school physics classes to improve students' theoretical understanding and science process skills. After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills.

There is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

Acknowledgment

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Contribution of this paper to literature

This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activity in physics class. The pilot study indicates modeling activity may stimulate students' CT dispositions, science process skills, and conceptual understanding.

Competing Interests:

The authors declare that they have no conflict of interest.

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Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Dear Editor of JEELR,

We would like to resubmit our article entitled "Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class" to JEELR.

We have revised our manuscript based on the referees' comments. Besides the revised manuscript, we attach the reply letter to this email.
The reply letter provides our detailed responses to the referees' comments.

We really hope that our manuscript can be published in JEELR

Thank you.

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3. Revision: August 21, 2023

Reply to Reviewer

We have revised our manuscript based on the valuable comments from reviewers. The following table shows the explanations of changes that have been made.

The List of Revisions Based on The Reviewers' Comments

No	Referees' Comments	Revisions
1	The abstract would benefit from the inclusion of more information pertaining to the research design, methodologies employed, people involved, and instruments utilized.	We have added more information about the methodologies, instruments, and participants involved in the abstract. We added the following sentences in the abstract: This study aims to design and implement collaborative modeling-based learning for high school physics classes. In order to investigate the effectiveness of collaborative modeling-based learning, a pilot study in a high school physics class is conducted. Research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. There are 89 students who participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.
2	The introduction is effectively composed and provides comprehensive elaboration.	-
3	Kindly add a section that discusses the significance of the study.	We have added a paragraph in the introduction to highlight the significance of the study, i.e. The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. CT dispositions is fundamental for encouraging students to apply CT aspects in their life, which is crucial in the current society.
4	The literature review should comprehensively examine recent	We have added recent studies' results to the literature review. A new section entitled studies on developing CT disposition and science process skills is added.

No	Referees' Comments	Revisions
	studies conducted within the past four years.	***Studies on Developing CT Disposition and Science Process Skills*** Science process skills can be cultivated by conducting active learning in the classroom. Students should be involved actively in investigating the nature. Inquiry learning model is one of strategy to stimulates students in developing science process skills (Baharom et al., 2020; Gunawan et al., 2019; Limatahu et al., 2018). Along with inquiry learning model, discovery learning model and problem based learning model are also effective in improving science process skills (Suryanti et al., 2020). Media utilized in learning activity can boost science process skills acquiring (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019). There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activity and physics class can enhance CT disposition of students.
5	The methodology is thoroughly explained in every one of its components.	-
6	Discussion is thorough however aligning your discussion with other contemporary studies to improve the quality of it.	We have included comparison with other cotemporary studies to enrich the discussions. In the discussion of science process skills, we added: This study's finding is in accordance with other studies. Ogan-Bekiroğlu & Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçalı & Selvi, 2022). Model-based learning stimulates students to inquire about nature phenomena. The improvement of science process skills in this study is consistent with previous studies which reported that inquiry-based approach stimulated science process skills of students (Aktamiş et al., 2016; Artayasa et al., 2017; Irwanto et al., 2019; Mulyeni et al., 2019). Within inquiry-based approach,

No	Referees' Comments	Revisions
		like in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas. By being responsible in those tasks, students can intensively practice science process skills. In the discussions of theoretical understanding, we made revisions such as: The modeling process support students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue et al., 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena et al. (2021) revealed that constructive combined with collaborative approach influence students learning outcomes In the discussions of computational thinking dispositions, we added: Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu et al., 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin et al. (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development. Students can practice CT skills aspects when they are actively engaged in modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun et al., 2017; Romero et al., 2017). It is supported by a study conducted by Gao & Hew (2022), the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.

No	Referees' Comments	Revisions
7	Please provide a more detailed explanation of the primary discoveries in the concluding section.	We have added a more detailed explanation of the primary discoveries in the concluding. The conclusion section is revised as follows: In this study, we designed collaborative modeling-based learning for fostering theoretical understanding, science process skills and CT dispositions in high school physics classes. The collaborative modeling-based learning engage students in modeling process that usually done by a physicist. The collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection. After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills. By involving in modeling process, students have direct experiences to practice science, hence it can foster the students' science process skills. It is also found that there is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.
8	Include a distinct segment dedicated to the examination of consequences and prospective recommendations.	We added a section entitled limitation and prospective recommendations to address the suggestions. **Limitation and Prospective Recommendation** This study has some limitations. CT disposition is only investigated through self-report checklist which is less comprehend. To explore more about the impact on CT disposition and CT skills, observation should be carefully performed. Collaborative modeling-based learning involve laboratory work in which experiment apparatus is necessary. In some school, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratory for schools in remote

No	Referees' Comments	Revisions
		area. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

3. Revision: August 21, 2023

Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

Computational thinking (CT) skills are essential in the era when technology develops tremendously. To cultivate CT skills, growing CT dispositions among students are also necessary. High school physics class has the potency to stimulate CT dispositions. On the other hand, science process skill is also emphasized in high school physics class. This study aims to design and implement collaborative modeling-based learning for high school physics classes. In order to investigate the effectiveness of collaborative modeling-based learning, a pilot study in a high school physics class is conducted. Research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. There are 89 students who participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.

Keywords: CT disposition, modeling-based learning, high school physics, science process skills.

A. Introduction

In recent years, a massive transformation of technology has changed people's lifestyles. This fact encourages educational institutions to prepare students for the more dynamic life and demands for job transformation. One of the crucial skills that students must possess is computational thinking (CT) skills (Esteve-Mon et al., 2020; Hsu et al., 2018).

CT has been described as an analytic approach to problem-solving that adapts the process on the computer (Sengupta & Kinnebrew, 2013). CT has become one of the fundamental skills, along with writing, reading, and arithmetic (Barr et al., 2011). CT is a problem-solving process that consists of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon et al., 2022; Yin et al., 2020). CT has become essential to science, technology, engineering, and mathematics (STEM). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Next Generation Science Standards (NGSS) have included computational thinking as a part of core scientific practices (NGSS, 2013). Developing CT skills in science courses, such as high school physics, has become necessary. CT and physics are closely related to each other. Physicists often employ CT skills when they do their job. Students may develop ideas relevant to computational thinking by engaging in experiments, problem-solving, and discussions during physics class.

Several studies have been conducted to explore how to integrate CT with science effectively. For example, Yin et al. (2019) try to integrate CT with physics and engineering learning through maker activities they have designed. Sengupta et al. (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). To develop CT skills, students' tendency to apply CT is an important thing. The attitudinal tendency to CT is called CT disposition. High school physics class has a crucial role in making CT disposition grow.

High school physics curriculum also emphasizes science process skills (Susilawati et al., 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge (Gunawan et al., 2019). To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning. Typically, science processes and CT skills are always used by physicists in understanding physical phenomena. Physicists always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist to acquire new knowledge about natural phenomena. The modeling process may be incorporated in high school physics classes to train science process skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning, which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell et al., 2015; Louca & Zacharia, 2012).

This study has objectives such as:

(1) Design collaborative modeling-based learning materials

(2) Implement collaborative modeling-based learning in a high school physics class

(3) Investigate the students' CT disposition and science process skills.

The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. CT dispositions is fundamental for encouraging students to apply CT aspects in their life, which is crucial in the current society.

B. Literature Review

Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon

(Passmore et al., 2014). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon, and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa et al., 2020). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

Modeling-based learning

The modeling process that physicists usually do can be adapted to the learning process. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence, and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. By involving students in modeling, students can develop their main conceptual view of science (Campbell et al., 2015; Dukerich, 2015). Students also can build their understanding of the nature of science.

According to Hestenes (2007), the modeling process comprises three main parts, i.e., modeling, model analysis, and validation. The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning cycles proposed.

Brew (2008), proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation; (3) application; (4) abstraction and generalization; (5) continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning cycle that consists of (1) exploration, (2) model adduction,(4) model formulation, (5) model deployment, and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang et al., 2018).

Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science (Cascarosa et al., 2020).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow et al., 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation, and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. After that, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they constructed. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving, and critical thinking (Yadav et al., 2016). CT can be regarded as thinking skills which aim to solve the problem effectively by adapting the process that occurs in a computer (Lee et al., 2020; Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking, and pattern generalization (Psycharis & Kotzampasaki, 2019; Yin et al., 2020). CT development for students has been attracting much attention, from early childhood to university (Bilbao et al., 2021; Kafai & Proctor, 2022; Papadakis, 2020). In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.

Thinking process needs not only knowledge and skills but also dispositions. Dispositions are a combination of attitudes, values, motivations and beliefs (Sovey et al., 2022). CT disposition can also be considered confident in dealing with complexity (Jong et al., 2020). CT dispositions are the value, motivations, feelings, and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency to CT (Tsai et al., 2021). CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively (Barr & Stephenson, 2011).

When people are engaged in CT, they have a CT disposition. CT dispositions are essential since it is a motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition in a learning process is also necessary to design and evaluate a specific intervention in the learning process.

Science Process Skills

Science process skills are used by scientists to construct knowledge for problems solving and result formulations (Özgelen, 2012). They are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills consist of observing, classifying, communicating, measuring, concluding, and predicting (Darmaji et al., 2019; Mulyeni et al., 2019). Meanwhile, integrated science process skills consist of controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting, and interpreting data (Elfeky et al., 2020).

Studies on Developing CT Disposition and Science Process Skills

Science process skills can be cultivated by conducting active learning in the classroom. Students should be involved actively in investigating the nature. Inquiry learning model is one of strategy to stimulates students in developing science process skills (Baharom et al., 2020; Gunawan et al., 2019; Limatahu et al., 2018). Along with inquiry learning model, discovery learning model and problem based learning model are also effective in improving science process skills (Suryanti et al., 2020). Media utilized in learning activity can boost science process skills acquiring (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019).

There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activity and physics class can enhance CT disposition of students.

C. Method

Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing science process skills is one of the primary purposes of physics courses. Students' Science process skills are also assessed based on students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement, respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-test design was implemented in the study. Pre- and post-test were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11^{th} participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

Instruments

The research instruments employed in the study are pre-test, post-test, CT dispositions checklist, and science process skills rubrics. The pre-and post-test consists of 5 essay problems about elasticity. At last, students are asked to fill a self-report checklist to assess students' CT disposition. The checklist consists of several statements about CT disposition with a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

Data Analysis

The score of the pre- and post-test is compared, and the normalized gain score is calculated. The formula to calculate the normalized gain score, $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score, and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1 (Widoyoko, 2016; Wirjawan et al., 2020).

Table 1. Criteria of the average score of students' CT dispositions checklist

No	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \leq 3.4$	Good
3	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq 1.6$	Very poor

D. Result and Discussions

Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation, and post-experiment discussion. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning

Stages	Activity Explanation
Pre-experiment	In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed. This activity aims to engage students at the beginning of the class. Students are also stimulated for questioning and constructing hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement. They plan experiments, arrange the apparatus, observe the phenomena, collect the data, and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide, along with the worksheet, is provided.
Post-experiment Discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Based on the data, students are asked to construct a model. A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.
Reflection	Students are asked to make a reflection on the learning activity.

Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding, and communicating. Figure 1 shows the average score of each science process skills aspect in percentage during the first learning cycle and second learning cycles. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the observing and formulating hypothesis can be categorized as fair. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding, and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process, hence their science process skills improve. The score for formulating a hypothesis in the learning cycle improve and can be categorized as good. Meanwhile, the others change significantly to be excellent.

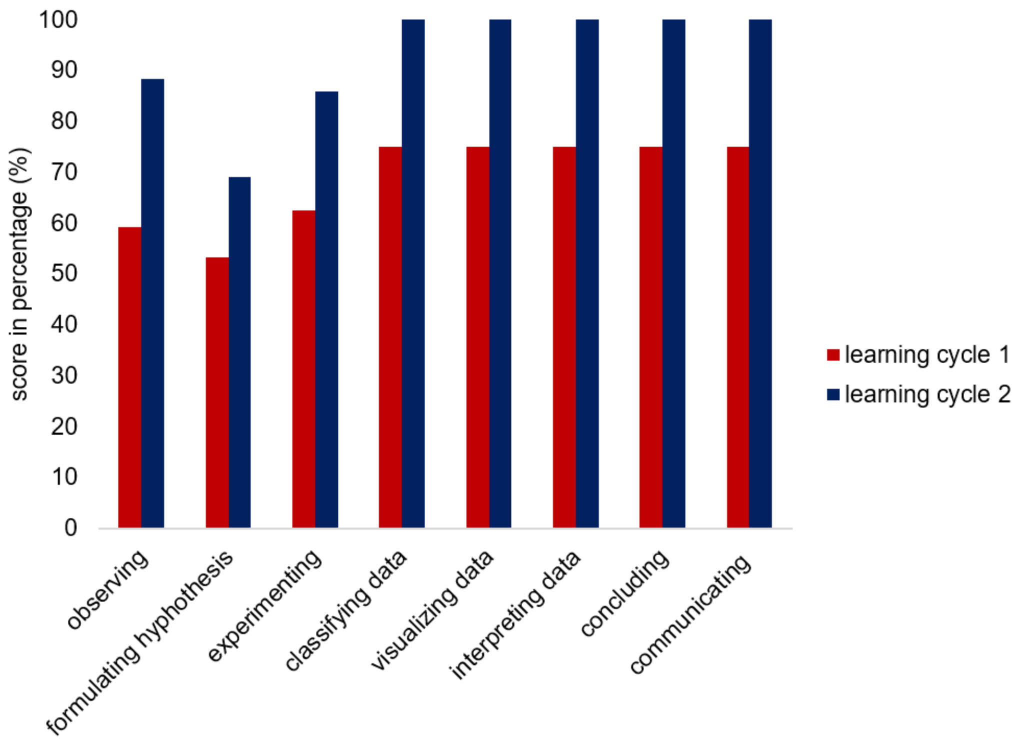

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2

The improvement of science process skills aspects indicates that students have been familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation, and revision.

This study's finding is in accordance with other studies. Ogan-Bekiroğlu & Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçalı & Selvi, 2022).

Model-based learning stimulates students to inquire about nature phenomena. The improvement of science process skills in this study is consistent with previous studies which reported that inquiry-based approach stimulated science process skills of students (Aktamiş et al., 2016; Artayasa et al., 2017; Irwanto et al., 2019; Mulyeni et al., 2019). Within inquiry-based approach, like in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas. By being responsible in those tasks, students can intensively practice science process skills.

Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the collaborative modeling-based learning with the topics of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 3 shows the result of pre-and post-test. There are significant improvements in students' theoretical understanding with an average $\langle g \rangle$ of 0.77. It can be categorized as a high gain. The average pre-test score of 89 students participating in this study is 21.3. Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students in acquiring process skills but also theoretical understanding.

Table 3. Pre-test and post-test results

Number of participants	Average pre-test score	Average post-test score	average $\langle g \rangle$	Classification
89	21.3	81.7	0.77	High

The modeling process support students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue et al., 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena et al. (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes

Computational Thinking Disposition

The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal. Each CT disposition is described in some statements in the questionnaires, such as in Table 4. Based on the self-report checklist, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00). However, students seem still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00), which is only categorized as acceptable.

Table 4. Score of CT dispositions

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best and my mind in working on difficult questions.	3.13	2.89	Good

		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and do more effort when dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best in working on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and do more effort when dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable

		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects (see Table 5). Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu et al., 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin et al. (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills aspects when they are actively engaged in modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun et al., 2017; Romero et al., 2017). It is supported by a study conducted by Gao & Hew (2022), the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.

E. Conclusions

In this study, we designed collaborative modeling-based learning for fostering theoretical understanding, science process skills and CT dispositions in high school physics classes. The collaborative modeling-based learning engage students in modeling process that usually done by a physicist. The collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection.

After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills. By being involved in modeling process, students have direct experiences to practice science, hence it can foster the students' science process skills.

It is also found that there is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through self-report checklist which is less comprehend. To explore more about the impact on CT disposition and CT skills, observation should be carefully performed. Collaborative modeling-based learning involve laboratory work in which experiment apparatus is necessary. In some school, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratory for schools in remote area. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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Contribution of this paper to literature

This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activity in physics class. The pilot study indicates modeling activity may stimulate students' CT dispositions, science process skills, and conceptual understanding.

Conflict of Interests:

The authors declare that they have no conflict of interest.

Authors' Contributions:

H. conceived the work and designed the research strategy. E.P dan H.K. made the research instruments. P.A. conducted the pilot study. P.A., E.P, and A.D.R did data analysis. All authors discussed the results and co-write the manuscript.

Data Availability Statement:

The authors confirm that the data supporting the findings of this study are available within the article.

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4. Paper accepted: September 2, 2023

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Asian Online Journal Publishing Group <editor@asianonlinejournals.com> Sat, Sep 2, 2023 at 2:29 PM
To: Kaprodi Fisika <hod-physics@ukwms.ac.id>

Editorial Decision: Article ID- 2040/JEELR

Dear Herwinarso

Congratulations!

We are happy to let you know that your article ***"Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class"*** has been selected for publication in *Journal of Education and e-Learning Research*. Your article was evaluated in a blind review process by two referees in addition to the input from the editor. Your article will be available online within **90 working days** after receiving the publication fee.

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Please remember to quote the manuscript number, 2040/JEELR, whenever inquiring about your manuscript. After receiving your publication process fee, we will publish your article in the upcoming issue.

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Acceptance Letter

Date: 06-09-2023

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Article Title: Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class.

Journal: Journal of Education and e-Learning Research

Article No.: 2040-JEELR

Congratulations!

I am pleased to inform you that your article **[Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class]** based on reviewer comments has been accepted by *"Journal of Education and e-Learning Research"* for publication in upcoming issue.

Thanks, and best regard.

Sara Lim

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5. Request for Table Adjustment: September 3, 2023

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Dear JEELR Editorial Team

Thank you for the confirmation about the publication fee payment.

We also want to revise our manuscript because we just found out that in the last revision, we misplaced the content of Table 5.
The revised manuscript is attached.

Thank you

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5. Request for Table Adjustment: September 3, 2023

Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

Computational thinking (CT) skills are essential in the era when technology develops tremendously. To cultivate CT skills, growing CT dispositions among students are also necessary. High school physics class has the potency to stimulate CT dispositions. On the other hand, science process skill is also emphasized in high school physics class. This study aims to design and implement collaborative modeling-based learning for high school physics classes. In order to investigate the effectiveness of collaborative modeling-based learning, a pilot study in a high school physics class is conducted. Research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. There are 89 students who participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.

Keywords: CT disposition, modeling-based learning, high school physics, science process skills.

A. Introduction

In recent years, a massive transformation of technology has changed people's lifestyles. This fact encourages educational institutions to prepare students for the more dynamic life and demands for job transformation. One of the crucial skills that students must possess is computational thinking (CT) skills (Esteve-Mon et al., 2020; Hsu et al., 2018).

CT has been described as an analytic approach to problem-solving that adapts the process on the computer (Sengupta & Kinnebrew, 2013). CT has become one of the fundamental skills, along with writing, reading, and arithmetic (Barr et al., 2011). CT is a problem-solving process that consists of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon et al., 2022; Yin et al., 2020). CT has become essential to science, technology, engineering, and mathematics (STEM). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Next Generation Science Standards (NGSS) have included computational thinking as a part of core scientific practices (NGSS, 2013). Developing CT skills in science courses, such as high school physics, has become necessary. CT and physics are closely related to each other. Physicists often employ CT skills when they do their job. Students may develop ideas relevant to computational thinking by engaging in experiments, problem-solving, and discussions during physics class.

Several studies have been conducted to explore how to integrate CT with science effectively. For example, Yin et al. (2019) try to integrate CT with physics and engineering learning through maker activities they have designed. Sengupta et al. (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). To develop CT skills, students' tendency to apply CT is an important thing. The attitudinal tendency to CT is called CT disposition. High school physics class has a crucial role in making CT disposition grow.

High school physics curriculum also emphasizes science process skills (Susilawati et al., 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge (Gunawan et al., 2019). To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning. Typically, science processes and CT skills are always used by physicists in understanding physical phenomena. Physicists always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist to acquire new knowledge about natural phenomena. The modeling process may be incorporated in high school physics classes to train science process skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning, which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell et al., 2015; Louca & Zacharia, 2012).

This study has objectives such as:

(1) Design collaborative modeling-based learning materials

(2) Implement collaborative modeling-based learning in a high school physics class

(3) Investigate the students' CT disposition and science process skills.

The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. CT dispositions is fundamental for encouraging students to apply CT aspects in their life, which is crucial in the current society.

B. Literature Review

Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon

(Passmore et al., 2014). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon, and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa et al., 2020). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

Modeling-based learning

The modeling process that physicists usually do can be adapted to the learning process. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence, and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. By involving students in modeling, students can develop their main conceptual view of science (Campbell et al., 2015; Dukerich, 2015). Students also can build their understanding of the nature of science.

According to Hestenes (2007), the modeling process comprises three main parts, i.e., modeling, model analysis, and validation. The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning cycles proposed.

Brew (2008), proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation; (3) application; (4) abstraction and generalization; (5) continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning cycle that consists of (1) exploration, (2) model adduction,(4) model formulation, (5) model deployment, and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang et al., 2018).

Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science (Cascarosa et al., 2020).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow et al., 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation, and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. After that, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they constructed. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving, and critical thinking (Yadav et al., 2016). CT can be regarded as thinking skills which aim to solve the problem effectively by adapting the process that occurs in a computer (Lee et al., 2020; Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking, and pattern generalization (Psycharis & Kotzampasaki, 2019; Yin et al., 2020). CT development for students has been attracting much attention, from early childhood to university (Bilbao et al., 2021; Kafai & Proctor, 2022; Papadakis, 2020). In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.

Thinking process needs not only knowledge and skills but also dispositions. Dispositions are a combination of attitudes, values, motivations and beliefs (Sovey et al., 2022). CT disposition can also be considered confident in dealing with complexity (Jong et al., 2020). CT dispositions are the value, motivations, feelings, and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency to CT (Tsai et al., 2021). CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively (Barr & Stephenson, 2011).

When people are engaged in CT, they have a CT disposition. CT dispositions are essential since it is a motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition in a learning process is also necessary to design and evaluate a specific intervention in the learning process.

Science Process Skills

Science process skills are used by scientists to construct knowledge for problems solving and result formulations (Özgelen, 2012). They are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills consist of observing, classifying, communicating, measuring, concluding, and predicting (Darmaji et al., 2019; Mulyeni et al., 2019). Meanwhile, integrated science process skills consist of controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting, and interpreting data (Elfeky et al., 2020).

Studies on Developing CT Disposition and Science Process Skills

Science process skills can be cultivated by conducting active learning in the classroom. Students should be involved actively in investigating the nature. Inquiry learning model is one of strategy to stimulates students in developing science process skills (Baharom et al., 2020; Gunawan et al., 2019; Limatahu et al., 2018). Along with inquiry learning model, discovery learning model and problem based learning model are also effective in improving science process skills (Suryanti et al., 2020). Media utilized in learning activity can boost science process skills acquiring (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019).

There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activity and physics class can enhance CT disposition of students.

C. Method

Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing science process skills is one of the primary purposes of physics courses. Students' Science process skills are also assessed based on students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement, respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-test design was implemented in the study. Pre- and post-test were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11^{th} participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

Instruments

The research instruments employed in the study are pre-test, post-test, CT dispositions checklist, and science process skills rubrics. The pre-and post-test consists of 5 essay problems about elasticity. At last, students are asked to fill a self-report checklist to assess students' CT disposition. The checklist consists of several statements about CT disposition with a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

Data Analysis

The score of the pre- and post-test is compared, and the normalized gain score is calculated. The formula to calculate the normalized gain score, $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score, and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1 (Widoyoko, 2016; Wirjawan et al., 2020).

Table 1. Criteria of the average score of students' CT dispositions checklist

No	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \leq 3.4$	Good
3	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq 1.6$	Very poor

D. Result and Discussions

Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation, and post-experiment discussion. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning

Stages	Activity Explanation
Pre-experiment	In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed. This activity aims to engage students at the beginning of the class. Students are also stimulated for questioning and constructing hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement. They plan experiments, arrange the apparatus, observe the phenomena, collect the data, and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide, along with the worksheet, is provided.
Post-experiment Discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Based on the data, students are asked to construct a model. A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.
Reflection	Students are asked to make a reflection on the learning activity.

Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding, and communicating. Figure 1 shows the average score of each science process skills aspect in percentage during the first learning cycle and second learning cycles. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the observing and formulating hypothesis can be categorized as fair. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding, and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process, hence their science process skills improve. The score for formulating a hypothesis in the learning cycle improve and can be categorized as good. Meanwhile, the others change significantly to be excellent.

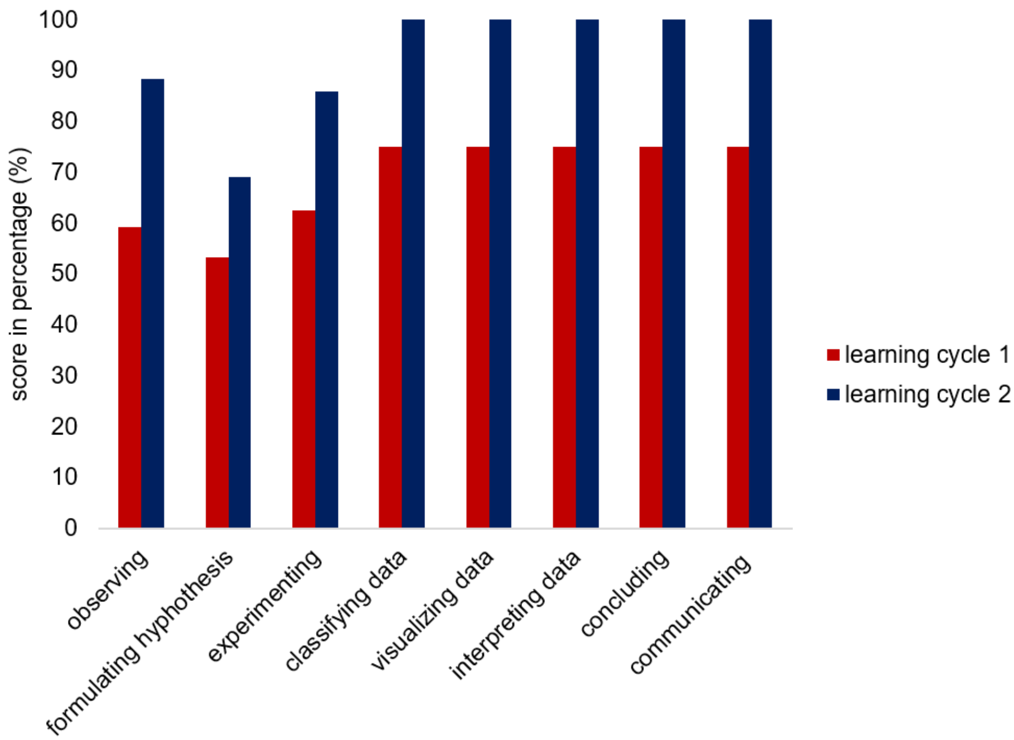

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2

The improvement of science process skills aspects indicates that students have been familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation, and revision.

This study's finding is in accordance with other studies. Ogan-Bekiroğlu & Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçalı & Selvi, 2022).

Model-based learning stimulates students to inquire about nature phenomena. The improvement of science process skills in this study is consistent with previous studies which reported that inquiry-based approach stimulated science process skills of students (Aktamiş et al., 2016; Artayasa et al., 2017; Irwanto et al., 2019; Mulyeni et al., 2019). Within inquiry-based approach, like in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas. By being responsible in those tasks, students can intensively practice science process skills.

Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the collaborative modeling-based learning with the topics of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 3 shows the result of pre-and post-test. There are significant improvements in students' theoretical understanding with an average $\langle g \rangle$ of 0.77. It can be categorized as a high gain. The average pre-test score of 89 students participating in this study is 21.3. Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students in acquiring process skills but also theoretical understanding.

Table 3. Pre-test and post-test results

Number of participants	Average pre-test score	Average post-test score	average $\langle g \rangle$	Classification
89	21.3	81.7	0.77	High

The modeling process support students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue et al., 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena et al. (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes

Computational Thinking Disposition

The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal. Each CT disposition is described in some statements in the questionnaires, such as in Table 4. Based on the self-report checklist, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00). However, students seem still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00), which is only categorized as acceptable.

Table 4. Score of CT dispositions

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best and my mind in working on difficult questions.	3.13	2.89	Good

		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and do more effort when dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT

No	Statements	Average Score	Criteria
1	I try to break down complex problems into simpler parts so that they are easy to understand and solve	3.06	Good
2	When facing complex problems, I gather general characteristics and filter out specific information that is not needed to solve the problem	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution	3.08	Good
4	I reduce complexity and look for main ideas through modes	2.83	Good
5	To solve many problems, I have developed a step-by-step solution that can be followed	3.16	Good
6	After solving a problem, I evaluate how the solution can be improved	3.05	Good
7	After finding a solution to a problem, I determine whether the solution is truly correct and efficient	3.11	Good

8	I compared the advantages and disadvantages of various alternative solutions to the problem and I took the best one	3.11	Good
Average		**3.06**	**Good**

According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects (see Table 5). Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu et al., 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin et al. (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills aspects when they are actively engaged in modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun et al., 2017; Romero et al., 2017). It is supported by a study conducted by Gao & Hew (2022), the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.

E. Conclusions

In this study, we designed collaborative modeling-based learning for fostering theoretical understanding, science process skills and CT dispositions in high school physics classes. The collaborative modeling-based learning engage students in modeling process that usually done by a physicist. The collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection.

After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills. By being involved in modeling process, students have direct experiences to practice science, hence it can foster the students' science process skills.

It is also found that there is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through self-report checklist which is less comprehend. To explore more about the impact on CT disposition and CT skills, observation should be carefully performed. Collaborative modeling-based learning involve laboratory work in which experiment apparatus is necessary. In some school, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratory for schools in remote area. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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Contribution of this paper to literature

This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activity in physics class. The pilot study indicates modeling activity may stimulate students' CT dispositions, science process skills, and conceptual understanding.

Conflict of Interests:

The authors declare that they have no conflict of interest.

Authors' Contributions:

H. conceived the work and designed the research strategy. E.P dan H.K. made the research instruments. P.A. conducted the pilot study. P.A., E.P, and A.D.R did data analysis. All authors discussed the results and co-write the manuscript.

Data Availability Statement:

The authors confirm that the data supporting the findings of this study are available within the article.

Ethical:

This study followed all ethical practices during writing

Institutional Review Board Statement:

The Review Board at the Faculty of Teacher Education of Universitas Katolik Widya Mandala Surabaya has declared that the research met all requirements of the Ethical Clearance (Ref. 224/WM02/T/2023)

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Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

Computational thinking (CT) skills are essential in the era when technology develops tremendously. To cultivate CT skills, growing CT dispositions among students are also necessary. High school physics class has the potency to stimulate CT dispositions. On the other hand, science process skill is also emphasized in high school physics class. This study aims to design and implement collaborative modeling-based learning for high school physics classes. In order to investigate the effectiveness of collaborative modeling-based learning, a pilot study in a high school physics class is conducted. Research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. There are 89 students who participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.

Keywords: CT disposition, High school physics, Modeling-based learning, Science process skills.

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Contribution of this paper to the literature
This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activity in physics class. The pilot study indicates modeling activity may stimulate students' CT dispositions, science process skills, and conceptual understanding.

1. Introduction

In recent years, a massive transformation of technology has changed people's lifestyles. This fact encourages educational institutions to prepare students for the more dynamic life and demands for job transformation. One of the crucial skills that students must possess is computational thinking (CT) skills (Esteve-Mon, Llopis, & Adell-Segura, 2020; Hsu, Chang, & Hung, 2018).

CT has been described as an analytic approach to problem-solving that adapts the process on the computer (Sengupta & Kinnebrew, 2013). CT has become one of the fundamental skills, along with writing, reading, and arithmetic (Barr, Harrison, & Conery, 2011). CT is a problem-solving process that consists of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon, Wong, Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020). CT has become essential to science, technology, engineering, and mathematics (STEM). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Next Generation Science Standards (NGSS) have included computational thinking as a part of core scientific practices (NGSS, 2013). Developing CT skills in science courses, such as high school physics, has become necessary. CT and physics are closely related to each other. Physicists often employ CT skills when they do their job. Students may develop ideas relevant to computational thinking by engaging in experiments, problem-solving, and discussions during physics class.

Several studies have been conducted to explore how to integrate CT with science effectively. For example, Yin et al. (2019) try to integrate CT with physics and engineering learning through maker activities they have designed. Sengupta and Kinnebrew (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). To develop CT skills, students' tendency to apply CT is an important thing. The attitudinal tendency to CT is called CT disposition. High school physics class has a crucial role in making CT disposition grow.

High school physics curriculum also emphasizes science process skills (Susilawati, Doyan, Mulyadi, Abo, & Pineda, 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge (Gunawan, Hermansyah, & Herayanti, 2019). To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning. Typically, science processes and CT skills are always used by physicists in understanding physical phenomena. Physicists always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist to acquire new knowledge about natural phenomena. The modeling process may be incorporated in high school physics classes to train science process skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning, which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell, Oh, Maughn, Kiriazis, & Zuwallack, 2015; Louca & Zacharia, 2012).

This study has objectives such as:

(1) Design collaborative modeling-based learning materials
(2) Implement collaborative modeling-based learning in a high school physics class
(3) Investigate the students' CT disposition and science process skills.

The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. CT dispositions is fundamental for encouraging students to apply CT aspects in their life, which is crucial in the current society.

2. Literature Review

2.1. Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore, Gouvea, & Giere, 2013). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon, and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa, Sánchez-Azqueta, Gimeno, & Aldea, 2021). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

2.2. Modeling-Based Learning

The modeling process that physicists usually do can be adapted to the learning process. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence, and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. By involving students in modeling, students can develop their main conceptual view of science (Campbell et al., 2015; Dukerich, 2015). Students also can build their understanding of the nature of science.

According to Hestenes (2007), the modeling process comprises three main parts, i.e., modeling, model analysis, and validation. The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning cycles proposed.

Brewe (2008), proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation; (3) application; (4) abstraction and generalization; (5) continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning cycle that consists of (1) exploration, (2) model adduction,(4) model formulation, (5) model deployment, and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang, Jou, Lv, & Huang, 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science (Cascarosa et al., 2021).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe & Sawtelle, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow, Frick, Barker, & Phelps, 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation, and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. After that, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they constructed. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

2.3. Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving, and critical thinking (Yadav, Hong, & Stephenson, 2016). CT can be regarded as thinking skills which aim to solve the problem effectively by adapting the process that occurs in a computer (Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking, and pattern generalization (Psycharis & Kotzampasaki, 2019; Yin et al., 2020). CT development for students has been attracting much attention, from early childhood to university (Bilbao, Bravo, García, Rebollar, & Varela, 2021; Kafai & Proctor, 2022; Papadakis, 2020). In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.

Thinking process needs not only knowledge and skills but also dispositions. Dispositions are a combination of attitudes, values, motivations and beliefs (Sovey, Osman, & Matore, 2022). CT disposition can also be considered confident in dealing with complexity (Jong, Geng, Chai, & Lin, 2020). CT dispositions are the value, motivations, feelings, and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency to CT (Tsai, Liang, & Hsu, 2021). CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively (Barr & Stephenson, 2011).

When people are engaged in CT, they have a CT disposition. CT dispositions are essential since it is a motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition in a learning process is also necessary to design and evaluate a specific intervention in the learning process.

2.4. Science Process Skills

Science process skills are used by scientists to construct knowledge for problems solving and result formulations (Özgelen, 2012). They are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills consist of observing, classifying, communicating, measuring, concluding, and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019). Meanwhile, integrated science process skills consist of controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting, and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020).

2.5. Studies on Developing CT Disposition and Science Process Skills

Science process skills can be cultivated by conducting active learning in the classroom. Students should be involved actively in investigating the nature. Inquiry learning model is one of strategy to stimulates students in developing science process skills (Baharom, Atan, Rosli, Yusof, & Hamid, 2020; Gunawan et al., 2019; Limatahu, Sutoyo, & Prahani, 2018). Along with inquiry learning model, discovery learning model and problem based learning model are also effective in improving science process skills (Suryanti, Widodo, & Budijastuti, 2020). Media utilized in learning activity can boost science process skills acquiring (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019).

There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activity and physics class can enhance CT disposition of students.

3. Method

3.1. Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing science process skills is one of the primary purposes of physics courses. Students' Science process skills are also assessed based on students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement, respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-test design was implemented in the study. Pre- and post-test were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

3.2. Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

3.3. Instruments

The research instruments employed in the study are pre-test, post-test, CT dispositions checklist, and science process skills rubrics. The pre-and post-test consists of 5 essay problems about elasticity. At last, students are asked to fill a self-report checklist to assess students' CT disposition. The checklist consists of several statements about CT disposition with a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

3.4. Data Analysis

The score of the pre- and post-test is compared, and the normalized gain score is calculated. The formula to calculate the normalized gain score, $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score, and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1 (Widoyoko, 2016).

Table 1. Criteria of the average score of students' CT dispositions checklist.

No.	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \leq 3.4$	Good
3	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq 1.6$	Very poor

4. Result and Discussions

4.1. Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation, and post-experiment discussion. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning.

Stages	Activity explanation
Pre-experiment	In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed. This activity aims to engage students at the beginning of the class. Students are also stimulated for questioning and constructing hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement. They plan experiments, arrange the apparatus, observe the phenomena, collect the data, and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide, along with the worksheet, is provided.
Post-experiment discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Based on the data, students are asked to construct a model. A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.
Reflection	Students are asked to make a reflection on the learning activity.

4.2. Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding, and communicating. Figure 1 shows the average score of each science process skills aspect in percentage during the first learning cycle and second learning cycles. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the observing and formulating hypothesis can be categorized as fair. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding, and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process, hence their science process skills improve. The score for formulating a hypothesis in the learning cycle improve and can be categorized as good. Meanwhile, the others change significantly to be excellent.

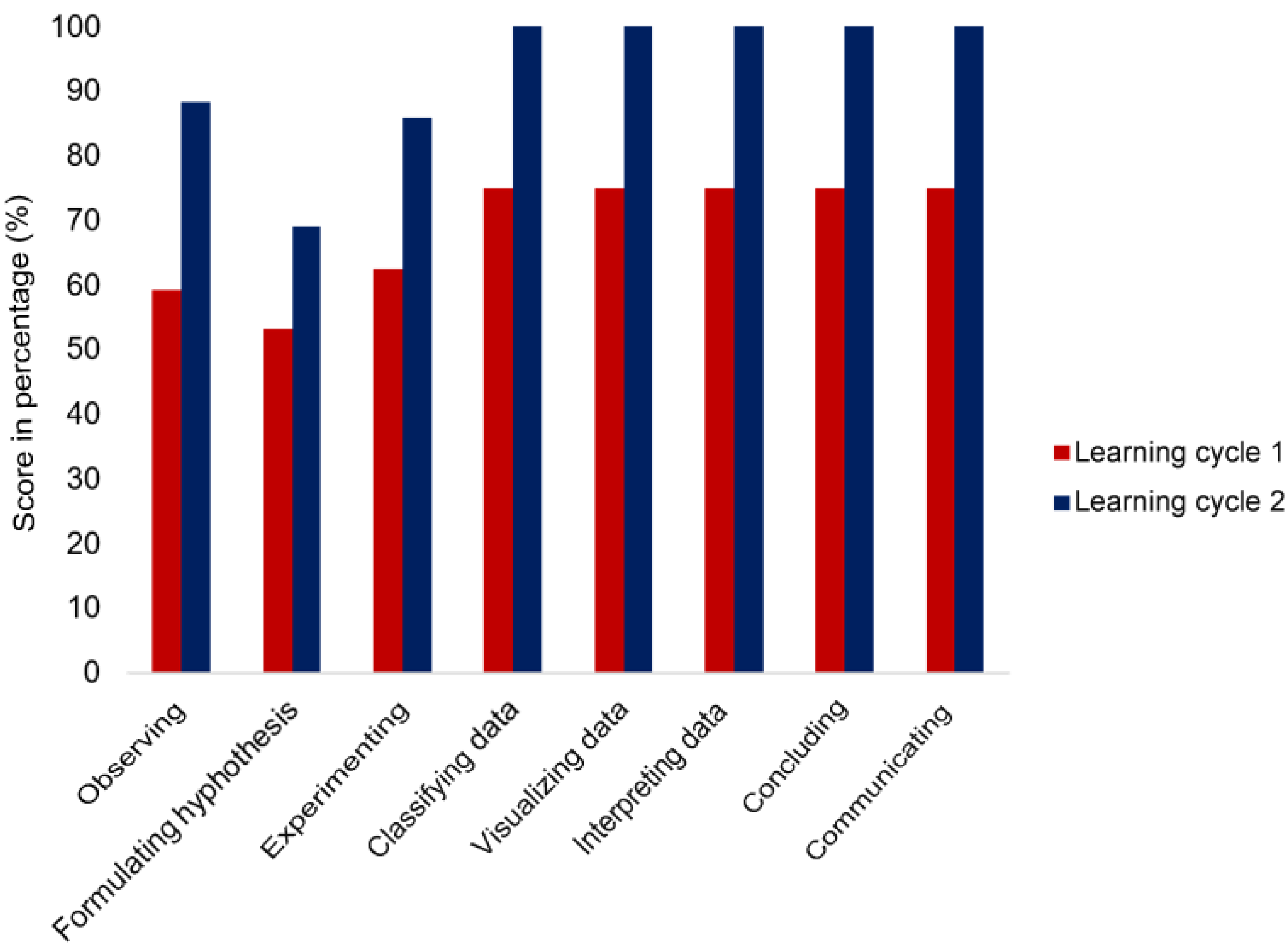

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2.

The improvement of science process skills aspects indicates that students have been familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation, and revision.

This study's finding is in accordance with other studies. Ogan-Bekiroğlu and Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçali & Selvi, 2022).

Model-based learning stimulates students to inquire about nature phenomena. The improvement of science process skills in this study is consistent with previous studies which reported that inquiry-based approach stimulated science process skills of students (Aktamiş, Hiğde, & Özden, 2016; Artayasa, Susilo, Lestari, & Indriwati, 2017; Mulyeni et al., 2019; Saputro, Rohaeti, & Prodjosantoso, 2019). Within inquiry-based approach, like in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas. By being responsible in those tasks, students can intensively practice science process skills.

4.3. Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the collaborative modeling-based learning with the topics of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 3 shows the result of pre-and post-test. There are significant improvements in students' theoretical understanding with an average $\langle g \rangle$ of 0.77. It can be categorized as a high gain. The average pre-test score of 89 students participating in this study is 21.3. Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students in acquiring process skills but also theoretical understanding.

Table 3. Pre-test and post-test results.

Number of participants	Average pre-test score	Average post-test score	average ⟨*g*⟩	Classification
89	21.3	81.7	0.77	High

The modeling process support students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue, Sun, Zhu, Huang, & Topping, 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena, Darmuki, and Hariyadi (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes

4.4. Computational Thinking Disposition

The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal. Each CT disposition is described in some statements in the questionnaires, such as in Table 4. Based on the self-report checklist, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00). However, students seem still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00), which is only categorized as acceptable.

Table 4. Score of CT dispositions.

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best and my mind in working on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and do more effort when dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT.

No	Statements	Average score	Criteria
1	I try to break down complex problems into simpler parts so that they are easy to understand and solve	3.06	Good
2	When facing complex problems, I gather general characteristics and filter out specific information that is not needed to solve the problem	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution	3.08	Good
4	I reduce complexity and look for main ideas through modes	2.83	Good
5	To solve many problems, I have developed a step-by-step solution that can be followed	3.16	Good
6	After solving a problem, I evaluate how the solution can be improved	3.05	Good
7	After finding a solution to a problem, I determine whether the solution is truly correct and efficient	3.11	Good
8	I compared the advantages and disadvantages of various alternative solutions to the problem and I took the best one	3.11	Good
Average		3.06	Good

According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects see Table 5. Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu, Perera, & Klein, 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin, Bowers, Krajcik, and Damelin (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills aspects when they are actively engaged in modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun, Han, & Kim, 2017; Romero, Lepage, & Lille, 2017). It is supported by a study conducted by Gao and Hew (2022), the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.

5. Conclusions

In this study, we designed collaborative modeling-based learning for fostering theoretical understanding, science process skills and CT dispositions in high school physics classes. The collaborative modeling-based learning engage students in modeling process that usually done by a physicist. The collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection.

After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills. By being involved in modeling process, students have direct experiences to practice science, hence it can foster the students' science process skills.

It is also found that there is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

5.1. Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through self-report checklist which is less comprehend. To explore more about the impact on CT disposition and CT skills, observation should be carefully performed. Collaborative modeling-based learning involve laboratory work in which experiment apparatus is necessary. In some school, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratory for schools in remote area. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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8. Send response: September 10, 2023

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manuscript Submission Inquiry

Kaprodi Fisika <hod-physics@ukwms.ac.id> Sun, Sep 10, 2023 at 11:51 AM
To: Asian Online Journal Publishing Group <editor@asianonlinejournals.com>

Dear Editors,

We are sending the revised manuscript, list of changes, and authors' information in this email.

The parts that we changed are highlighted in blue.

Thank you
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8. Send response: September 10, 2023

Dear Editor,

We have carefully read the comments and revised the manuscript. The changes that we have made are listed in the following table. All changes in the manuscript are highlighted in blue.

No	Comments	Author's response
1	The journal accepts the abstract of 200 to 250 words. Revise the abstract in the structured abstract style. Avoid using headings and follow the sentence structure of Purpose, Design/Methodology/Approach, Findings, and Practical Implications. In this section you need to specify what makes this study original. What have you done differently that hasn't been done before? Your contribution shouldn't be more than 50 words. Please rewrite following sentence in order to fix the issue of text overlap. Please rewrite following sentence in order to fix the issue of text overlap. References highlighted are incomplete. Please provide complete details.	The abstract has been edited : *This study aims to design and implement collaborative modeling-based learning for high school physics classes that stimulate computational thinking (CT) and science process skills. In order to investigate the effectiveness of collaborative modeling-based learning, a pilot study in a high school physics class is conducted. Research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. There are 89 students who participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.*
2	Please rewrite following sentence in order to fix the issue of text overlap. CT has been described as an analytic approach to problem-solving that adapts the process on the computer (Sengupta & Kinnebrew, 2013) . CT has become one of the fundamental skills, along with	The paragraph has been re-written: *CT concept is emerged from the process caried out on computer that is adapted as an analytic approach to problem solving (Sengupta & Kinnebrew, 2013). CT is a fundamental skills, just like writing reading, and arithmetic (Barr, Harrison, & Conery, 2011). CT comprises aspects of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon, Wong, Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et*

No	Comments	Author's response
	writing, reading, and arithmetic (Barr, Harrison, & Conery, 2011) . CT is a problem-solving process that consists of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon, Wong,Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020) . CT has become essential to science, technology, engineering, and mathematics (STEM). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020) . Next Generation Science Standards (NGSS) have included computational thinking as a part of core scientific practices (NGSS, 2013). Developing CT skills in science courses, such as high school physics, has become necessary. CT and physics are closely related to each other. Physicists often employ CT skills when they do their job. Students may develop ideas relevant to computational thinking by engaging in experiments, problem- solving, and discussions during physics class.	*al., 2020). Physics is closely related to CT, CT skills is employed in most physics investigations. Hence, developing CT skills in high school physics, has become necessary. Students may develop ideas relevant to CT by engaging in experiments, problem-solving, and discussions during physics class.*
3	Please rewrite following sentence in order to fix the issue of text overlap. Science process skills are used by scientists to construct knowledge for problems solving and result formulations (Özgelen, 2012) . They are necessary to discover and build scientific knowledge. In many	The paragraph has been re-written: *In order to construct new knowledge or solve a problem, scientist always use science process skills (Özgelen, 2012). They are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills includes skills for observing, classifying, communicating, measuring, concluding, and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019). Meanwhile, integrated science*

No	Comments	Author's response
	studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019) . Basic science process skills consist of observing, classifying, communicating, measuring, concluding, and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019) . Meanwhile, integrated science process skills consist of controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting, and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020) .	*process skills comprises skills for controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting, and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020).*
4	Please Check that given the names and surnames of the authors have been recognized properly and are presented in the preferred order.	The names and surnames of the authors are correct
5	In these references, Please add missing volume number, issue number and page no. **List of References** Krajcik, J., & Merritt, J. (2012). Engaging students in scientific practices : What does constructing and revising models look like in the science classroom. *The Science Teacher*, *79*(3), 38. > done	The reference has been edited: Krajcik, J., & Merritt, J. (2012). Engaging students in scientific practices : What does constructing and revising models look like in the science classroom. *The Science Teacher*, *79*(3), 38-41
6	**Please check the following references-**	We removed (NGSS, 2013) and Hestenes (2007).

No	Comments	Author's response
	(NGSS, 2013), Yin et al. (2019), Hestenes (2007)	Meanwhile Yin et al. (2019) is changed to Yin, Y., Hadad, R., Tang, X., & Lin, Q. (2020), which has been listed in the references
7	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** Papadakis, S. (2020). Apps to promote computational thinking concepts and coding skills in children of preschool and pre-primary school age in mobile learning applications in early childhood education. In (pp. 101–121): IGI Global. Selby, C. C., & Woollard, J. (2013). Computational thinking: The developing definition. *Special Interest Group on Computer Science Education*.	We revised the references: Selby, C. C., & Woollard, J. (2013). Computational thinking: The developing definition. In *Special Interest Group on Computer Science Education*. We removed: Papadakis, S. (2020). Apps to promote computational thinking concepts and coding skills in children of preschool and pre-primary school age in mobile learning applications in early childhood education. In (pp. 101–121): IGI Global. Widoyoko, E. P. (2016). *Learning program evaluation: A practical guide for educators and prospective educators*.

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Investigation of Science Process Skills and Computational Thinking Disposition during Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

This study aims to design and implement collaborative modeling-based learning for high school physics classes that stimulate computational thinking (CT) and science process skills. In order to investigate the effectiveness of collaborative modeling-based learning, a pilot study in a high school physics class is conducted. Research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. There are 89 students who participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.
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Contribution of this paper to the literature

This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activity in physics class. New finding in this study is that modeling activity may stimulate students' CT dispositions.

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1. Introduction

In recent years, a massive transformation of technology has changed people's lifestyles. This fact encourages educational institutions to prepare students for the more dynamic life and demands for job transformation. One of the crucial skills that students must possess is computational thinking (CT) skills (Esteve-Mon, Llopis, & Adell-Segura, 2020; Hsu, Chang, & Hung, 2018).

CT concept is emerged from the process caried out on computer that is adapted as an analytic approach to problem solving (Sengupta & Kinnebrew, 2013). CT is a fundamental skills, just like writing reading, and arithmetic (Barr, Harrison, & Conery, 2011). CT comprises aspects of decomposition, abstraction, algorithmic thinking, generalization, and evaluation (Voon, Wong, Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Physics is closely related to CT, CT skills is employed in most physics investigations. Hence, developing CT skills in high school physics, has become necessary. Students may develop ideas relevant to CT by engaging in experiments, problem-solving, and discussions during physics class.

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Several studies have been conducted to explore how to integrate CT with science effectively. For example, Yin, Y., Hadad, R., Tang, X., & Lin, Q. (2020) try to integrate CT with physics and engineering learning through maker activities they have designed. Sengupta and Kinnebrew (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). To develop CT skills, students' tendency to apply CT is an important thing. The attitudinal tendency to CT is called CT disposition. High school physics class has a crucial role in making CT disposition grow.

High school physics curriculum also emphasizes science process skills (Susilawati, Doyan, Mulyadi, Abo, & Pineda, 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge (Gunawan, Hermansyah, & Herayanti, 2019). To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning. Typically, science processes and CT skills are always used by physicists in understanding physical phenomena. Physicists always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist to acquire new knowledge about natural phenomena. The modeling process may be incorporated in high school physics classes to train science process skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning, which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell, Oh, Maughn, Kiriazis, & Zuwallack, 2015; Louca & Zacharia, 2012).

This study has objectives such as:

(1) Design collaborative modeling-based learning materials
(2) Implement collaborative modeling-based learning in a high school physics class
(3) Investigate the students' CT disposition and science process skills.

The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. CT dispositions is fundamental for encouraging students to apply CT aspects in their life, which is crucial in the current society.

2. Literature Review

2.1. Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore, Gouvea, & Giere, 2013). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon, and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa, Sánchez-Azqueta, Gimeno, & Aldea, 2021). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

2.2. Modeling-Based Learning

The modeling process that physicists usually do can be adapted to the learning process. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence, and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. By involving students in modeling, students can develop their main conceptual view of science (Campbell et al., 2015; Dukerich, 2015). Students also can build their understanding of the nature of science.

The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning cycles proposed. Brewe (2008), proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation; (3) application; (4) abstraction and generalization; (5) continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning cycle that consists of (1) exploration, (2) model adduction,(4) model formulation, (5) model deployment, and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang, Jou, Lv, & Huang, 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science (Cascarosa et al., 2021).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe & Sawtelle, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow, Frick, Barker, & Phelps, 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation, and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. After that, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they constructed. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

2.3. Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving, and critical thinking (Yadav, Hong, & Stephenson, 2016). CT can be regarded as thinking skills which aim to solve the problem effectively by adapting the process that occurs in a computer (Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking, and pattern generalization (Psycharis & Kotzampasaki, 2019). CT development for students has been attracting much attention, from early childhood to university (Bilbao, Bravo, García, Rebollar, & Varela, 2021; Kafai & Proctor, 2022). In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.

Thinking process needs not only knowledge and skills but also dispositions. Dispositions are a combination of attitudes, values, motivations and beliefs (Sovey, Osman, & Matore, 2022). CT disposition can also be considered confident in dealing with complexity (Jong, Geng, Chai, & Lin, 2020). CT dispositions are the value, motivations, feelings, and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency to CT (Tsai, Liang, & Hsu, 2021). CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively (Barr & Stephenson, 2011).

When people are engaged in CT, they have a CT disposition. CT dispositions are essential since it is a motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition in a learning process is also necessary to design and evaluate a specific intervention in the learning process.

2.4. Science Process Skills

In order to construct new knowledge or solve a problem, scientist always use science process skills (Özgelen, 2012). They are necessary to discover and build scientific knowledge. In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills (Derilo, 2019). Basic science process skills includes skills for observing, classifying, communicating, measuring, concluding, and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019). Meanwhile, integrated science process skills comprises skills for controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting, and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020).

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2.5. Studies on Developing CT Disposition and Science Process Skills

Science process skills can be cultivated by conducting active learning in the classroom. Students should be involved actively in investigating the nature. Inquiry learning model is one of strategy to stimulates students in developing science process skills (Baharom, Atan, Rosli, Yusof, & Hamid, 2020; Gunawan et al., 2019; Limatahu, Sutoyo, & Prahani, 2018). Along with inquiry learning model, discovery learning model and problem based learning model are also effective in improving science process skills (Suryanti, Widodo, & Budijastuti, 2020). Media utilized in learning activity can boost science process skills acquiring (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019).

There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin, Y., Hadad, R., Tang, X., & Lin, Q. (2020) indicates that integrating maker activity and physics class can enhance CT disposition of students.

3. Method

3.1. Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing science process skills is one of the primary purposes of physics courses. Students' Science process skills are also assessed based on students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement, respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-test design was implemented in the study. Pre- and post-test were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

3.2. Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

3.3. Instruments

The research instruments employed in the study are pre-test, post-test, CT dispositions checklist, and science process skills rubrics. The pre-and post-test consists of 5 essay problems about elasticity. At last, students are asked to fill a self-report checklist to assess students' CT disposition. The checklist consists of several statements about CT disposition with a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

3.4. Data Analysis

The score of the pre- and post-test is compared, and the normalized gain score is calculated. The formula to calculate the normalized gain score, $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score, and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3, and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1.

Table 1. Criteria of the average score of students' CT dispositions checklist.

No.	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \leq 3.4$	Good
3	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq 1.6$	Very poor

4. Result and Discussions

4.1. Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation, and post-experiment discussion. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning.

Stages	Activity explanation
Pre-experiment	In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed. This activity aims to engage students at the beginning of the class. Students are also stimulated for questioning and constructing hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement. They plan experiments, arrange the apparatus, observe the phenomena, collect the data, and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide, along with the worksheet, is provided.
Post-experiment discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Based on the data, students are asked to construct a model. A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Within the group, students discuss how to solve some related problems by applying the model that has been developed.
Reflection	Students are asked to make a reflection on the learning activity.

4.2. Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding, and communicating. Figure 1 shows the average score of each science process skills aspect in percentage during the first learning cycle and second learning cycles. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the observing and formulating hypothesis can be categorized as fair. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding, and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process, hence their science process skills improve. The score for formulating a hypothesis in the learning cycle improve and can be categorized as good. Meanwhile, the others change significantly to be excellent.

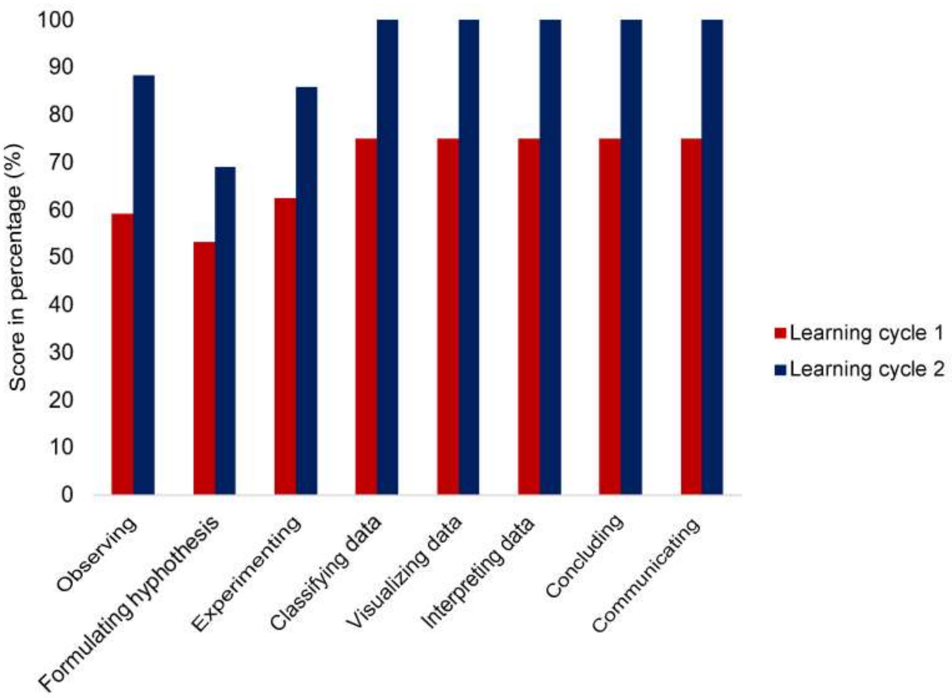

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2.

The improvement of science process skills aspects indicates that students have been familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation, and revision.

This study's finding is in accordance with other studies. Ogan-Bekiroğlu and Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçali & Selvi, 2022).

Model-based learning stimulates students to inquire about nature phenomena. The improvement of science process skills in this study is consistent with previous studies which reported that inquiry-based approach stimulated science process skills of students (Aktamiş, Hiğde, & Özden, 2016; Artayasa, Susilo, Lestari, & Indriwati, 2017; Mulyeni et al., 2019; Saputro, Rohaeti, & Prodjosantoso, 2019). Within inquiry-based approach, like in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas. By being responsible in those tasks, students can intensively practice science process skills.

4.3. Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the collaborative modeling-based learning with the topics of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 3 shows the result of pre-and post-test. There are significant improvements in students' theoretical understanding with an average $\langle g \rangle$ of 0.77. It can be categorized as a high gain. The average pre-test score of 89 students participating in this study is 21.3. Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students in acquiring process skills but also theoretical understanding.

Table 3. Pre-test and post-test results.

Number of participants	Average pre-test score	Average post-test score	average $\langle g \rangle$	Classification
89	21.3	81.7	0.77	High

The modeling process support students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing, and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue, Sun, Zhu, Huang, & Topping, 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena, Darmuki, and Hariyadi (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes

4.4. Computational Thinking Disposition

The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal. Each CT disposition is described in some statements in the questionnaires, such as in Table 4. Based on the self-report checklist, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00). However, students seem still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00), which is only categorized as acceptable.

Table 4. Score of CT dispositions.

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best and my mind in working on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and do more effort when dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT.

No	Statements	Average score	Criteria
1	I try to break down complex problems into simpler parts so that they are easy to understand and solve	3.06	Good
2	When facing complex problems, I gather general characteristics and filter out specific information that is not needed to solve the problem	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution	3.08	Good
4	I reduce complexity and look for main ideas through modes	2.83	Good
5	To solve many problems, I have developed a step-by-step solution that can be followed	3.16	Good
6	After solving a problem, I evaluate how the solution can be improved	3.05	Good
7	After finding a solution to a problem, I determine whether the solution is truly correct and efficient	3.11	Good
8	I compared the advantages and disadvantages of various alternative solutions to the problem and I took the best one	3.11	Good
Average		3.06	Good

According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects see Table 5. Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising, and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu, Perera, & Klein, 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin, Bowers, Krajcik, and Damelin (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills aspects when they are actively engaged in modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun, Han, & Kim, 2017; Romero, Lepage, & Lille, 2017). It is supported by a study conducted by Gao and Hew (2022), the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.

5. Conclusions

In this study, we designed collaborative modeling-based learning for fostering theoretical understanding, science process skills and CT dispositions in high school physics classes. The collaborative modeling-based learning engage students in modeling process that usually done by a physicist. The collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection.

After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent science process skills. By being involved in modeling process, students have direct experiences to practice science, hence it can foster the students' science process skills.

It is also found that there is a potential contribution of collaborative modeling-based learning to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

5.1. Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through self-report checklist which is less comprehend. To explore more about the impact on CT disposition and CT skills, observation should be carefully performed. Collaborative modeling-based learning involve laboratory work in which experiment apparatus is necessary. In some school, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratory for schools in remote area. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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Investigation of Science Process Skills and Computational Thinking Dispositions during the Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

Computational thinking (CT) skills are essential ~~in the era~~ with the rapid advancement of technology. ~~when technology develops tremendously.~~ Developing CT attitudes in students is also required for improving CT skills. ~~To cultivate CT skills, growing CT dispositions among students are also necessary.~~ On the other hand, science process skills are ~~is~~ also emphasized in high school physics class. This study aims to design and implement collaborative modeling-based learning for high school physics classes that stimulates computational thinking (CT) and science process skills. The learning activities use ~~employ~~ a collaborative approach and adapt the modeling process that scientists usually use. A pilot study in a high school physics class was conducted to investigate the effectiveness of collaborative modeling-based learning. The research ~~Research~~ instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills ~~,~~ and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. Eighty-nine students participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. According to the self-report checklist, students also demonstrated positive CT attitudes and indicated that they planned to apply CT aspects to their learning. ~~Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.~~ It indicates that the modeling process has engaged students to think computationally and develop their process skills.

Keywords: CT disposition, High school physics, Modeling-based learning, Science process skills.

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Contents

Contribution of this paper to the literature: This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activities ~~activity~~ in physics class. This study's new findings demonstrate that modelling activities may encourage students' CT dispositions. ~~New finding in this study is that modeling activity may stimulate students' CT dispositions.~~

1. Introduction

A significant technological development has affected people's lifestyles in recent years ~~In recent years, a massive transformation of technology has changed people's lifestyles. This fact~~ encourages educational institutions to prepare students for a ~~the~~ more dynamic life and demands ~~for~~ job transformation. One of the crucial skills that students must possess is computational thinking (CT) ~~skills~~ (Esteve-Mon, Llopis, & Adell-Segura, 2020; Hsu, Chang, & Hung, 2018).

The CT concept ~~is~~ emerged from the process ~~caried~~ carried out on computers that is adapted as an analytic approach to problem solving (Sengupta & Kinnebrew, 2013). CT is a fundamental skills ~~,~~ just like writing, reading ~~,~~ and arithmetic (Barr, Harrison, & Conery, 2011). CT comprises aspects of decomposition, abstraction, algorithmic thinking, generalization ~~,~~ and evaluation (Voon, Wong, Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Physics is closely related to CT. ~~; CT skills is~~CT skills are used ~~employed~~ in most physics investigations. Hence, developing CT skills in high school ~~physics,~~physics has become necessary. Students may develop ideas relevant to CT by engaging in experiments, problem-solving ~~,~~ and discussions during physics class.

Effective integration of CT with science has been the subject of several studies. ~~Several studies have been conducted to explore how to integrate CT with science effectively.~~ For example, Yin et al. (2020) try to integrate CT with physics and engineering learning through ~~maker~~ activities they have designed. Sengupta and Kinnebrew (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). Students' tendency to apply CT is an important way ~~To~~to develop CT skills. ~~, students' tendency to apply CT is an important thing.~~ The attitudinal tendency towards CT is called CT disposition. High school physics class has a crucial role in making CT disposition. ~~grow.~~

High school physics curriculum also emphasizes science process skills (Susilawati, Doyan, Mulyadi, Abo, & Pineda, 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge (Gunawan, Hermansyah, & Herayanti, 2019). A specific approach to teaching high school physics classes is necessary to help students experience meaningful learning and help them acquire science process and CT abilities. ~~To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning.~~ Physicists usually use scientific methods and CT skills to understand physical phenomena. ~~Typically, science processes and CT skills are always used by physicists in understanding physical phenomena.~~ They ~~Physicists~~ always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist ~~to~~ acquire new knowledge about natural phenomena. The modeling process may be incorporated into high school physics classes to train scientific ~~science process~~ skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning ~~,~~ which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell, Oh, Maughn, Kiriazis, & Zuwallack, 2015; Louca & Zacharia, 2012).

The following are the objectives of this research: ~~This study has objectives such as:~~

(1) Design collaborative modeling-based learning materials.
(2) Implement collaborative modeling-based learning in a high school physics class.
(3) Investigate the students' CT disposition and science process skills.

The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. ~~CT dispositions is~~CT dispositions are fundamental for encouraging students to apply CT aspects in their life ~~,~~ which is crucial in the current society.

2. *Modeling-Based Learning*

It is possible to modify the modelling method that physicists typically use for learning. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. Students can develop their main conceptual view of science by involving students in modeling (Campbell et al., 2015; Dukerich, 2015). Students can also build their understanding of the nature of science.

Literature Review

2.1. Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore, Gouvea, & Giere, 2013). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an

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epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon~~,~~ and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa, Sánchez-Azqueta, Gimeno, & Aldea, 2021). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

2.2. Modeling-Based Learning

It is possible to modify the modelling method that physicists typically use for learning. ~~The modeling process that physicists usually do can be adapted to the learning process.~~ During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence~~,~~ and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. Students can develop their main conceptual view of science by ~~By~~ involving them ~~students~~ in modeling~~, students can develop their main conceptual view of science~~ (Campbell et al., 2015; Dukerich, 2015). Students ~~also~~ can also build their understanding of the nature of science.

The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning processes ~~cycles~~ proposed. Brewe (2008)~~,~~ proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation~~,~~ (3) application~~,~~ (4) abstraction and generalization~~,~~ (5) and continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning processes ~~cycle~~ that consists of (1) exploration, (2) model adduction, (4) model formulation, (5) model deployment~~,~~ and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang, Jou, Lv, & Huang, 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science ~~Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science~~ (Cascarosa et al., 2021).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe & Sawtelle, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow, Frick, Barker, & Phelps, 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation~~,~~ and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. ~~After~~Subsequently, ~~that,~~ students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they ~~constructed~~ develop. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

2.3. Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving~~,~~ and critical thinking (Yadav, Hong, & Stephenson, 2016). CT can be regarded as thinking skills that ~~which~~ aim to solve the problem effectively by adapting the process that occurs in a computer (Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking~~,~~ and pattern generalization (Psycharis & Kotzampasaki, 2019). CT development for students has been attracting much attention ~~,~~ from early childhood to university (Bilbao, Bravo, García, Rebollar, & Varela, 2021; Kafai & Proctor, 2022). Integration of CT in computer science, math, physics, chemistry, biology and art courses has been a particular strategy taken in the educational system to develop CT. ~~In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.~~

In addition to information and abilities, thinking requires certain attitudes. A person's attitudes, values, motivations and beliefs are component of their disposition ~~Thinking process needs not only knowledge and skills but also dispositions. Dispositions are a combination of attitudes, values, motivations and beliefs~~ (Sovey, Osman, & Matore, 2022). CT disposition can also be considered confident in dealing with complexity (Jong, Geng, Chai, & Lin, 2020). CT dispositions are the values, motivations, feelings~~,~~ and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency towards ~~to~~ CT (Tsai, Liang, & Hsu, 2021). CT dispositions category includes willingness to work cooperatively to accomplish a common goal, capacity to handle ambiguity, confidence in the face of complexity, determination in the face of hardship and recognition of one's own strengths and weaknesses when working cooperatively ~~CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively~~ (Barr & Stephenson, 2011).

~~When people are engaged in CT, they have a CT disposition.~~ CT dispositions are essential since they are ~~it is a~~ motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition ~~in a learning process~~ is also necessary to design and evaluate a specific intervention in the learning process.

2.4. Science Process Skills

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~~In~~ Scientists always use science process skills in order to construct new knowledge or solve a problem~~,~~ ~~scientist always use science process skills~~ (Özgelen, 2012). They are necessary to discover and build scientific knowledge. Numerous studies divide science process skills into two categories: integrated science process skills and basic science process skills ~~In many studies, science process skill is categorized into two, i.e., basic science process skills and integrated science process skills~~ (Derilo, 2019). Basic science process skills includes skills for observing, classifying, communicating, measuring, concluding~~,~~ and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019). Meanwhile, integrated science process skills comprise~~es~~ skills for controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting~~,~~ and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020).

2.5. Studies on Developing CT Disposition and Scientific ~~Science Process~~ Skills

~~Science process~~ *Scientific* skills can be cultivated by conducting active learning in the classroom. Students should be actively involved ~~actively~~ in investigating ~~the~~ nature. Inquiry learning ~~model~~ is one of strategy to stimulates students in developing scientific ~~science process~~ skills (Baharom, Atan, Rosli, Yusof, & Hamid, 2020; Gunawan et al., 2019; Limatahu, Sutoyo, & Prahani, 2018). ~~Along with inquiry learning model,~~ The discovery ~~discovery~~ learning model and problem -based learning model are also effective in improving scientific skills along with the inquiry learning model ~~science process skills~~ (Suryanti, Widodo, & Budijastuti, 2020). Media used ~~utilized~~ in learning activity can boost scientific ~~science process~~ skills acquisition ~~acquiring~~ (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019).

There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activity and physics class can enhance the CT disposition of students.

3. Method

3.1. Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing ~~science process skills~~ scientific skills is one of the primary purposes of physics courses. Students' scientific skills ~~Science process skills~~ are also assessed based on the students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement~~,~~ respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-tests design was implemented in the study. Pre- and post-tests were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

3.2. Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

3.3. Instruments

The research instruments employed in the study are pre-test, post-tests, CT dispositions checklists~~,~~ and scientific ~~science process~~ skills rubrics. The pre-and post-test consists of five ~~5~~ essay problems about elasticity. ~~At last, s~~Students are asked to fill a self-report checklist to assess students' CT disposition. The checklist consists of several statements about CT disposition on ~~with~~ a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

3.4. Data Analysis

The scores of the pre- and post-tests are ~~is~~ compared~~,~~ and the normalized gain score is calculated. The formula to calculate the normalized gain score~~,~~ $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score~~,~~ and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3~~,~~ and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1.

Table 1. Criteria of the average score of students' CT dispositions checklist~~.~~

No.	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \le 3.4$	Good
3	$2.2 < \bar{X} \le 2.8$	Acceptable
4	$1.6 < \bar{X} \le 2.2$	Poor
5	$\bar{X} \le 1.6$	Very poor

4. Results and Discussions

4.1. Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation~~,~~ and post-experiment discussion. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning~~.~~

Stages	Activity explanation
Pre-experiment	Students are asked to observe a film that depicts real-world occurrences related to the subjects discussed in the pre-experiment activity. ~~In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed.~~ This activity aims to engage students at the beginning of the class. Students are also stimulated to questions ~~for questioning~~ and construct ~~ing~~ hypotheses.
Investigation	Students have to explore physics phenomena through collaborative experiments. The physics phenomena studied are Hooke's law and spring arrangement. They plan experiments, arrange the apparatus, observe the phenomena, collect the data ~~,~~ and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide ~~, along with the worksheet,~~ is provided along with the worksheet. ~~.~~
Post-experiment discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Students are asked to develop a model based ~~Based~~ on the data. ~~, students are asked to construct a model.~~ A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Students discuss how to solve some related problems by applying the model that has been developed within ~~Within~~ the group. ~~, students discuss how to solve some related problems by applying the model that has been developed.~~
Reflection	Students are asked to make a reflection on the learning activity.

Commented [WU1]: This sentence sounds complex. Kindly rephrase it.

4.2. Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding ~~,~~ and communicating. Figure 1 shows the average score of each science process skills aspect in percentage during the first ~~learning cycle~~ and second learning ~~cycles~~ processes. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the hypothesis that was observed and formulated can be classified as reasonable. ~~the observing and formulating hypothesis can be categorized as fair.~~ Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding ~~,~~ and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling ~~process,~~process; hence, their science process skills improve. The score for formulating a hypothesis in the learning cycle improves and can be categorized as good. Meanwhile, the others change significantly to be excellent.

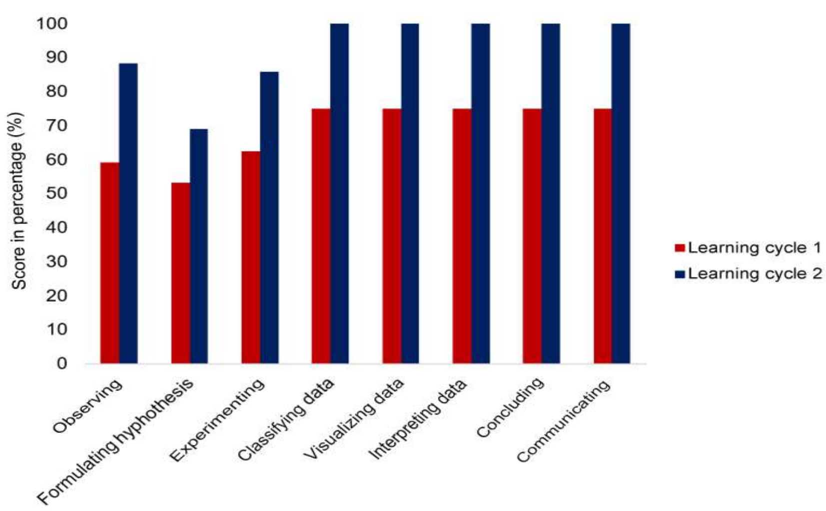

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2~~.~~

The improvement in science ~~of science process~~ skills aspects indicates that students have become ~~been~~ familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation ~~,~~ and revision.

The results of this study are consistent with previous research. ~~This study's finding is in accordance with other studies.~~ Ogan-Bekiroğlu and Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçali & Selvi, 2022).

Model-based learning stimulates students to inquire about natural ~~nature~~ phenomena. The improvement of science process skills in this study is consistent with previous studies that ~~which~~ reported that inquiry-based approaches stimulated the scientific skills ~~science process skills~~ of students (Aktamiş, Hiğde, & Özden, 2016;

Artayasa, Susilo, Lestari, & Indriwati, 2017; Mulyeni et al., 2019; Saputro, Rohaeti, & Prodjosantoso, 2019). Students are encouraged to take responsibility for completing the experiment, analyzing the data and presenting their findings when using an inquiry-based approach when studying collaborative modelling. ~~Within inquiry-based approach, like in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas.~~ Students can practice science process skills widely by being responsible in those assignments. ~~By being responsible in those tasks, students can intensively practice science process skills.~~

4.3. Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the collaborative modeling-based learning on ~~with~~ the topic ~~s~~ of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 3 shows the results of the pre- and post-tests. There are significant improvements in students' theoretical understanding with an average ⟨*g*⟩ of 0.77. It can be categorized as a high gain. The average pre-test score of the 89 students participating in this study is 21.3. Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students acquire ~~in acquiring~~ process skills but also theoretical understanding.

Table 3. Pre-test and post-test results~~.~~

Number of participants	Average pre-test score	Average post-test score	Average ⟨*g*⟩	Classification
89	21.3	81.7	0.77	High

The modeling process supports students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing~~,~~ and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue, Sun, Zhu, Huang, & Topping, 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena, Darmuki, and Hariyadi (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes.

4.4. Computational Thinking Disposition

Collaborative modeling-based learning examines many CT dispositions such as resilience in the face of adversity, ambiguity handling skills, confidence in the face of complexity and teamwork in pursuing common goal. ~~The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal.~~ Each CT disposition is described in some statements in the questionnaires ~~, such as in~~ (see Table 4). Students have good confidence when facing complexity, good persistence when working with difficulty and good collaboration ability. The score on those aspects is above 2.80 (out of 4.00) ~~Based~~ based on the self-report checklist. ~~, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00).~~ However, students seem to be still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00) ~~,~~ which is only categorized as acceptable.

Table 4. Score of CT dispositions~~.~~

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best ~~and my mind in~~ to work ~~working~~ on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and put ~~do~~ more effort into ~~when~~ dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good

		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT~~.~~

No	Statements	Average score	Criteria
1	I attempt to deconstruct complicated issues into simpler components to make them easier to comprehend and resolve. ~~I try to break down complex problems into simpler parts so that they are easy to understand and solve~~	3.06	Good
2	When addressing complicated issues, I collect broad characteristics and filter out specific details that are unnecessary for the problem's solution. ~~When facing complex problems, I gather general characteristics and filter out specific information that is not needed to solve the problem~~	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution.	3.08	Good
4	I reduce complexity and look for main ideas through modes.	2.83	Good
5	I have developed a step-by-step solution that can be followed to ~~To~~ solve many problems. ~~, I have developed a step-by-step solution that can be followed~~	3.16	Good
6	I assess how it might be improved after resolving an issue. ~~After solving a problem, I evaluate how the solution can be improved~~	3.05	Good
7	I determine whether the solution is truly correct and efficient after ~~After~~ finding a solution to a problem. ~~, I determine whether the solution is truly correct and efficient~~	3.11	Good
8	I considered several different approaches to the problem and evaluated their benefits and drawbacks before selecting the best one. ~~I compared the advantages and disadvantages of various alternative solutions to the problem and I took the best one~~	3.11	Good
Average		3.06	Good

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The self-report checklist indicates that students used CT elements while engaging in collaborative modeling-based learning (see Table 5). ~~According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects see Table 5.~~ The preliminary result indicates that CT skills may be developed through collaborative modeling-based learning, despite the fact that our study did not thoroughly examine the CT skills outcomes. ~~Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning.~~ Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising~~,~~ and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu, Perera, & Klein, 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin, Bowers, Krajcik, and Damelin (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills ~~aspects~~ when they are actively engaged in the modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun, Han, & Kim, 2017; Romero, Lepage, & Lille, 2017). ~~It is supported by a study conducted by~~ Gao and Hew's (2022) study provides evidence that integrating active learning into the 5E framework: engagement, exploration, explanation, elaboration and evaluation improves students' comprehension of CT ideas and their ability to solve problems. ~~, the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.~~

5. Conclusion~~s~~

In this study, we designed collaborative modeling-based learning ~~for fostering~~ to foster theoretical understanding, science process skills and CT dispositions in high school physics classes. ~~The collaborative~~Collaborative modeling-based learning engages students in a modeling process that is usually done by a physicist. ~~The c~~ Collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection.

After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent scientific skills. ~~science process skills.~~ By being involved in the modeling process, students have direct experiences with ~~to~~ practicing ~~practice~~ science~~;~~, hence, it can foster the students' ~~science process skills~~ scientific skills.

It is also found that ~~there is a potential contribution of~~ collaborative modeling-based learning can contribute to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

5.1. Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through a self-report checklist which is less ~~comprehend~~comprehended. ~~To explore more about the impact on CT disposition and CT skills, o~~ Observation should be carefully performed to explore more about the impact on CT disposition and CT skills. Collaborative modeling-based learning involves laboratory work in which experiment apparatus is necessary. In some schools, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratories laboratory for schools in remote areas. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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We would like to apologize that we did not notice your email and it caused the late revision.
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With sincere regards,

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Investigation of Science Process Skills and Computational Thinking Dispositions during the Implementation of Collaborative Modeling-Based Learning in High School Physics Class

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Abstract

Computational thinking (CT) skills are essential ~~in the era~~ with the rapid advancement of technology. ~~when technology develops tremendously.~~ Developing CT attitudes in students is also required for improving CT skills. ~~To cultivate CT skills, growing CT dispositions among students are also necessary.~~ On the other hand, science process skills are ~~is~~ also emphasized in high school physics ~~class~~classes. This study aims to design and implement collaborative modeling-based learning for high school physics classes that stimulates computational thinking (CT) and science process skills. The learning activities use ~~employ~~ a collaborative approach and adapt the modeling process that scientists usually use. A pilot study in a high school physics ~~class~~ course was conducted to investigate the effectiveness of collaborative modeling-based learning. The research ~~Research~~ instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills, ~~,~~ and a self-report checklist to assess CT dispositions. A one-group pre-and post-test design is employed in the pilot study. Eighty-nine students participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. According to the self-report checklist, students also demonstrated positive CT attitudes and indicated that they planned to apply CT aspects to their learning. ~~Based on the self-report checklist, students also had good CT dispositions and stated they were likely to use CT aspects during the learning process.~~ It indicates that the modeling process has engaged students to think computationally and develop their process skills.

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Keywords: CT disposition, High school physics, Modeling-based learning, Science process skills.

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Authors' Contributions: H. conceived the work and designed the research strategy. E.P dan H.K. made the research instruments. P.A. conducted the pilot study. P.A., E.P, and A.D.R did data analysis. All authors discussed the results and co-write the manuscript.
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Contents

Contribution of this paper to the literature: This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activities ~~activity~~ in physics class. This study's new findings demonstrate that modelling activities may encourage students' CT dispositions. ~~New finding in this study is that modeling activity may stimulate students' CT dispositions.~~

1. Introduction

A significant technological development has affected people's lifestyles in recent years ~~In recent years, a massive transformation of technology has changed people's lifestyles. This fact~~ encourages educational institutions to prepare students for a ~~the~~ more dynamic life and demands ~~for~~ job transformation. One of the crucial skills that students must possess is computational thinking (CT) ~~skills~~ (Esteve-Mon, Llopis, & Adell-Segura, 2020; Hsu, Chang, & Hung, 2018).

The CT concept ~~is~~ emerged from the process ~~caried~~ carried out on computers that is adapted as an analytic approach to problem solving (Sengupta & Kinnebrew, 2013). CT is a fundamental skills ~~,~~ just like writing, reading ~~,~~ and arithmetic (Barr, Harrison, & Conery, 2011). CT comprises aspects of decomposition, abstraction, algorithmic thinking, generalization ~~,~~ and evaluation (Voon, Wong, Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Physics is closely related to CT. ~~,~~ ~~CT skills is~~CT skills are used ~~employed~~ in most physics investigations. Hence, developing CT skills in high school ~~physics,~~physics has become necessary. Students may develop ideas relevant to CT by engaging in experiments, problem-solving ~~,~~ and discussions during physics class.

Effective integration of CT with science has been the subject of several studies. ~~Several studies have been conducted to explore how to integrate CT with science effectively.~~ For example, Yin et al. (2020) try to integrate CT with physics and engineering learning through ~~maker~~ activities they have designed. Sengupta and Kinnebrew (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). Students' tendency to apply CT is an important way ~~To~~to develop CT skills. ~~, students' tendency to apply CT is an important thing.~~ The attitudinal tendency towards CT is called CT disposition. High school physics class has a crucial role in making CT disposition. ~~grow.~~

High school physics curriculum also emphasizes science process skills (Susilawati, Doyan, Mulyadi, Abo, & Pineda, 2022). Scientific process skills are behaviors that encourage skills to acquire knowledge (Gunawan, Hermansyah, & Herayanti, 2019). A specific approach to teaching high school physics classes is necessary to help students experience meaningful learning and help them acquire science process and CT abilities. ~~To develop science process and CT skills, high school physics classes must be delivered in a certain way so students can experience meaningful learning.~~ Physicists usually use scientific methods and CT skills to understand physical phenomena. ~~Typically, science processes and CT skills are always used by physicists in understanding physical phenomena.~~ They ~~Physicists~~ always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicist ~~to~~ acquire new knowledge about natural phenomena. The modeling process may be incorporated into high school physics classes to train scientific ~~science process~~ skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning ~~,~~ which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science process and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell, Oh, Maughn, Kiriazis, & Zuwallack, 2015; Louca & Zacharia, 2012).

The following are the objectives of this research: ~~This study has objectives such as:~~

(1) Design collaborative modeling-based learning materials.
(2) Implement collaborative modeling-based learning in a high school physics class.
(3) Investigate the students' CT disposition and science process skills.

The present study is significant because it tries to find out alternative learning strategies that give experiences for students to grow their CT dispositions and develop their skills. ~~CT dispositions is~~CT dispositions are fundamental for encouraging students to apply CT aspects in their life ~~,~~ which is crucial in the current society.

~~2. *Modeling-Based Learning*~~

~~It is possible to modify the modelling method that physicists typically use for learning. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. Students can develop their main conceptual view of science by involving students in modeling (Campbell et al., 2015; Dukerich, 2015). Students can also build their understanding of the nature of science.~~

2. Literature Review

2.1. Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore, Gouvea, & Giere, 2013). The scientific model is an epistemological construction in natural science, usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents characteristics of a natural phenomenon, explains the mechanism behind a phenomenon ~~,~~ and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa, Sánchez-Azqueta, Gimeno, &

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Aldea, 2021). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain, and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

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2.2. Modeling-Based Learning

It is possible to modify the modelling method that physicists typically use for learning. ~~The modeling process that physicists usually do can be adapted to the learning process.~~ During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence ~~,~~ and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. Students can develop their main conceptual view of science by ~~By~~ involving them ~~students~~ in modeling ~~, students can develop their main conceptual view of science~~ (Campbell et al., 2015; Dukerich, 2015). Students ~~also~~ can also build their understanding of the nature of science.

The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning processes ~~cycles~~ proposed. Brewe (2008) ~~,~~ proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation~~,~~ (3) application ~~,~~ (4) abstraction and generalization ~~,~~ (5) and continued incremental development (Brewe, 2008). Meanwhile, Halloun (2007) described a modeling-based learning processes ~~cycle~~ that consists of (1) exploration, (2) model adduction, (4) model formulation, (5) model deployment ~~,~~ and (6) paradigmatic synthesis (Halloun, 2007). There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang, Jou, Lv, & Huang, 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science ~~Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students to connect theory and experimental results, improving problem-solving skills, and helping students understand the nature of science~~ (Cascarosa et al., 2021).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe & Sawtelle, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow, Frick, Barker, & Phelps, 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation ~~,~~ and post-laboratory activity.

Demonstration and discussion can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. ~~After~~Subsequently, ~~that,~~ students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they ~~constructed~~ develop. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

2.3. Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving ~~,~~ and critical thinking (Yadav, Hong, & Stephenson, 2016). CT can be regarded as thinking skills that ~~which~~ aim to solve the problem effectively by adapting the process that occurs in a computer (Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking ~~,~~ and pattern generalization (Psycharis & Kotzampasaki, 2019). CT development for students has been attracting much attention ~~,~~ from early childhood to university (Bilbao, Bravo, García, Rebollar, & Varela, 2021; Kafai & Proctor, 2022). Integration of CT in computer science, math, physics, chemistry, biology and art courses has been a particular strategy taken in the educational system to develop CT. ~~In school, attempts to develop CT has been made by integrating CT in computer science, math, physics, chemistry, biology, and art course.~~

In addition to information and abilities, thinking requires certain attitudes. A person's attitudes, values, motivations and beliefs are component of their disposition ~~Thinking process needs not only knowledge and skills but also dispositions. Dispositions are a combination of attitudes, values, motivations and beliefs~~ (Sovey, Osman, & Matore, 2022). CT disposition can also be considered confident in dealing with complexity (Jong, Geng, Chai, & Lin, 2020). CT dispositions are the values, motivations, feelings ~~,~~ and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency towards ~~to~~ CT (Tsai, Liang, & Hsu, 2021). CT dispositions category includes willingness to work cooperatively to accomplish a common goal, capacity to handle ambiguity, confidence in the face of complexity, determination in the face of hardship and recognition of one's own strengths and weaknesses when working cooperatively ~~CT dispositions category includes confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, willingness to collaborate to achieve a common goal, and recognizing one's strengths and weaknesses when working collaboratively~~ (Barr & Stephenson, 2011).

~~When people are engaged in CT, they have a CT disposition.~~ CT dispositions are essential since they are ~~it is a~~ motivator for persistently distinguishing complex problem. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition ~~in a learning process~~ is also necessary to design and evaluate a specific intervention in the learning process.

2.4. Science Process Skills

~~In~~ Scientists always use science process skills in order to construct new knowledge or solve a problem ~~, scientist always use science process skills~~ (Özgelen, 2012). They are necessary to discover and build scientific knowledge. Numerous studies divide science process skills into two categories: integrated science process skills and basic science process skills ~~In many studies, science process skill is categorized into two, i.e., basic science process skills and~~

~~integrated science process skills~~ (Derilo, 2019). Basic science process skills includes skills for observing, classifying, communicating, measuring, concluding ~~,~~ and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019). Meanwhile, integrated science process skills comprise ~~es~~ skills for controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting ~~,~~ and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020).

2.5. Studies on Developing CT Disposition and Scientific ~~Science Process~~ Skills

~~Science process~~ *Scientific* -skills can be cultivated by conducting active learning in the classroom. Students should be actively involved ~~actively~~ in investigating ~~the~~ nature. Inquiry learning ~~model~~ is one of strategy to stimulates students in developing scientific ~~science process~~ skills (Baharom, Atan, Rosli, Yusof, & Hamid, 2020; Gunawan et al., 2019; Limatahu, Sutoyo, & Prahani, 2018). ~~Along with inquiry learning model,~~ The discovery ~~discovery~~ learning model and problem -based learning model are also effective in improving scientific skills along with the inquiry learning model ~~science process skills~~ (Suryanti, Widodo, & Budijastuti, 2020). Media used ~~utilized~~ in learning activity can boost scientific ~~science process~~ skills acquisition ~~acquiring~~ (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been showed to enhance science process skills (Kurniawan et al., 2019).

There is still limited study on the improvement of CT disposition through science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activity and physics class can enhance the CT disposition of students.

3. Method

3.1. Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing ~~science process skills~~ scientific skills- is one of the primary purposes of physics courses. Students' scientific skills ~~Science process skills~~ are also assessed based on the students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement ~~,~~ respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A one-group pre-and post-tests design was implemented in the study. Pre- and post-tests were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

3.2. Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants, which consist of 27 male and 62 female students.

3.3. Instruments

The research instruments employed in the study are pre-test, post-tests, CT dispositions checklists ~~,~~ and scientific ~~science process~~ skills rubrics. The pre-and post-test consists of five ~~5~~ essay problems about elasticity. ~~At last, s~~Students are asked to fill a self-report checklist to assess students' CT disposition. The checklist consists of several statements about CT disposition on ~~with~~ a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

3.4. Data Analysis

The scores of the pre- and post-tests are ~~is~~ compared ~~,~~ and the normalized gain score is calculated. The formula to calculate the normalized gain score ~~,~~ $\langle g \rangle$, is given as:

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

where $\%pre$ is the percentage of the pre-test score ~~,~~ and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3 ~~,~~ and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1.

Table 1. Criteria of the average score of students' CT dispositions checklist ~~.~~

No.	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \leq 3.4$	Good
3	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq 1.6$	Very poor

4. Results and Discussions

4.1. Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-experiment, investigation ~~,~~ and post-experiment discussion. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning ~~.~~

Stages	Activity explanation

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Pre-experiment	Students are asked to observe a film that depicts real-world occurrences related to the subjects discussed in the pre-experiment activity. ~~In the pre-experiment activity, students are asked to observe a video showing everyday life phenomena related to the topics being discussed.~~ This activity aims to engage students at the beginning of the class. Students are also stimulated to questions ~~for questioning~~ and construct~~ing~~ hypotheses.
Investigation	Students have to explore the elasticity~~physics~~ phenomena through collaborative experiments. ~~The physics phenomena studied are Hooke's law and spring arrangement.~~ They plan experiments, arrange the apparatus, observe the phenomena, collect the data~~,~~ and make documentation. During group investigation, the teacher has a role in monitoring how the investigation goes. An experiment guide~~, along with the worksheet,~~ is provided along with the worksheet. ~~,~~
Post-experiment discussion	Students discuss the result of the investigation in the group. They are stimulated to analyze the data and interpret it. Students are asked to develop a model– based ~~Based~~ on the data. ~~, students are asked to construct a model.~~ A whiteboard is provided for each group to facilitate model construction. After each group builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Students discuss how to solve some related problems by applying the model that has been developed within ~~Within~~ the group. ~~, students discuss how to solve some related problems by applying the model that has been developed.~~
Reflection	Students are asked to make a reflection on the learning activity.

4.2. Science Process Skills

Some aspects of science process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding~~,~~ and communicating. Figure 1 shows the average score of each science process skills aspect in percentage during the first ~~learning cycle~~ and second learning~~cycles~~ processes. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the hypothesis that was observed and formulated can be classified as ~~reasonable~~acceptable. ~~the observing and formulating hypothesis can be categorized as fair.~~ Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding ~~,~~ and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling ~~process,~~process; hence, their science process skills improve. The score for formulating a hypothesis in the learning cycle improves and can be categorized as good. Meanwhile, the others change significantly to be excellent.

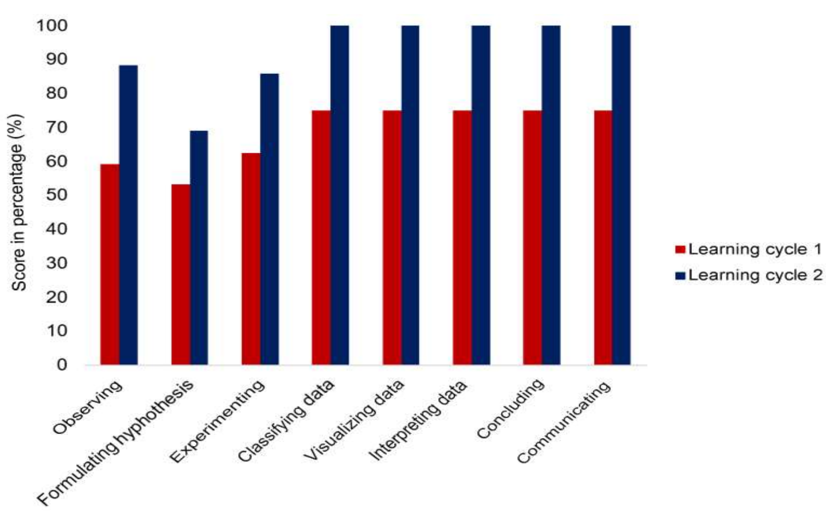

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2~~.~~

The improvement in science process ~~of science process~~ skills aspects indicates that students have become ~~been~~ familiar with a modeling activity in learning cycle 2. Students' science process skills grow gradually through the modeling process. Each learning phase stimulates students to practice science process skills. Engaging students in the modeling process makes the learning process more meaningful. Students are actively involved in model construction, evaluation~~,~~ and revision.

The results of this study are consistent with previous research. ~~This study's finding is in accordance with other studies.~~ Ogan-Bekiroğlu and Arslan (2014) researched the impact of model-based inquiry on students' science process skills and conceptual knowledge. In their study, science process skills dimensions are improved after pre-service teachers are exposed to modeling-based teaching. In another study, the development of science process skills depends on the teaching method used. It also revealed that modeling-based learning is more effective in improving science process skills than just implementing textbook-oriented teaching (Demirçali & Selvi, 2022).

Model-based learning stimulates students to inquire about natural ~~nature~~ phenomena. The improvement of science process skills in this study is consistent with previous studies that ~~which~~ reported that inquiry-based approaches stimulated the scientific skills ~~science process skills~~ of students (Aktamiş, Hiğde, & Özden, 2016; Artayasa, Susilo, Lestari, & Indriwati, 2017; Mulyeni et al., 2019; Saputro, Rohaeti, & Prodjosantoso, 2019). Students are encouraged to take responsibility for completing the experiment, analyzing the data and presenting their findings when using an inquiry-based approach when studying collaborative modelling. ~~Within inquiry-based approach, like~~

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~~in collaborative modeling-based learning, students are prompted to be responsible in completing the experiment, processing the data, and presenting their ideas.~~ Students can practice science process skills widely by being responsible in those assignments. ~~By being responsible in those tasks, students can intensively practice science process skills.~~

4.3. Theoretical Understanding

Students' theoretical understanding of elasticity is evaluated through a written test. A pre-test was given before students participated in the collaborative modeling-based learning on ~~with~~ the topic ~~s~~ of elasticity. After the students finished the learning process, they were asked to do the post-test. Table 3 shows the results of the pre-and post-tests. There are significant improvements in students' theoretical understanding with an average $\langle g \rangle$ of 0.77. It can be categorized as a high gain. The average pre-test score of the 89 students participating in this study is 21.3. Meanwhile, the average post-test score is 81.7. On average, students show good theoretical mastery after they finish modeling-based learning. It indicates that modeling-based learning is not only helping students acquire ~~in acquiring~~ process skills but also theoretical understanding.

Table 3. Pre-test and post-test results ~~.~~

Number of participants	Average pre-test score	Average post-test score	Average $\langle g \rangle$	Classification
89	21.3	81.7	0.77	High

The modeling process supports students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing ~~,~~ and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue, Sun, Zhu, Huang, & Topping, 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their mind and information that deduced from observation and social contact. Supena, Darmuki, and Hariyadi (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes.

4.4. Computational Thinking Disposition

Collaborative modeling-based learning examines many CT dispositions such as resilience in the face of adversity, ambiguity handling skills, confidence in the face of complexity and teamwork in pursuing common goal. ~~The aspects of CT dispositions investigated during collaborative modeling-based learning include confidence when facing complexity, persistence when working with difficulty, ability to handle ambiguity, and ability to work collaboratively to achieve a common goal.~~ Each CT disposition is described in some statements in the questionnaires ~~, such as in~~ (see Table 4). Students have good confidence when facing complexity, good persistence when working with difficulty and good collaboration ability. The score on those aspects is above 2.80 (out of 4.00) ~~Based~~ based on the self-report checklist. ~~, students generally have good confidence when facing complexity, good persistence when working with difficulty, and good collaboration ability. The score of those aspects is above 2.80 (out of 4.00).~~ However, students seem to be still not so confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00) ~~,~~ which is only categorized as acceptable.

Table 4. Score of CT dispositions ~~.~~

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best ~~and my mind in~~ to work ~~working~~ on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and put ~~do~~ more effort into ~~when~~ dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT .

No	Statements	Average score	Criteria
1	I attempt to deconstruct complicated issues into simpler components to make them easier to comprehend and resolve. I try to break down complex problems into simpler parts so that they are easy to understand and solve	3.06	Good
2	When addressing complicated issues, I collect broad characteristics and filter out specific details that are unnecessary for the problem's solution. When facing complex problems, I gather general characteristics and filter out specific information that is not needed to solve the problem	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution.	3.08	Good
4	I reduce complexity and look for main ideas through modes.	2.83	Good
5	I have developed a step-by-step solution that can be followed to To solve many problems. , I have developed a step-by-step solution that can be followed	3.16	Good
6	I assess how it might be improved after resolving an issue. After solving a problem, I evaluate how the solution can be improved	3.05	Good
7	I determine whether the solution is truly correct and efficient after After finding a solution to a problem. , I determine whether the solution is truly correct and efficient	3.11	Good
8	I considered several different approaches to the problem and evaluated their benefits and drawbacks before selecting the best one. I compared the advantages and disadvantages of various alternative solutions to the problem and I took the best one	3.11	Good
Average		3.06	Good

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The self-report checklist indicates that students used CT elements while engaging in collaborative modeling-based learning (see Table 5). According to the self-report checklist, during participating in collaborative modeling-based learning, students likely have used CT aspects see Table 5. The preliminary result indicates that CT skills may be developed through collaborative modeling-based learning, despite the fact that our study did not thoroughly examine the CT skills outcomes. Even though our study had not profoundly explored the CT skills outcomes, the initial finding shows that CT skills can potentially be developed through collaborative modeling-based learning. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising , and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu, Perera, & Klein, 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin, Bowers, Krajcik, and Damelin (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills aspects when they are actively engaged in the modeling process. The initial finding of this study is in align with studies showing that active learning stimulates students to practice CT (Jun, Han, & Kim, 2017; Romero, Lepage, & Lille, 2017). It is supported by a study conducted by Gao and Hew's (2022) study provides evidence that integrating active learning into the 5E framework: engagement, exploration, explanation, elaboration and evaluation improves students' comprehension of CT ideas and their ability to solve problems. , the implementation of active learning within 5E framework, which consists of engagement, exploration, explanation, elaboration, and evaluation, enhances students' understanding of CT concepts and the performance of problem-solving.

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5. Conclusion s

In this study, we designed collaborative modeling-based learning for fostering to foster theoretical understanding, science process skills and CT dispositions in high school physics classes. The collaborative Collaborative modeling-based learning engages students in a modeling process that is usually done by a physicist. The c Collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application, and reflection.

After students participated in collaborative modeling-based learning, students had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' science process skills improve during the learning cycle. In the last cycle, students have excellent scientific skills. science process skills. By being involved in the modeling process, students have direct experiences with to practicing practice science;, hence, it can foster the students' science process skills scientific skills.

It is also found that there is a potential contribution of collaborative modeling-based learning can contribute to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and likely use CT aspects.

5.1. Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through a self-report checklist which is less comprehend comprehended. To explore more about the impact on CT disposition and CT skills, o Observation should be carefully performed to explore more about the impact on CT disposition and CT skills. Collaborative modeling-based learning involves laboratory work in which experiment apparatus is necessary. In some schools, experiment apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is by providing mobile laboratories laboratory for schools in remote areas. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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Investigation of science process skills and computational thinking dispositions during the implementation of collaborative modeling-based learning in high school physics class

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Keywords: CT disposition, High school physics, Modeling-based learning, Science process skills.

Abstract

Computational thinking (CT) skills are essential with the rapid advancement of technology. Developing CT attitudes in students is also required for improving CT skills. On the other hand, science process skills are also emphasized in high school physics classes. This study aims to design and implement collaborative modeling-based learning for high school physics classes that stimulates computational thinking (CT) and science process skills. The learning activities use a collaborative approach and adapt the modeling process that scientists usually use. A pilot study in a high school physics course was conducted to investigate the effectiveness of collaborative modeling-based learning. The research instruments used in this study include a test for assessing theoretical understanding, an observational rubric for assessing science process skills and a self-report checklist to assess CT dispositions. A pre-and post-test design is employed in the pilot study. Eighty-nine students participated in this study. Students who participated in collaborative modeling-based learning gained a theoretical understanding. Moreover, they have excellent science process skills. According to the self-report checklist, students also demonstrated positive CT attitudes and indicated that they planned to apply CT aspects to their learning. It indicates that the modeling process has engaged students to think computationally and develop their process skills.

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Investigation of science process skills and computational thinking dispositions during the implementation of collaborative modeling-based learning in high school physics class

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Abstract

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Keywords: CT disposition, High school physics, Modeling-based learning, Science process skills.

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Contents

Contribution of this paper to the literature
This research contributes to the existing literature on modeling-based learning and the integration of computational thinking in physics education. This paper explains the adaptation of modeling activities in physics class. This study's new findings demonstrate that modelling activities may encourage students' CT dispositions.

1. Introduction

A significant technological development that has affected people's lifestyles in recent years encourages educational institutions to prepare students for a more dynamic life and demands job transformation. One of the crucial skills that students must possess is computational thinking (CT) (Esteve-Mon, Llopis, & Adell-Segura, 2020; Hsu, Chang, & Hung, 2018).

The CT concept emerged from the process carried out on computers that is adapted as an analytic approach to problem solving (Sengupta & Kinnebrew, 2013). CT is a fundamental skills just like writing, reading and arithmetic (Barr, Harrison, & Conery, 2011). CT comprises aspects of decomposition, abstraction, algorithmic thinking, generalization and evaluation (Voon, Wong, Wong, Khambari, & Syed-Abdullah, 2022; Yin, Hadad, Tang, & Lin, 2020). Problem-solving in science and engineering disciplines mainly requires thinking computationally (Li et al., 2020). Physics is closely related to CT. CT skills are used in most physics investigations. Hence, developing CT skills in high school physics has become necessary. Students may develop ideas relevant to CT by engaging in experiments, problem-solving and discussions during physics class.

Effective integration of CT with science has been the subject of several studies. For example, Yin et al. (2020) try to integrate CT with physics and engineering learning through activities they have designed. Sengupta and Kinnebrew (2013) have attempted to cultivate CT skills in elementary students using simulation and modeling to understand concepts in kinematics and ecology. Game-based learning has also enhanced CT (Yoon & Khambari, 2022). Students' tendency to apply CT is an important way to develop CT skills. The attitudinal tendency towards CT is called CT disposition. High school physics class has a crucial role in making CT disposition.

The high school physics curriculum also emphasizes scientific process skills (Susilawati, Doyan, Mulyadi, Abo, & Pineda, 2022). Scientific skills are behaviors that encourage skills to acquire knowledge (Gunawan, Hermansyah, & Herayanti, 2019). A specific approach to teaching high school physics classes is necessary to help students experience meaningful learning and help them acquire scientific process and CT abilities. Physicists usually use scientific methods and CT skills to understand physical phenomena. They always conduct modeling in their work. Modeling is a process of model construction to simplify a physical phenomenon. It helps physicists acquire new knowledge about natural phenomena. The modeling process may be incorporated into high school physics classes to train scientific skills and grow CT disposition.

In this research, we design and implement collaborative modeling-based learning which adapts modeling to the learning process. Collaborative modeling-based learning aims to cultivate students' science processes and CT skills. In modeling-based learning, students are encouraged to use the modeling process to develop their scientific knowledge (Campbell, Oh, Maughn, Kiriazis, & Zuwallack, 2015; Louca & Zacharia, 2012).

The following are the objectives of this research:

(1) Design collaborative modeling-based learning materials.
(2) Implement collaborative modeling-based learning in a high school physics class.
(3) Investigate the students' CT disposition and scientific process skills.

The present study is significant because it tries to find out alternative learning strategies that give students experiences to grow their CT dispositions and develop their skills. CT dispositions are fundamental for encouraging students to apply CT aspects in their life which is crucial in our current society.

2. Literature Review

2.1. Model and Modeling in Physics

Physics is a subject that aims to explore and understand how natural phenomena work. In physics, a model is used to simplify a part of the physical world so that the mechanism can be understood more easily. A model can be used to justify a physical phenomenon (Passmore, Gouvea, & Giere, 2013). The scientific model is an epistemological construction in natural science usually in interpretative representation (Nicolaou & Constantinou, 2014). As an epistemological entity, a model represents the characteristics of a natural phenomenon, explains the mechanism behind a phenomenon and can be used to predict a phenomenon. Some physicists also consider models as representations of a particular target that become a bridge between theory and experiment (Cascarosa, Sánchez-Azqueta, Gimeno, & Aldea, 2021). Modeling is a process of model construction from a physical phenomenon. Physicists always do modeling to understand, explain and predict a physical phenomenon. The modeling process involves various activities such as observation, experimentation, data analysis, data interpretation, etc.

2.2. Modeling-Based Learning

It is possible to modify the modelling method that physicists typically use for learning. During physics learning, students can be trained to construct a model, explain the consistency of the model based on evidence and explain the model's limitations (Krajcik & Merritt, 2012). There are some pedagogical purposes for engaging students in the modeling process. Students can develop their main conceptual view of science by involving them in modeling (Campbell et al., 2015; Dukerich, 2015). Students can also build their understanding of the nature of science.

The adaptation of modeling in the learning process creates the concept of modeling-based learning. There are some modeling-based learning processes proposed. Brewe (2008) proposed a learning syntax that consists of (1) introduction and representation, (2) coordination of representation, (3) application, (4) abstraction and generalization (5) and continued incremental development. Meanwhile, Halloun (2007) described a modeling-based learning processes that consists of (1) exploration, (2) model adduction, (4) model formulation, (5) model deployment and (6) paradigmatic synthesis. There is also modeling-based learning that is implemented in a flipped learning environment. The learning steps consist of (1) exploration, (2) model adduction, (3) model formulation, and (4) model deployment (Wang, Jou, Lv, & Huang, 2018). Implementation of modeling-based learning in school positively impacts reducing alternative conceptions, improving argumentation skills, helping students connect theory and experimental results, improving problem-solving skills and helping students understand the nature of science (Cascarosa et al., 2021).

Another framework that adapts the modeling process in science teaching is modeling instruction. Modeling instruction is based on conceptual model development and testing (Brewe & Sawtelle, 2018). There are two main steps of modeling instruction: model development and model deployment (Barlow, Frick, Barker, & Phelps, 2014). Model development consists of three activities, i.e., pre-laboratory, laboratory investigation and post-laboratory activity.

Demonstrations and discussions can be initiated in the pre-laboratory to stimulate students to question phenomena related to the learned topics. Subsequently, students can conduct laboratory investigations to clarify and answer the questions generated in the previous steps. Students are encouraged to formulate and evaluate the model based on the experimental results. In the post-laboratory activity, students communicate the new model they develop. Model deployment is a phase where students are asked to apply the model they build to another similar situation.

2.3. Computational Thinking Disposition

Recently, digital technology has developed tremendously. In the digital era, computational thinking (CT) must be acquired by students (Li et al., 2020). CT is a thinking skill in accordance with other important skills such as creativity, problem-solving and critical thinking (Yadav, Hong, & Stephenson, 2016). CT can be regarded as thinking skills that aim to solve the problem effectively by adapting the process that occurs in a computer (Selby & Woollard, 2013). CT consists of abstraction, decomposition, algorithmic thinking and pattern generalization (Psycharis & Kotzampasaki, 2019). CT development for students has been attracting attention from early childhood to university (Bilbao, Bravo, García, Rebollar, & Varela, 2021; Kafai & Proctor, 2022). Integration of CT in computer science, math, physics, chemistry, biology and art courses has been a particular strategy taken in the educational system to develop CT.

In addition to information and abilities, thinking requires certain attitudes. A person's attitudes, values, motivations and beliefs are components of their disposition (Sovey, Osman, & Matore, 2022). CT disposition can also be considered confident in dealing with complexity (Jong, Geng, Chai, & Lin, 2020). CT dispositions are the values, motivations, feelings and attitudes applicable to CT (Barr & Stephenson, 2011). It is a construct that describes an attitudinal tendency towards CT (Tsai, Liang, & Hsu, 2021). The CT dispositions category includes willingness to work cooperatively to accomplish a common goal, capacity to handle ambiguity, confidence in the face of complexity, determination in the face of hardship and recognition of one's own strengths and weaknesses when working cooperatively (Barr & Stephenson, 2011).

CT dispositions are essential since they are motivators for persistently distinguishing complex problems. It is also known that internal motivation positively correlates with thinking skills. Hence, measuring CT disposition is also necessary to design and evaluate a specific intervention in the learning process.

2.4. Science Process Skills

Scientists always use science process skills in order to construct new knowledge or solve a problem (Özgelen, 2012). It is necessary to discover and build scientific knowledge. Numerous studies divide scientific process skills into two categories: integrated scientific process skills and basic scientific process skills (Derilo, 2019). Basic scientific process skills include skills for observing, classifying, communicating, measuring, concluding and predicting (Darmaji, Kurniawan, & Irdianti, 2019; Mulyeni, Jamaris, & Suprjyati, 2019). Meanwhile, integrated scientific process skills comprise skills for controlling variables, constructing operational definitions, identifying and controlling variables, making hypotheses, experimenting and interpreting data (Elfeky, Masadeh, & Elbyaly, 2020).

2.5. Studies on Developing CT Disposition and Scientific Skills

Scientific skills can be cultivated by conducting active learning in the classroom. Students should be actively involved in investigating nature. Inquiry learning is one strategy to stimulate students in developing scientific skills (Baharom, Atan, Rosli, Yusof, & Hamid, 2020; Gunawan et al., 2019; Limatahu, Sutoyo, & Prahani, 2018).The discovery learning model and problem -based learning model are also effective in improving scientific skills along with the inquiry learning model (Suryanti, Widodo, & Budijastuti, 2020). Media used in learning activities can boost scientific skill acquisition (Osman & Vebrianto, 2013). For instance, using multimedia practicum has been shown to enhance scientific process skills (Kurniawan et al., 2019).

There is still a limited study on the improvement of CT disposition in science class. However, active learning in science class may also grow CT disposition. A study conducted by Yin et al. (2020) indicates that integrating maker activities and physics classes can enhance the CT disposition of students.

3. Method

3.1. Research Design

The effectiveness of collaborative modeling-based learning in high school physics courses is investigated through a pilot study. Developing scientific skills is one of the primary purposes of physics courses. Students' scientific skills are also assessed based on the students' work on the modeling module. The pilot study has two learning cycles with sub-topics of Hooke's law and spring arrangement respectively. The CT disposition is investigated by asking students to complete a self-report checklist. The impact of the intervention on the students' theoretical understanding is also investigated. A pre-and post-tests design was implemented in the study. Pre- and post-tests were given before and after students participated in the collaborative modeling-based learning in the physics classroom.

3.2. Research Participants

The pilot study was done in a private school in Surabaya, Indonesia. Students in grade 11th participated in the pilot study. In total, there are 89 participants which consist of 27 male and 62 female students.

3.3. Instruments

The research instruments employed in the study are pre- and post-tests, CT dispositions checklists and scientific skills rubrics. The pre-and post-tests consist of five essay problems about elasticity. Students are asked to fill out a self-report checklist to assess their CT disposition. The checklist consists of several statements about CT disposition on a scale of 1-4. Students' work at each learning cycle was assessed using a rubric to measure students' science process skills.

3.4. Data Analysis

The scores of the pre- and post-tests are compared and the normalized gain score is calculated. The formula to calculate the normalized gain score $\langle g \rangle$, is given as:

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

Where $\%pre$ is the percentage of the pre-test score and $\%post$ is the percentage of the post-test score. The $\langle g \rangle$ score is then classified using criteria given in Hake (1998).

Students' CT dispositions are measured by using a checklist. The students' answers on each item on the checklist are converted into score such as "strongly disagree" = 1, "disagree" = 2, "agree" = 3 and "strongly agree" = 4. The mean CT disposition score is interpreted using criteria as shown in Table 1.

Table 1. Criteria for the average score of students' CT dispositions checklist.

No.	Score interval	Criteria
1	$\bar{X} > 3.4$	Very good
2	$2.8 < \bar{X} \leq 3.4$	Good
3	$2.2 < \bar{X} \leq 2.8$	Acceptable
4	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq 1.6$	Very poor

4. Results and Discussions

4.1. Learning Process

The learning syntax is constructed by adapting the modeling process. It consists of model development and model deployment. Model development is divided into pre-and post-experiment and investigation. Meanwhile, model deployment comprises model application and reflection. Each stage is explained in Table 2.

Table 2. The stages of collaborative-modeling-based learning.

Stages	Activity explanation
Pre-experiment	Students are asked to observe a film that depicts real-world occurrences related to the subjects discussed in the pre-experiment activity. This activity aims to engage students at the beginning of the class. Students are also stimulated to ask questions and construct hypotheses.
Investigation	Students have to explore the elasticity phenomenon through collaborative experiments. They plan experiments, arrange the apparatus, observe the phenomena, collect the data and make documentation. During group investigations, the teacher has a role in monitoring how the investigation goes. An experiment guide is provided along with the worksheet.
Post-experiment discussion	Students discuss the results of the investigation in the group. They are stimulated to analyze the data and interpret it. Students are asked to develop a model based on the data. A whiteboard is provided for each group to facilitate model construction. After each group, builds the model, they are asked to communicate it in the class forum. During the class discussion, other groups can ask questions or suggest an idea to improve the constructed model.
Model application	Students discuss how to solve some related problems by applying the model that has been developed within the group.
Reflection	Students are asked to make a reflection on the learning activity.

4.2. Scientific Process Skills

Some aspects of scientific process skills are observed in this study, i.e., observing, formulating hypotheses, experimenting, classifying, visualizing, interpreting, concluding and communicating. Figure 1 shows the average score of each scientific process skill aspect in percentage during the first and second learning processes. All of the aspects improve from learning cycle 1 to learning cycle 2. In learning cycle 1, the hypothesis that was observed and formulated can be classified as acceptable. Meanwhile, the aspects of experimenting, classifying, visualizing, interpreting, concluding and communicating can be classified as good. In learning cycle 2, students seem to be getting familiar with the modeling process; hence, their scientific process skills improve. The score for formulating a hypothesis in the learning cycle improves and can be categorized as good. Meanwhile, the others change significantly to be excellent.

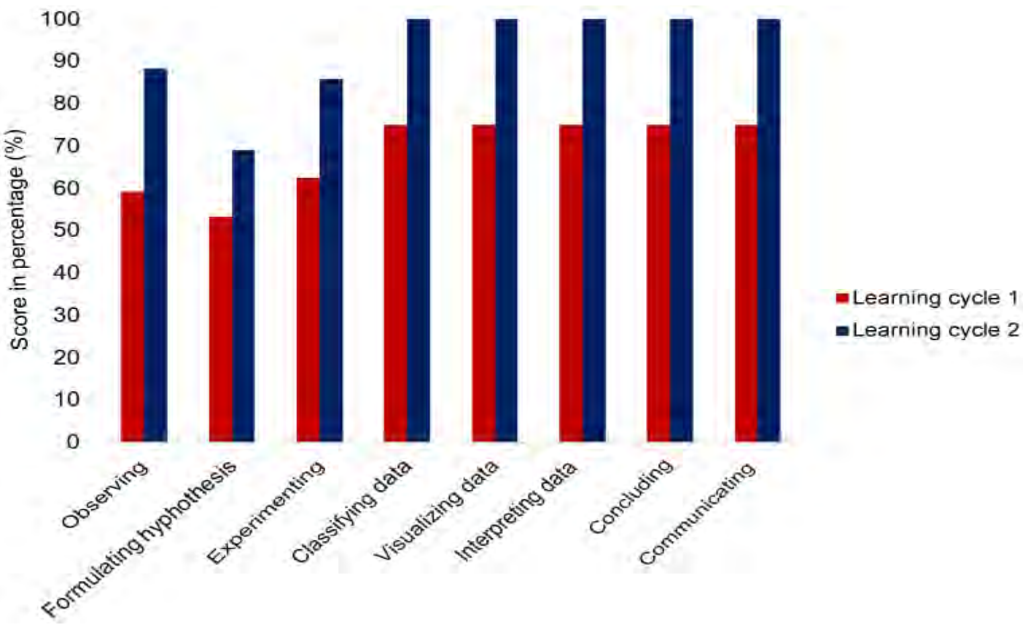

Figure 1. The score of observed science process skills during learning cycle 1 and learning cycle 2.

Number of participants	Average pre-test score	Average post-test score	Average ⟨g⟩	Classification
89	21.3	81.7	0.77	High

The modeling process supports students in acquiring cognitive domains since during the modeling process, students use analyzing, relational reasoning, synthesizing, testing and debugging (Louca & Zacharia, 2012). Previous studies also showed a positive impact of the modeling process on conceptual understanding and other cognitive domains (Campbell et al., 2015; Dukerich, 2015; Taqwa & Taurusi, 2021; Xue, Sun, Zhu, Huang, & Topping, 2022). Collaborative modeling-based learning is a form of constructivist learner-centered instructional method. Students construct their own understanding of physical phenomena according to the interaction between the existing information in their minds and information deduced from observation and social contact. Supena, Darmuki, and Hariyadi (2021) revealed that constructivist and collaborative approach positively influence students learning outcomes.

4.3. Computational Thinking Disposition

Collaborative modeling-based learning examines many CT dispositions such as resilience in the face of adversity, ambiguity handling skills, confidence in the face of complexity and teamwork in pursuing a common goal. Each CT disposition is described in some statements in the questionnaires (see Table 4). Students have good confidence when facing complexity, good persistence when working with difficulty and good collaboration ability. The score on those aspects is above 2.80 (out of 4.00) based on the self-report checklist. However, students seem to be confident in handling ambiguity. The average score for that aspect is 2.54 (out of 4.00) which is only categorized as acceptable.

Table 4. Score of CT dispositions.

No	CT dispositions aspects	Statements	Average score	Average score of each aspect	Criteria
1	Confidence when facing complexity	I feel confident when facing complex problems.	2.63	3.00	Good
		I am able to solve complex problems if I continuously try.	3.23		
		I am able to solve complex problems at an appropriate time.	3.14		
2	Persistence when working with difficulty	I tried my best to work on difficult questions.	3.13	2.89	Good
		I am very persistent when working to solve problems.	2.78		
		I want to have extra time and put more effort into dealing with complex problems.	2.77		
3	Ability to handle ambiguity	I can solve open-ended questions (Problems that do not have only one solution).	2.44	2.54	Acceptable
		I can solve questions that have more than one answer.	2.63		
		I am not easily ambiguous (Confused) in working on questions.	2.55		
4	Skills to work collaboratively to achieve a common goal	I can communicate and work well with the team when I have to accomplish a common goal.	3.16	3.08	Good
		I was a reliable team member when working on a team.	2.92		
		I can work in groups productively.	3.15		

Table 5. Frequency of using CT.

No	Statements	Average score	Criteria
1	I attempt to deconstruct complicated issues into simpler components to make them easier to comprehend and resolve.	3.06	Good
2	When addressing complicated issues, I collect broad characteristics and filter out specific details that are unnecessary for the problem's solution.	3.06	Good
3	I'm looking for similarities or patterns between questions to find a solution.	3.08	Good
4	I reduce complexity and look for main ideas through modes.	2.83	Good
5	I have developed a step-by-step solution that can be followed to solve many problems.	3.16	Good
6	I assess how it might be improved after resolving an issue.	3.05	Good
7	I determine whether the solution is truly correct and efficient after finding a solution to a problem.	3.11	Good
8	I considered several different approaches to the problem and evaluated their benefits and drawbacks before selecting the best one.	3.11	Good
Average		3.06	Good

The self-report checklist indicates that students used CT elements while engaging in collaborative modeling-based learning (see Table 5). The preliminary result indicates that CT skills may be developed through collaborative modeling-based learning, despite the fact that our study did not thoroughly examine the CT skills outcomes. Students can practice CT aspects through modeling-based learning while constructing, evaluating, revising and applying the model. Previous studies also support the finding (Hutchins et al., 2020; Liu, Perera, & Klein, 2017). Hutchins et al. (2020) showed that incorporating a learning-by-modeling approach using computer simulation improves CT skills. Shin, Bowers, Krajcik, and Damelin (2021) also explain that modeling process features in project-based learning that they have implemented can support CT development.

Students can practice CT skills when they are actively engaged in the modeling process. The initial finding of this study is in alignment with studies showing that active learning stimulates students to practice CT (Jun, Han, & Kim, 2017; Romero, Lepage, & Lille, 2017). Gao and Hew's (2022) study provides evidence that integrating active learning into the 5E framework (engagement, exploration, explanation, elaboration and evaluation) improves students' comprehension of CT ideas and their ability to solve problems.

5. Conclusion

In this study, we designed collaborative modeling-based learning to foster theoretical understanding, science process skills and CT dispositions in high school physics classes. Collaborative modeling-based learning engages students in a modeling process that is usually done by a physicist. Collaborative modeling-based learning comprises some stages, i.e., pre-experiment, investigation, post-experiment discussion, model application and reflection.

After students participated in collaborative modeling-based learning, they had excellent theoretical knowledge. Direct experiences to observe physical phenomena and social interaction during the collaboration with the peer support students to build their own knowledge. Moreover, students' scientific process skills improve during the learning cycle. In the last cycle, students had excellent scientific skills. By being involved in the modeling process, students have direct experiences with practicing science; hence, it can foster the students' scientific skills.

It has also been found that collaborative modeling-based learning can contribute to developing computational thinking. Activities in the modeling stimulate CT competence. We conducted an initial investigation by using a self-report checklist to evaluate CT disposition and frequency of using CT aspects. We found that students have good CT dispositions and use CT aspects.

5.1. Limitation and Prospective Recommendation

This study has some limitations. CT disposition is only investigated through a self-report checklist which is less comprehended. Observation should be carefully performed to explore more about the impact on CT disposition and CT skills. Collaborative modeling-based learning involves laboratory work in which experimentation apparatus is necessary. In some schools, experimentation apparatus is still limited. Hence, an innovation to provide alternative options should be created. One of them is providing mobile laboratories for schools in distant areas. The development of such media will be our next project to widen the impact of collaborative modeling-based learning.

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