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Abstract. Over several decades, many physics teachers have taken a crucial responsibility for improving conceptual understanding of students. To enhance students' understanding, generally they have adopted an alternative teaching approach to classes. However, such that approach does not always yield positive learning outcomes. Many researchers reported that a teaching and learning sequence was one of the essential factors needed to take into account. In this study, the teaching and learning sequence was proceeded by 5E inquiry-based learning which was grouped as active learning. Therefore, the goal of this study was to analyze the teaching and learning sequence for Newton's third law designed by a pre-service teacher together with the physicists' comments on that sequence. This was viewed as the initial phase of research in finding a suitable framework for future training pre-service teachers about how to design a teaching-learning sequence. The teaching and learning sequence was implemented to the two classes of grade 9 students. From the analysis, we found that the teaching and learning sequence were complicated and some physics situations were not clear. To help support the students' conceptual understanding, all unclear physics situations were refined and corrected in line with physicists' comments to be used in the classes but remained the primary structure of such that designed sequence. The standardized test about force was administered to the students after completing the lesson. The results were found that the designed sequence yielded low learning outcomes even were taught with the interactive engagement. This was the evidence shown that the teaching and learning sequence affected students' leaning and there was a need about seeking a framework to help pre-service teachers in a process of designing a teaching and learning sequence.

1. Introduction

In term of physics education research, many reports have demonstrated that students who can solve physics calculation problems often do not provide the correct physics conception underline such those problems [1-4]. Besides, there has been found that students who have high achievement scores in physics, it does not imply that they have solidify physics concepts [5-6]. In particular, the concept of force and motions were commonly explained from students' common-sense beliefs or intuitions [1]. This difficulty provoked many physics researchers to invent standardized tests [2, 7-9] in order to investigate and identify students' misconceptions for improving instruction. Halloun and Hestense (1985) found that most students related force with velocity. For example, they thought that an object was moving with a constant velocity due to a constant force exerting on it [1]. Similarly, a speeding up object with a uniform rate was caused by an increasing force at a steady rate. Even the small conceptual area of Newton's third law was seemed to be quite simple for teaching, it also became one of the most difficult topics for students. Bao *et al.* (2012) reported that there were four contextual features: velocity, mass, pushing, and acceleration used to explain action and reaction forces [10]. For the velocity feature, students thought that an object moving with a greater initial velocity would exert a greater force than another object moving with a smaller velocity when they collided. For the mass feature, the students' idea was that a heavy object would exert a greater force than a light object. The pushing feature was expressed that when an object pushed another one, the object being pushed would exert a smaller force than the other one. The acceleration feature involved to an idea about an object with a high acceleration would exert a force more than another one with a low acceleration only.

According to the findings about the students' misconceptions, active learning has been promoted to classes instead of traditional teaching, as it could help students achieve a higher level of their conceptual understanding [11-14]. For example, a well-known research—the massive study of Hake (1998) with a total number of 6542 students found that Interactive Engagement (IE) could enhance the students' conceptual understanding and problem solving ability of mechanics higher than the traditional instruction [15]. In addition, many research studies in Thailand has been also reported the similar findings when implemented courses based on active learning towards various strategies, e.g., peer instruction, 5E inquiry, or interactive lecture demonstrations [7, 12, 13-14, 16]. Even though, another research area reported that active based learning was not sufficient to support students' learning. Designing of teaching and learning sequence was suggested instead [17-18]. Since a group of physics education research at the Leibniz Institute for Science and Mathematics Education (IPN) introduced a framework for designing a teaching and learning sequence called 'Model of Educational Reconstruction (MER)' and found the high effectiveness on students' learning outcomes [19-20]. This has been disseminated to science disciplines. Even it was used in different subjects, the results were found positive trends [21-22].

The key idea of the MER is transforming science content to be science content for instruction—with a particular emphasis on making the content to be accessible and understandable for students. That means teachers have to understand science content matters to be taught and curriculums together with their students' conceptual understanding [19, 20].

Therefore, this study is viewed as a case study which aims to analyze the teaching and learning sequence designed by a pre-service teacher with the semi-structured educational framework and the result of students' learning outcomes when they learned with the designed sequence. This will be an initial phase involving to the MER—investigating how the teacher transferred the content of Newtons' third law to the students which can be used to be a guidance onward to help improve pre-service science teachers in designing their teaching plan for teaching this topic.

2. Research methodology

2.1. Contexts of the study

The participants were a pre-service teacher and her 36 students. The teacher was a fifth-year university student from Department of General Science, Faculty of Education who enrolled a course of teaching practicum. She was assigned to practice teaching in a small-size public school. The whole students were from two classes: one class with 13 students and the other one with 23 students. They were studying Chinese and English programs in grade 9. Therefore, the background of them was mostly not involved to science. Besides, they were the students from the local area of this school where the community slightly gave importance to getting educated.

2.2. Research design and data collection

To substantially understand the teaching-learning sequence designed by the pre-service teacher for transferring Newton's third law of motion to the students, the qualitative method—observing the pre-service teacher's teaching practice before going to the classes together with analyzing the teaching and learning sequence were processed. Specially, we also asked a physicist who has over 10 years of experience in teaching physics to give suggestions about the teaching-learning content. Then, some situational content was refined and corrected in line with physicists' comments to be used in the classes but remained the primary structure of such that designed sequence.

Then, there was tracking on how much the teaching-learning sequence could help improve students' conceptual understanding. A standardized test—Force and Motion Conceptual Evaluation (FMCE) [7] was administered to the students after they participated the lecture classes. There were 10 multiple-choice questions relating to action-reaction forces. The questions covered four contextual features about mass, velocity, pushing, and acceleration.

3. Results and discussion

The result of this study was from observation of the teaching practice which was part of training in the teaching practicum course on the topic of action-reaction force, analysis of the teaching plan by stressing on the teaching activities to be used in the classes together with the physicist' views, and analysis of the students' individual responses on the FMCE test.

3.1. Analysis of the teaching-learning sequence

The pre-service teacher prepared her lesson in the topic of types of forces based on the 2001 Basic Education Core Curriculum designed by the Institute for the Promotion of Teaching Science and Technology (IPST). This topic was generally exposed to the formal concepts of forces, i.e., gravitational force, tension, centripetal force, frictions, buoyancy, moment of forces, and action-reaction forces [23]. The time duration for completion of this topic was about 100 minutes. The teaching-learning sequence was designed based on the 5E inquiry-based instructional model [16]. This strategy generally provided teachers an opportunity in engaging students to exercise their curiosity, to learn about the natural world, and develop problem-solving skill [24].

From the observation, we found that the teacher spent about 35 minutes in total to complete the action-reaction forces lesson. The detail of her teaching-learning activities corresponding to the 5E inquiry steps was summarized as shown in table 1.

Table 1. A summary of the analysed teaching-learning sequences.

5E inquiry step	Teacher's teaching-learning sequence
Engagement	The teacher started engaging the students by showing the picture of rowing a boat as shown in figure 1 and asked them to determine the action and reaction forces. Then she showed the action and reaction arrows to represent the action and reaction forces, respectively.
Exploration and Explanation	**Pulling of two springs connected in series:** The teacher displayed the picture of pulling two springs connected in series as shown in figure 2 (a) and asked the students to determine the action and reaction forces. Then she represented $\overrightarrow{F_1}$ as the action force, $\overrightarrow{F_2}$ the reaction force on the left side of spring and used $\overrightarrow{F_4}$ as the action force, $\overrightarrow{F_3}$ the reaction force on the right- side of spring, respectively. **Flying balloon:** The teacher showed the picture of a flying balloon as shown in figure 2 (b) and asked the students to determine the action and reaction forces. Then she showed the action force and reaction force and mutually explained that "the gas rushing out of the balloon is the action and the movement of the balloon in the opposite direction is the reaction".

	Dragging a block on the floor by pulling a rope connected to the block: The teacher showed the picture of a man is dragging a block on the floor by pulling a rope connected to the block as shown in figure 2 (c) and asked the students to determine the action and reaction forces. Then she showed the action and reaction forces and mutually described that "the pulling force from the man is the action and the tension on the rope is the reaction." **Flying rocket**: The teacher showed the picture of a flying rocket as shown in figure 2 (d) and asked the students to determine the action and reaction forces. Then she showed the action and reaction forces and mutually explained that "the hot gases produced by burning of fuel rushing out at the bottom of the rocket is the action and the equal opposite force of the downward moving gasses pushes the rocket upward.". **Bouncing ball:** The teacher displayed the situation of a bouncing ball as shown in figure 2 (e) and asked the students to determine the action and reaction forces. Then, she explained that "when you drop a ball; it is hitting the floor; the ball pushes on the floor. The floor also exerts a reaction force on the ball causing it to bounce in the opposite direction". **Forces between two magnets:** The teacher displayed the picture of two magnets then asked that "are there action-reaction forces between these magnets?". Then, she shortly let them explain their ideas. After that, the teacher explained (without sketching any forces) "there are the attractive forces which have the same magnitude with the opposite directions between the magnets. These forces are the pair of action and reaction between the magnets which are not in contact".
Elaboration	The teacher asked the students to create an experiment about the action and reaction forces and then demonstrated their experiment to the class. The teacher taught how to make a paper propeller then explained about the action and reaction forces occurring on the propeller. The teacher summarized that "if you press an object with your hand, you will feel the object pushes back to your hand. It means that your hand exerts a force to the object while the object also exerts a force to your hand. The force that object 1 exerts on object 2 is popularly called the action force, and the force of object 2 on object 1 is called the reaction force". Finally, the teacher stated that Newton's third law of motion was about "every action force always causes the reaction force which has the same magnitude and opposite direction" and showed the formula; "Action force = Reaction force".
Evaluation	The teacher asked questions about the action-reaction forces to her students and let them write their answers on their own science workbook.

Each of the steps is further thoroughly described as follows:

3.1.1. Engagement. The teacher started her classes by displaying the situation of rowing a boat as shown in figure 1 (a). After that, she asked her students "when we row a boat, an oar is pushed backward; why does the boat move forward?" She gave the students a few minutes to think about the answer. Lastly, she showed the solution as shown in figure 1 (b) and then explained that "there is an action force exerting by a boatman in the backward direction so there is a reaction force occurring on the boat in the opposite direction. Thus, the boat moves forward".

From the physicist's view, it would be better if the teacher started by asking her students to determine the forces appearing in the situation and identify which object exerts the considering force and the force was exerted on which object. The words of "action force" and "reaction force" would be introduced later. To explain the occurring forces, the key idea of rowing was to push water backwards with a blade of an oar. The explanation about the third law of motion was that the water will push forward on the blade of the oar, and mutually will push forward on the boat (see figure 2 (c)). Furthermore, the action and reaction forces should act along the same line.

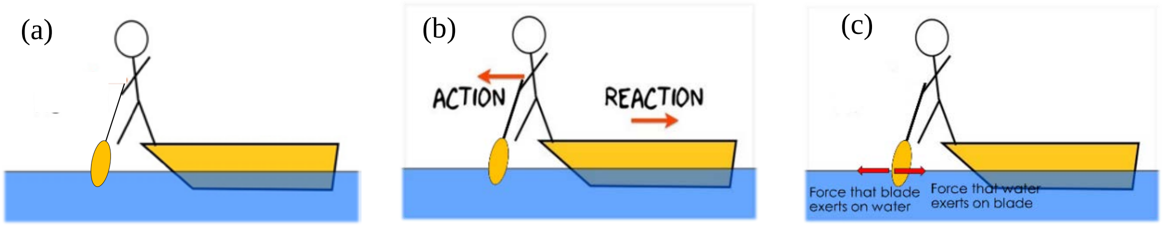

Figure 1. (a) The situation of rowing a boat represented by the pre-service teacher, (b) the solution provided by the teacher, and (c) The solution corresponds to the physicist's suggestion.

3.1.2. Exploration and explanation. The teacher separated the students into groups of 3 and asked them to work on tasks about determining action-reaction forces in the four given situations; pulling of two springs connected in series, a flying balloon, dragging a block on a floor by pulling a rope attached to the block, a flying rocket, and a bouncing ball. The solutions of the teacher for all situations are shown in figure 2. Her explanations for these situations are summarized in table 1 in the exploration and explanation steps. After that, the teacher displayed the figure of two magnets then asked "Are there action-reaction forces occurring between these magnets?" and let them explain their ideas. Then, the teacher shortly explained that "there are the attractive forces with the same magnitudes and the opposite directions occurring between these magnets". "These forces are the action and reaction force pair at a distance".

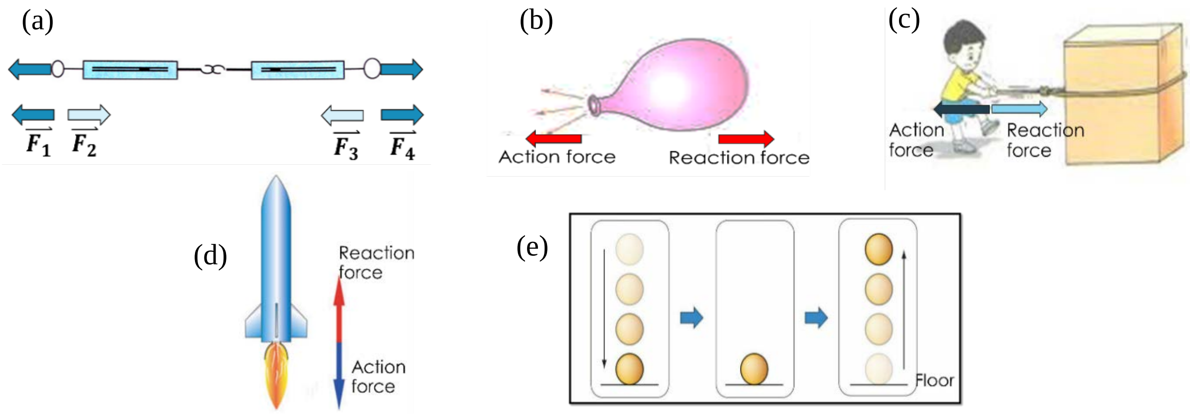

Figure 2. The vectors of action-reaction forces represented by the teacher in cases of (a) pulling of two springs connected in series, (b) a flying balloon, (c) dragging a block on a floor by pulling a rope attached to the block, (d) a flying rocket, and (e) a bouncing ball.

From the physicist's view, the vectors of action-reaction forces in the situations above should be represented and taught as shown in figure 3. The action-reaction pair vectors must be aligned in the same line and the detail of the existing forces that exerted by which object and exerted to which object should provide clearly. Most given situations were too much complicated for the ninth-grade students to understand. From figure 2, this shows that the teacher mostly provided inexplicit drawings and unclear labelling for the vectors of forces in all situations. In figure 2 (c), the teacher should give the clear instruction about the position required for finding the action-reaction forces because there were many action-reaction force pairs, for example, (1) the forces occurring between the man and the rope, (2) the forces occurring between the rope and the block, and (3) the forces occurring between the block and the floor. The situations about a flying balloon and a flying rocket were similar. The acceleration of the gases emerging from the balloon or the rocket creates the thrust that accelerates and propels it. For the bouncing ball situation, the physicist suggested to take out. This was rather the difficult situational concept for students. When the ball is hitting the floor, there are two forces acting on the ball: the force exerted by the floor and by the earth; whereas there is only one force exerting to the floor in the downward direction. Therefore, it was hard to describe to the students that the force exerting on the ball by the floor is equal to the force exerting on the floor by the ball. The last activity was to determine the action-reaction forces between two magnets. The physicist concerned that some students might have no or low prior-knowledge about magnetic force. Anyway, this situation remained in the teaching plan.

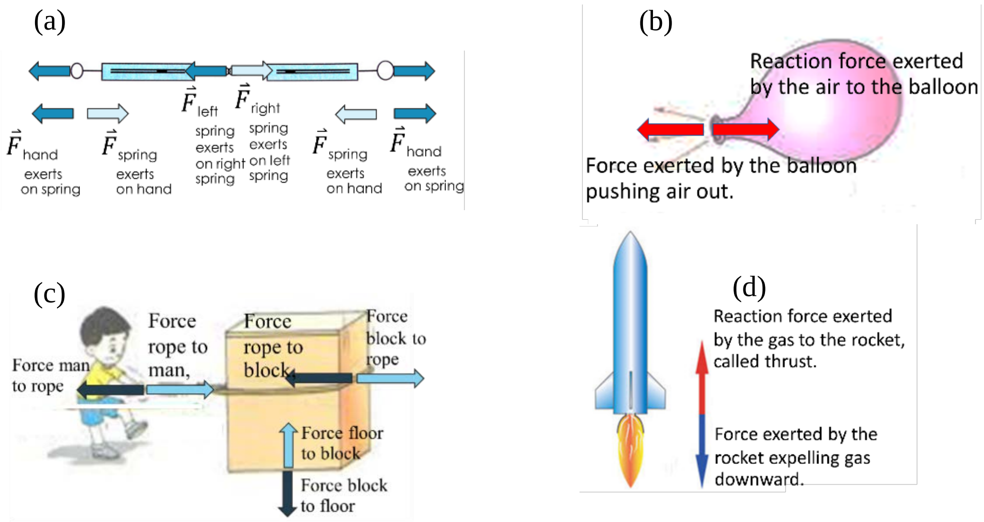

Figure 3. The vectors of action-reaction forces refined by physicist's view in cases of (a) pulling of two springs connected in series, (b) a flying balloon, (c) dragging a block across a floor by pulling a rope attached to the block, and (d) a flying rocket.

3.1.3. Elaboration. The teacher asked the students to create a new situation about action and reaction forces, and described about them to the classes. After that, she implemented the classes with the hands-on activity (a paper propeller) as shown in figure 4. Then, she firstly asked the students to explain their conception about the action-reaction forces till she knew the whole ideas of the classes. She then helped the students summarize that the propeller could float in the air because of the reaction force from the air.

This activity was also too complicated for the students. From the physicist view, the students needed to imagine about the forces between the propeller blades and gas molecules. The floating of paper propeller in the air was described as "the whirling blades are shaped to force air particles moving downward, and the air forces the blades going upward".

(a) (b)

Figure 4. (a) A paper propeller, and (b) The vectors of action-reaction forces refined by physicist's view.

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3.1.4. Evaluation. The teacher summarized about the concepts of action-reaction forces which students had already learnt as follows; "if you press an object on your hand, you will feel the object pushing back to your hand". "This means that your hand exerts a force to the object while the object also exerts a force to your hand". "The force that object 1 exerts on object 2 is known as 'the action force', and the force of object 2 on object 1 is called the 'reaction force'". Finally, the teacher stated about the Newton's third law of motion "every action force always causes the reaction force which has the same magnitudes and the opposite directions" and showed the formula of action-reaction forces

The first suggestion from the physicist was that it should be understood that when we considered the action-reaction forces between two objects, any objects could be considered as the first object. Thus, either of the forces could be labeled as the action or reaction force. The second suggestion was about the formula; "Action force = Reaction force" provided in the teaching document. It may cause confusions to students. This formula did not mention about the direction of both forces.

The purpose of the evaluation step was to allow the teacher to conclude about the concept and determine the students' understanding. She asked some questions about the action-reaction forces to the students and let them write down the answers on their workbook, and administered the conceptual test called the Force and Motion Conceptual Evaluation (FMCE) to them.

3.2. The students' learning outcomes

The average scores of the FMCE test from the two groups of students (worth 10 marks) were 2.62 ± 1.04 for the 13 students and 1.91± 0.42 for the left 23 students. We note that mostly the students had a very low achievement after learning with the complicated teaching-learning sequence designed by the teacher. There were only 3 students receiving the highest score of 4. Furthermore, the result of students' responses on each item showed that generally less than 20 % of the students were able to give correct responses for almost all questions. Except questions 4 and 8, most students (about 86% and 51% of students, respectively) provided the correct response on them (See table 2). We noted that question 4 was a simple contextual feature—the collision between two cars having the same weight and moving with the same initial speed. This was similar to the feature of question 8—the car, still pushing the truck, is at cruising speed and continues to travel at the same speed.

Table 2. Average percentage of students on each item.

Item No.	Description of questions	Average percentage of students who gave Newtonian answers	
		Group A (13 students)	Group B (23 students)
1	A collision of the truck and the car which are moving at the same speed	46.2%	4.3%
2	A collision of the car which is moving much faster than the truck	23.1%	8.7%
3	The car hits the heavier truck which is standing still.	23.1%	0.0%
4	A collision of the two cars with the same weights which are moving at the same speed	76.9%	95.7%
5	The car hits another which has the same weight and is standing still.	7.7%	13.0%
6	The car which is pushing the heavy truck but sufficient to make it move.	0.0%	4.3%
7	The car which still is pushing the truck and is speeding up to get cruising speed	23.1%	8.7%
8	The car which still is pushing the truck at the cruising speed and continues to move at the same speed	46.2%	56.5%

9	The car which still is pushing the truck at the cruising speed when the truck puts on its brakes and causes the car to slow down	0.0%	4.4%
10	The student' feet is in contact with another student's knees causing the chairs which they are on to move.	7.7%	0.0%

For the other questions, the main cause of students' misunderstanding was from the complex contexts such as the collisions between two bodies with different masses or different speeds as same as Halloun *et al*. [1]. For example, on question 6, the situation was that the car is pushing on the heavy truck, but not hard enough to cause the car's movement. This caused only about 3% of the students could answer correctly.

According to this result, we found that the students related force with mass and initial or final speed of an object, instead of a change in momentum when two objects collide.

4. Conclusion

The set goal of this study was to analyze the teaching and learning sequence designed by the pre-service teacher and her students' learning outcomes. From the analysis of the teaching practice, the teaching plan, and the physicist's comments, there were findings that the sequencing of the teaching and learning content and activities was too complicated and not suitable for the study level of the students. The teacher gave a very short-brief conception about Newton's third law of motion and followed by asking for exploring many complex situations and explaining the situation which involved to the advanced physics conception—non-contact forces or magnetic forces. Moreover, we also found that the teacher did not clearly identify the two objects to be considered during a collision.

Even the teacher paid a high effort to create many contextual situations and provided them to the students which included the hands-on activity (inventing a paper propeller). All of her teaching steps were designed based on the inquiry learning. Anyway, it was not effective to help develop the students' conceptual understanding. The post-test average score was very low with several misconceptions.

This was an evidence shown that there will be some pre-service teachers still needs help improve and redesign his/her teaching-learning sequence as they have low teaching experience. These findings would provoke researchers and university lecturers in particular the lecturers from Faculty of Education to find a way or a framework to enhance and practice pre-service teachers on how to design and sequence their instructional content.

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