JPII 9 (1) (2020) 79-90

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

A SIMPLE APPROACH TO TEACH NEWTON'S THIRD LAW

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DOI: 10.15294/jpii.v9i1.21775

Accepted: November 6th 2019. Approved: March 2nd 2020. Published: March 31st 2020

ABSTRACT

The results of previous researches indicated that there were problems with the mental model and students' conceptual understanding of the action-reaction law (Newton's third law, NTL). This research aimed to reveal the effect of a simple approach in teaching NTL. The research was conducted in the first-year of pre-service physics teachers at the Physics Education Department of Tadulako University. Research designs for three consecutive years were (1) one-group, pre-test, and post-test design, (2) a static group comparison (pre-test for the experimental group), and (3) a quasi-experimental. The approach used was an interactive demonstration that consisted of five phases, i.e: eliciting an intuitive argument, demonstrating a continuous force: pulling, demonstrating a continuous force: pushing, demonstrating impulsive force: collisions, and refining the concept with Elby's pair. Data were collected using a multiple-choice test developed in previous research. The results of the data analyses showed that the approach could improve students' understanding of the action-reaction law, supporting conceptual change by exhibiting N-gain in the moderate and high categories. The instructional design can be considered for implementation in learning in high schools, lecture on pre-service physics teachers and basic physics lecture, in general.

Keywords: Elby's pair; interactive demonstration; NTL

INTRODUCTION

A Reviews of university fundamental physics textbooks, such as Tipler & Mosca (2007), Halliday et al. (2013), Ling et al. (2016) and high school physics books such as Kanginan (2013) and Handayani & Damari (2009) shows that no examples of NTL provided in the context of impulsive force. The law is typically taught in the references to a continuously applied force (e.g., a student pulls on a fixed rope; a book is on a table, etc.). Using examples, the authors engage readers to consider the magnitude and orientation of the action-reaction force pair, and this consideration is used to explain NTL.

Presentation of examples in textbooks is dominant in the case of continuous force that can be thought to affect the understanding of students and physics teachers about NTL for impulsive force cases. This is supported by research Mansyur et al. (2010) which shows that 8 high school students, 13 pre-service physics teacher students, 7 physics teachers and 4 master program students (who were also physics teachers) were only familiar with the examples of continuous forces but had difficulty in problem-solving for impulsive force case. None of them had the correct mental model associated with NTL for impulsive force case. They had contradictory arguments and inadequate lines of reasoning when explaining action-reaction law for the case. Some of them did not agree that NTL can also be applied to the case.

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Common examples of impulsive force interactions conceptually examine the collision of two objects where one is of a much larger mass (e.g., a car crashes into a truck, an apple falls to the ground, etc). When students are asked about the magnitude of forces involved (e.g., ”Which object experiences more force?” or ”When does an object exert a stronger force on the other object?”), they generally refer to mass, velocity, size or a combination of the mass and velocity of the objects. Responses stating that “the faster object” or “the more massive object” exerts a greater force on the other are common. These embedded misconceptions challenge the teacher or lecturer in laying a correct conceptual framework of Newton’s laws. According to a widely held constructivist view, this is associated with the idea that students enter physics classes with a set of concepts about how the physical world works that are often contradictory to canonical scientific understanding (Sharma et al., 2010) so that it is a challenge for educators (Brown et al., 2018), where many of the concepts are controversial, or counter-intuitive (Nadelson et al., 2018).

At the practical level, students’ understanding of NTL is often difficult to be developed (Terry & Jones, 1986). Typically, examples of this concept are provided by reviewing contact forces more closely related to the student’s daily experiences. Although this is beneficial in general, reaction forces can sometimes be taken for granted, and students can turn to lose the opportunity to truly think about what is happening. For magnetic forces, however, determining the force of action applied at a certain distance requires a careful inspection of the force involved and a more detailed analysis of the situation. Research presented highlights failures in the validity of NTL related to moving charged particles (Kneubil, 2016). Other research found junior secondary school students, senior high school and university students to experience difficulty when distinguishing between interaction and balance forces (Zhou et al., 2015). In Feldman’s (2011) work, a simple demonstration of NTL is presented in the context of a magnet falling through a hollow conducting tube. The results are unambiguous and lead students to an irrefutable verification of NTL.

Zhou et al. (2015) classified various situations related to NTL into two groups: static and dynamic groups. In a static group, bodies in contact are considered. The dynamic group focuses on students’ levels of understanding of cases in which bodies are moving.

A popular issue related to NTL concerns students’ misconception (Low & Wilson, 2017) and difficulties with comprehending coarse quantitative aspects according to interaction forces that are always equal in magnitude (Zhou et al., 2015).

About teaching, Savinainen et al. (2012) investigated the use of interaction diagrams in fostering students’ understanding of NTL. Smith & Wittman (2008) investigated ways of teaching NTL based on the style of three tutorial materials taken from other researchers. Their study examined three tutorials designed to improve student understanding of NTL: Tutorials in Introductory Physics (TIP), Activity-Based Tutorials (ABT), and the Open Source Tutorials (OST). Each tutorial is designed with a certain purpose and agenda and is implemented using different methods to help students understand physics. In using Force and Motion Conceptual Evaluation (FMCE) (Thornton & Sokoloff, 1998) and lectures, the authors found students using the OST version of the tutorial to perform better than those using the other two methods. The response to the phenomena related to NTL is influenced by existing knowledge and it is a facet of knowledge.

A facet is closely related to the specific context and is less involved than the p-prim in terms of its underlying properties. A facet may apply several concepts related to ways of representing an individual’s understanding of a situation. A facet can be a piece of generic knowledge or a specific context of reasoning or it can refer to a specific strategy (Galili & Hazan, 2000). An example of a generic piece of knowledge is the expression ”more means more”.

Other examples presented in previous studies on NTL draw on mental models (Smith & Wittman, 2008; Bao et al., 2002). A situation involving an object (mass M) moving at a certain velocity and colliding with another object (mass m, $m < M$) can involve abstract primitive reasoning whereby the ‘greater agent’ has a ‘great effect’ (Mansyur et al., 2014). When the agent is mapped to ’mass’ while ’effect’ is mapped to ’force,’ a facet results: ’a massive object exerts the larger force during the collision’. This reflects incorrect mapping. When ’the agent’ is mapped to ’mass’ while ’effect is mapped to ’the change velocity’, the following facet results: ’the massive object creates a change of greater velocity’. This is an example of correct mapping. From this example, it could be stated that reasoning can be mapped as an incorrect or correct facet. Primitive reasoning was defined (e.g., ’a lower mass car reacts more during a collision’) as raw intuition that could be refined into two forms (Elby, 2001). One of the forms may lead to an incorrect implication. In the previous study (Zollman, 1994), students considered velocity to the lower mass car. If the force serves as a reference, this implies an inappropriate use of NTL. When the change in velocity (acceleration) is used as a reference, then NTL is satisfied.

As explained earlier that it was easy for the students and teachers to understand the law when the example involves a continuous force but had difficulties solving NTL problems associated with impulsive forces. Studies are needed that can be a bridge between the habit of presenting in textbooks and learning practices.

Based on the research findings and recommendations of Zollman (1994), Redish (1994) and Bao et al. (2002) related to the cognitive science research for effective teaching, Mansyur et al. (2010) proposed a hypothetical approach for teaching NTL that involves the impulsive force. The proposed approach has been tried out through an open lecture with an interactive demonstration lecture (IDL) that was attended 13 science magister program students (physics major) of Tadulako University and junior and senior high school physics teachers in Palu City. The lecture was a part of the development process of the approach. At the end of the lecture, they discussed the advantages and the weaknesses of the approach and asked them to give suggestions for enhancing the structure quality of the approach. The approach has a simple structure with five phases and uses some simple equipment, i.e: ropes, springs, and masses.

From the discussion above, our problem: how does the approach support teaching NTL? Can the approach design support the conceptual understanding of NTL?

METHODS

Population and Sample

The research was conducted on first-year students at the Physics Education Department, Tadulako University for three years. The students had different backgrounds and were predominantly from high school in Central Sulawesi. These students were heterogeneously distributed into three classes for each year. A description of the populations, samples and sampling method is presented in Table 1.

Table 1. Research Population, Sample and Sampling Method

Year	Population, N	Sample, n	Gender	Sampling Method
First	120	39	12 males, 27 females	Purposive (1 of 3 classes)
Second	122	31 (Exp.) 29 (Cont.)	9 males, 22 females 8 males, 21 females	Purposive (2 of 3 classes)
Third	125	37 (Exp.) 41 (Cont.)	8 males, 29 females 11 males, 30 females	Purposive (2 of 3 classes)

The samples were selected purposively from the classes of first-year students who were taking the Basic Physics I course. The lecturer in the selected classes was the first author. The lecturer taught in these classes based on an assignment and a schedule from the department so that he did not require special permission to carry out the research. The lecturer involved in the teachingwas only in the experimental group. In the control group, the teaching activities were handled by another lecturer. The instructional design for the control group followed a regular lecture, and we categorized it as a conventional lecture. In addition to the experiment, we also conducted reflective teaching to enhance and mature the structural quality of the approach.

Experimental Design

In the first year, we conducted a pre-experiment on one group by conducting pre- and post-test. Treatment for the experiment involved IDL applying the instructional design described in the next section. We identified opportunities for the approach that can support the improvement of students' conceptual understanding. The experimental design was applied to one class (Figure 1). The learning effects were observed from the improvements in the students' levels of understanding. Pretest and posttest used the same instrument.

O X O

Figure 1. Pre-experimental Design (O = Pretest or Posttest, X = Treatment with IDL)

The experimental design of the second year involved two groups, i.e., an experimental group and a control group. We applied the Static Group Comparison Design but as a pretest for the group. The purpose of this pretest of the experimental group was to obtain data for calculating N-gain. The design was limited however in that it did not involve testing the equivalence of the two groups before the experiment was carried out. Conclusions were drawn by comparing the performance of each group to determine the effect of the treatment on one group and namely, the experimental group. The experimental design adopted is presented in Figure 2.

O X O

\- O

Figure 2. Static Group Comparison

The third year of this research applied a quasi-experimental (non-equivalent) design (Creswell & Creswell, 2017). The experimental design used is presented in Figure 3.

O X O

O - O

Figure 3. Quasi-experimental Non-equivalent Design

In this experiment, the two groups are considered to be not equivalent because no group member was applied settings. In this case, there was no random determination of group members. Researchers selected both groups, as distributed as determined by the department. Before applying the treatment, the two groups completed the pre-test and then the treatment was applied to the experimental group while conventional learning was applied to the control group following instructional guidelines.

Instructional Design

An approach design for a lecture must be prepared to construct students' conceptual understanding of NTL. We applied the design in a small-scale introductory course provided at Tadulako University for over three years. The use of simple equipment in the overall phases is an advantage of the teaching. A constraint related to the availability of equipment for effective teaching could be treated by choosing the simple equipment.

The general description of the phases of the instructional for the experimental group is presented in the following. The instructional design for the control group used a conventional lecture.

Phase-1: Eliciting an Intuitive Argument. In this phase, students are asked to answer a question intuitively. A problem (e.g., the R-FCI problem) (Hestenes et al., 1992) is presented on an LCD projector. Phase-2: Demonstrating a Continuous Force-Pulling. This phase was used to facilitate discussion on the continuous force. The previous study showed that students are very familiar with continuous forces (Bao et al., 2002) with identifying action-reaction force pairs. Phase-3: Demonstrating a Continuous Force-Pushing. This phase was applied to show and discuss the continuous force. Students could identify force pairs. Phase-4: Demonstrating Impulsive Force-Collisions. In this phase, the lecturer facilitated the students in demonstrating a collision of two objects. Phase-5: Refining the Concept with Elby's Pair. To make a refining concept from the previous phases, the lecturer introduced Elby's pair (Elby, 2001). The detail steps for each phase are presented in Appendix.

Data Collection and Instrument

Data collection was carried out through testing. The same test was applied for the pre-test and post-test. Data were collected during three academic years.

The students' levels of conceptual achievement were measured using a test of 30 items on NTL (Mansyur et al., 2014). The test covered multiple-choice items focused on five central force contexts: gravitation, electrostatics, magnetics, pushing, and crashing (impulsive force). The test items were designed using various representations (i.e., verbal, diagram/vectorial and graphical). The test was developed through development and validation. A summary of the results of test analysis and the test items as a whole is presented in Mansyur et al. (2014) based on criteria (desired values) (Nieminen et al., 2010).

The test has a limitation related to its scope and construction. Although the results of our items analysis and test as a whole illustrate the appropriateness of the items and test used for data collection, the test employed is limited by the scope of the examined concept. Results of the test (Mansyur et al., 2014) found the overall statements of correct answers to test items to be similar. For instance, a respondent referring to NTL or the general statement that "a force involving A acting on B is equal to a force involving B acting on A" for all test items can have completed the test with mostly correct answers.

Data Analysis

Data of the experiments were analyzed using quantitative-descriptive on pretest, posttest and normalized gain (N-gain) according to Hake (1999). We also carried out a qualitative analysis of data on conceptual changes and analysis of the advantages and weaknesses of the approach.

During the research, the researchers conducted several controls to ensure consistency and avoid bias: (i) Both lecture versions of each group used the same conceptual content; (ii) Because the two groups were handled by different lecturers, the lecturers always conducted coordination and communication related to the lectures scenario; (iii) Duration for both classes was the same and followed the regular lecture schedule; and (iv) In both groups, students were asked to put away all materials that can distract attention (mobile phone, paper, etc.), both during the lectures and while taking the tests.

RESULTS AND DISCUSSION

Result for the First Year

Our analysis of the pretest and posttest scores generated the average N-gain for the first year pre-experimental design presented in Figure 4. Figure 4 shows an increase from the pre-test to the post-test with a high N-gain. This illustrates that learning activities applying the instructional design structure described above can effectively support the learning of the studied concepts.

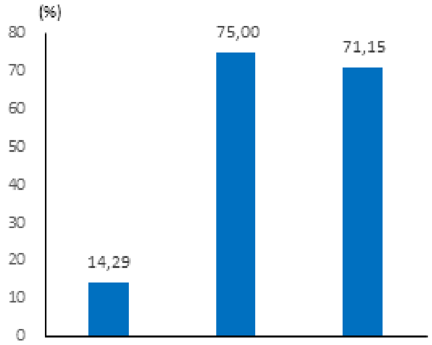


Figure 4. Pre-test, Post-test and N-gain Results of the Pre-experimental Design.

Result for the Second Year

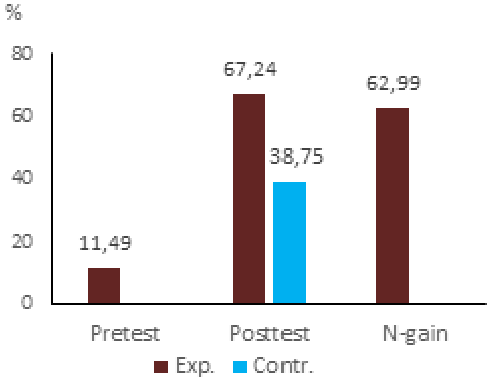


Figure 5. Results of Pretest, Posttest, and N-gain from Static Group Comparison Design with Additional Pretest in the Experimental Group.

An analysis of the results of tests conducted in the first year with the static group comparison design (with additional pretest applied to the control group) is presented in Figure 5.

Figure 5 shows a moderate improvement in performance (N-gain) for the experimental group. The difference observed in the x posttest results of the two groups also shows that the experimental group (moderate category) is superior to the control group (low category). The posttest results illustrate the advantages of an applied instructional design relative to the conventional design.

Result for the Third Year

The results of applying the quasi-experimental design with experimental group intervention, the above listed instructional design and traditional methods to the control group are presented in Figure 6.

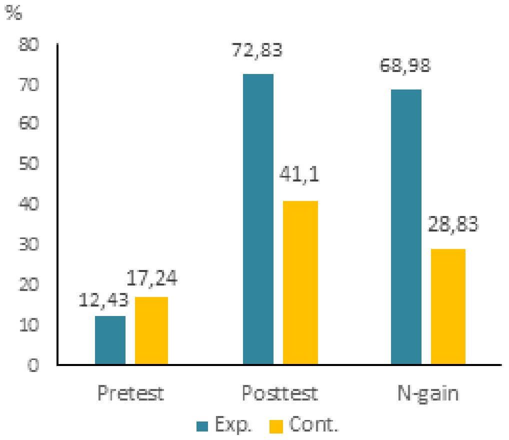


Figure 6. Pretest, Posttest and N-gain Results for the Two Groups.

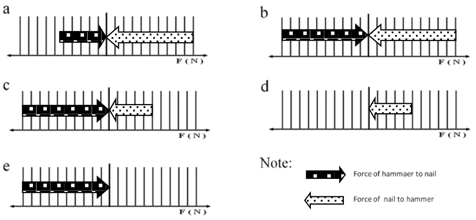
The pretests of both groups generated similar results while striking differences were observed from the post-test, and thus the intervention effectively improved the students' levels of understanding. The striking differences in N-gain values observed qualitatively confirm the influence of the intervention on the experimental group.

From the N-gain values observed from year to year for the experimental group, we observe slight fluctuations. Average N-gain values were recorded as 71.15%; 62.99% and 68.98%, indicating that moderate to pronounced changes occurred. The N-gain data show that the interventions involving interactive demonstration learning and the five-phases design had a strong influence on the students' conceptual understanding. The learning structure and design focused on developing intuitive arguments (Phase-1: Eliciting an Intuitive Argument) by submitting a case that encouraged the students to participate in the lecture. This fits a view of Redish (1994) and Miller et al. (2013) that the involvement of students' capital (resource) even when it is simplistic helps them realize their potential. Students entering a class are not seen as empty vessels that are merely ready to be filled (DiSessa & Sherin, 1998). The intuition forms as part of the content in the vessel that already exists and that can be added or arranged together with new content. In this case, learning steps have accommodated the intuitions of some students to be integrated with new knowledge and to become adequate knowledge useful for solving problems. The process of conceptualizing intuitive knowledge into conceptual knowledge through construction in the intuition activation stage until the refining phase has been successfully applied to improve learning outcomes.

All teaching phases covered (encouragement, attraction, and impulsivity) with stages ranging from simple to more complex accompanied by refinement as the final phase are key to the success of the learning design examined in this research. The dynamic involvement of the instructor through the above learning structure serves as an integral part of that success. This is consistent with the constructivist view suggesting that students are involved through interactivity (Sharma et al., 2010). While learning, students can respond by asking questions or by presenting their opinions to the instructor directly. Some of the students examined help demonstrate certain concepts when the instructor asked questions to the demonstrator and students. They can feel the force of 'resistance' (as a reaction) upon pulling the rope one end of which was tied to a window. The findings of this research regarding the contributions of demonstrations to learning reinforce finding that demonstration is a remarkably simple but strikingly effective approaching requiring the use of specialized equipment (Feldman, 2011).

Using the apparatus to study impulsive forces was very helpful for students to observe the effects of the collision of two objects through changes in the length of spring as an indicator of the force acting on both objects. The final phase reviewed Elby's pair while addressing the case of impulsive forces supported the refinement of the conceptualization process of the action-reaction law. As examples of intervention effects on the students' conceptual understanding, we choose test results for two problems (Problems 15 and 30) related to impulsive forces as displayed in Figure 7.

15. A carpenter hits a nail (on a wood bar) using a hammer. The diagram below describes the forces involved when the hammer hits the nail, which are...



30. Udin and Ical each throw a ball. Ical's ball is larger than Udin's and Ical throws his ball faster than Udin. The balls knock into each other in the air. The diagram below illustrates the forces involved during the collision, which are...

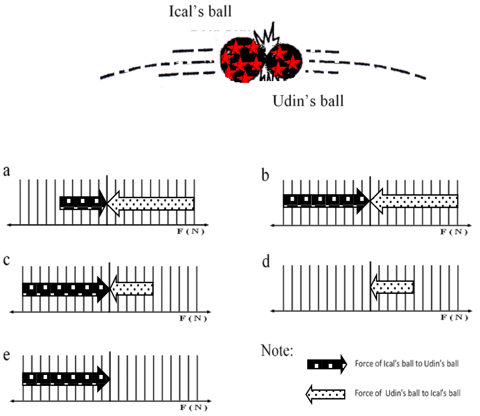
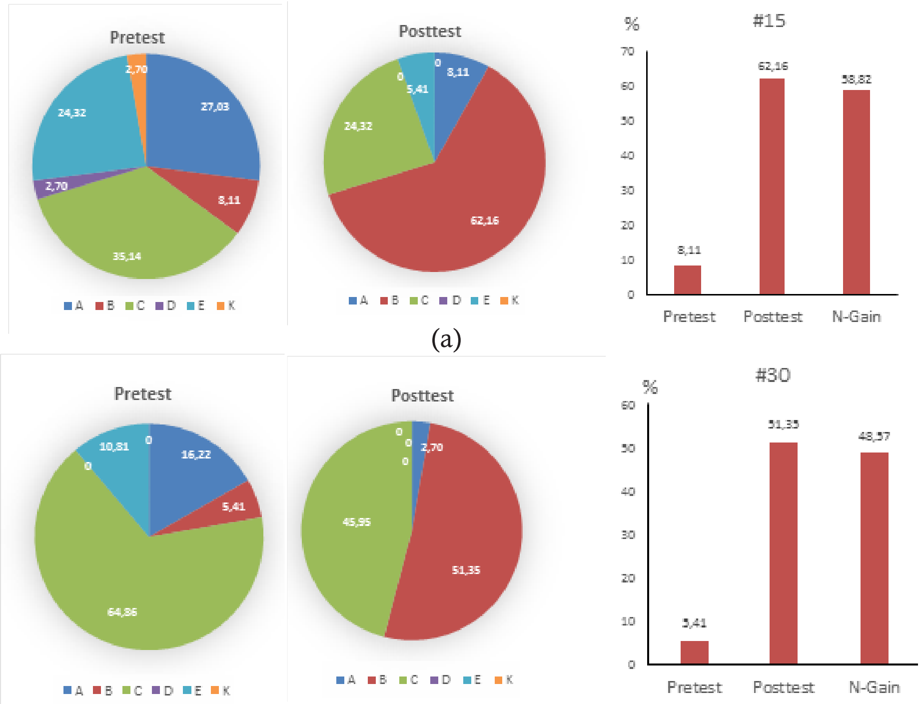


Figure 7. Problems (15 and 30, translated) on Impulsive Forces Involved in the Collision of Two Objects (Mansyur et al., 2014)

What is interesting about the findings of this study is that although the examined demonstration only focused on forces involved when pushing an object or pulling on a rope, on the impulsive imposed on an object and the collision of two objects, the students can extend the application of their knowledge to concepts related to forces related to other contexts. They can also solve problems involving electrostatic, magnetic and gravitational forces. It can thus be concluded that students can effectively apply what is learned to new isomorphic problems. In other words, learned information was applied from one context to another. This application of knowledge can be understood with the Lobato's Model (Lobato, 2003) of "actor-oriented transfer" (AOT), which defines transfer learning as the "personal construction of similarities" between two contexts. Lobato's model focuses on how these "actors" (or learners) see two contexts as the same (Cui et al., 2006).

Conceptual change does not just happen, as support from the environment and learning systems is indispensable to the success achieved. A learning structure originating from a review of the attraction force and forces acting on an impulsive determines the conceptual change that occurs. Demonstrations of a simple case are then followed by an examination of more complex cases, contributing to the average N-gain achieved through this research. The students did not merely observe the change in the length of the two springs when the lecturer demonstrated the pair of action-reaction forces acting on the rope, as they were also invited to review several pairs of actions and reactions acting on the rope starting from the pair of forces acting on a point on a wall to the pair of forces exerted onto the demonstrator's hand. By asking probing questions and assisting while having the students watch what happened during the demonstration, the instructor helped the students develop their knowledge base. This confirms the findings of Kestin et al. (2020) that IDL can help the students to understand the underlying phenomena and concepts by asking them to make predictions of the outcome and then discuss them with each other.

An initially inappropriate conception can be converted into an appropriate conception. The results of this study show that a demonstration through "refining raw intuitions" can improve students' understanding as reflected by the N-gain (in the first year) and by learning outcomes superior to those of traditional learning (the second year posttest comparison and the third year N-gain).



(a)

(b)

Figure 8. Distribution of Students' Responses based on Available Options and Changes of Choices made from the Pretest to the Posttest and from N-gain for Problems 15 (a) and 30 (b). The Correct answer for both Problems is B. 'Option' K Represents a Blank Response.

Striking differences in N-gain (the third year) values observed for both groups confirm the benefits of learning through the interactive demonstration over conventional lectures. The proposed instructional design can also mitigate the action dependent facet whereby one object exerts a force while another object is subjected to that force (Smith & Wittmann, 2008).

Figure 8 shows the shift in the distribution of answers given from the pretest to the posttest. The figure shows that the percentage of students selecting the correct answer increased with N-gain values are 58,82% and 48,57%.

Even though it has decreased in proportion, there were still many students from 35,14% to 24,32% (Problem 15) who misunderstood the case of the collision of two objects. They understood that an object that is mass/larger in size and comes crashing into a resting object gives a greater force compared to rest objects whose small mass/size and speed. A larger proportion (from 64,86% to 45,95% for Problem 30) occurs when an object that is larger and faster collides an object of smaller size and speed. This illustrates that the context that includes the mass/size and speed of objects affects the conception of the students. This situation can not be completely overcome by the approach. This is in line with the findings that the conceptual change associated with NTL should be viewed in conjunction with changes in the students' overall understanding of the notion of force (Terry & Jones, 1986) and context features (Bao et al., 2002).

The variance (qualitatively) in the students' answers for the pretest was markedly more pronounced than the posttest. Thus, learning outcomes achieved through the interactive demonstration successfully reduced levels of variance in the students' understanding of the collision of two objects. The learning process successfully helped the students develop an accurate conceptual understanding of the action-reaction force for the studied case. An overview of Elby's pair can be used to illustrate the implications of two paths of reasoning. The first path of reasoning does not meet the conditions of NTL while the second implies the fulfillment of the law. This shows that even though there is still weakness related to variations of the context in the demonstration process, the learning design structure has advantages in supporting the achievement of learning objectives, in general.

CONCLUSION

We applied an approach with interactive demonstration learning in which students negotiated their understanding and their raw intuition. The phases of this approach have helped students build their understanding by learning from simple cases and are generally exemplified in textbooks to more complex NTL cases. A review of Elby's pair in the final phase is an integral and crucial part of this approach for refining the raw intuition that leads to an appropriate understanding of NTL. The approach improved the students' understanding of action-reaction forces, supporting conceptual change and exhibiting average normalized gains of the moderate to high categories. The design can be considered for implementation at high school or introductory physics course and physics teacher preparation program.

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APPENDIX

INSTRUCTIONAL DESIGN FOR THE EXPERIMENTAL GROUP

Procedure

a. Phase-1: Eliciting the Intuitive Argument

In this stage, students are asked to answer a question intuitively. A problem (e.g., the R-FCI problem) is presented on an LCD projector.

In the figure below, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another, which student feels the greater force?

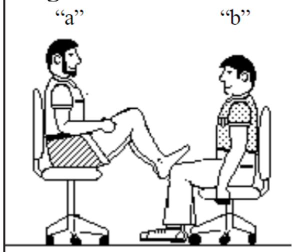

Figure A. An R-FCI Case (Hestenes et al., 1992)

Count the percentage of students providing each type of answer and ask the students to explain their choices. Do not discuss their arguments. Continue to the next phase.

b. Phase-2: Demonstrating the Continuous Force-Pulling

The previous study showed that students are very familiar with continuous forces with identifying action-reaction pairs. This was used to facilitate discussion on the impulsive force.Procedure:

1. Tie a rope to a wall.

2. Ask the student to predict interaction forces between the rope and wall by asking questions such as the following: "What would happen if we pulled on (applied force to) the rope? How about the wall?" The common answer (potentially due to high school experience): "The wall would exert a force (reaction force) onto the rope".

3. The lecturer may continue to be asking the following question: what is the magnitude of the force (if present)? The students may answer the following (alternatives): it is the same, it is different, there is no force, etc. To accommodate the "no force" answer, the students are asked to state what they feel when pulling the rope. The lecturer, in this case, may use a cognitive conflict. In asking questions, the lecturer must make sure that the students are aware of the presence of the force placed on the rope and themselves.

4. When it is determined that the force is the same, the lecturer asks: "Why are they are same? (common answer based on NTL). Could you show that they are the same/different?"

5. Introduce the position variable restoring the force concept of a spring or Hooke's Law. Show that from the formula: $F = -k\ \Delta x$ or $F \infty \Delta x$. Have the students demonstrate that Δx directly represents a measure of F (Figure B). Measure the spring length (e.g., x_0).

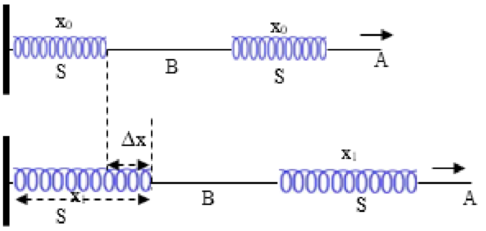

Figure B. Description of Changes in Springs

6. Take another piece rope and tie it to both springs. Spring-1 (S1) represents the 'action' force placed on the wall and S2 represents the 'reaction' to rope (Figure C).

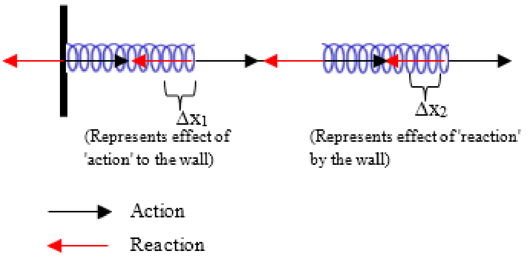

Figure C. Description of an Action-reaction Force Pair

7. Have the students demonstrate that pulling the wall (spring S1) by pulling Rope A reflects an 'action' directed at the wall. Our attention must focus on S1. When Rope A is pulled, ask the students to notice the change in the length of S1. What happens to another spring (S2) or the length of S2? To have the students determine the magnitude of Δx, measure the last spring's length (x_1) and ask them to compare the approximate change in length of both springs ($\Delta x = x_1 - x_0$).

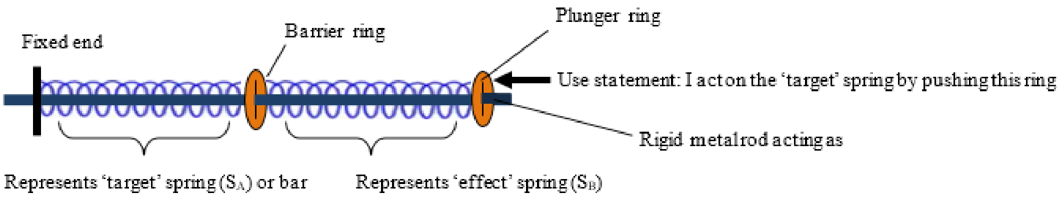

Figure D. Description of Springs Used for a Pushing Force

8. When they find similarities in the changes in spring lengths, continue to the next phase. Introduce the terms 'action force' and 'reaction force'. (The students should understand the pairs of forces by using a diagram such as a diagram below).

c. Phase-3: Demonstrating the Continuous Force-Pushing

1. Arrange two springs as shown in figure 5.
2. Negotiate the springs' status. The first is a 'target' spring and the other is an 'effect' spring.
3. Push the plunger ring (slowly and continuously) (figure 6) and ask the students to look at the 'target' spring. State: "I am applying a force to the target spring (S_A)." Hold the plunger ring to form an 'effect' spring (S_B). Ask the students to notice the change in S_A's length. What happens to the 'effect' spring (S_B)? Ask the students to identify similarities or differences (when present) in the latter spring's length.

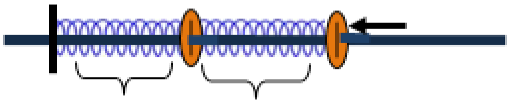

Figure E. Description of the Action-reaction Force Pair

4. Ensure that all students recognize the presence of the pair of action-reaction forces acting on the case.

d. Phase-4: Impulsive Force-Collision

1. Arrange the apparatus as schematically shown in Figure F. Ask the students to predict the change in the springs. Hold Mass A at rest. Push Mass B to the left and then release the force. In this case, we have $m_A = m_B$ and $v_A = 0$ and $v_B = v$ (assumed). Observe the change in S_A's length during the collision. Ask the students to look at S_B. Ask them to compare changes in the lengths of S_A and S_B. Have them notice similarities (or differences) in changes in lengths of the springs.
2. Replace Mass B with another larger mass of roughly double that of Mass B. In this case, we have $m_B > m_A$ and $v_A = 0$ and $v_B = v$.
3. Repeat the procedure illustrated in Point 1.
4. Exchange the positioning of Mass A and Mass B ('target' and 'effect'). Repeat the procedure listed in Point 1 ($m_A > m_B$ and $v_A = 0$ and $v_B = v$).

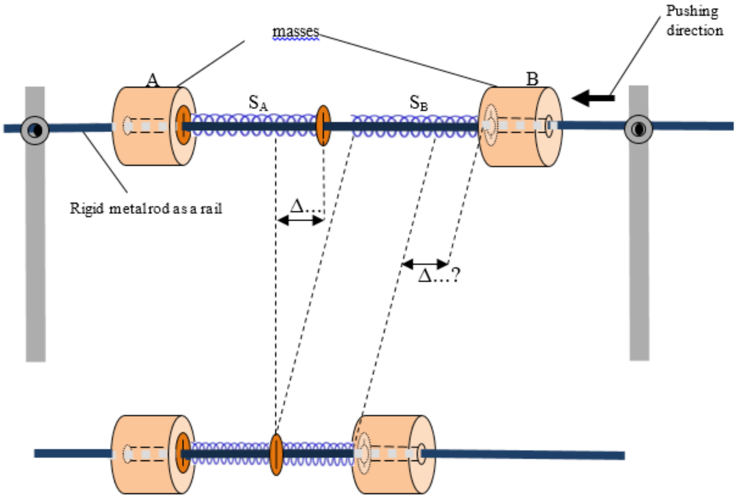

Figure F. Construction of the Two-object Collision Rail

5. Repeat the procedure illustrated above for the other cases and tabulate the data (Table A) based on the observations made.

6. Have the students review the last column of Table 1. Conclude the data by focusing on tendencies (not accurate) observed from the rows.

Table A. The Change in the Spring Length Observed from Each Case

No	Case		Changes of spring lengths
	Mass	**Velocity**	
1	$m_B = m_A$	$v_A = 0$ and $v_B = v$	Δx_A .... Δx_B
2	$m_B > m_A$	$v_A = 0$ and $v_B = v$	Δx_A .... Δx_B
3	$m_A > m_B$	$v_A = v$ and $v_B = 0$	Δx_A .... Δx_B
4	$m_A = m_B$	$v_A = v$ and $v_B = v$	Δx_A .... Δx_B
5	$m_A > m_B$	$v_A = v$ and $v_B = v$	Δx_A .... Δx_B
6	$m_A = m_B$	$v_A > v_B$	Δx_A .... Δx_B
7	$m_A > m_B$	$v_A > v_B$	Δx_A .... Δx_B

Ask the students to consider the terms: 'action' and 'reaction.' Remind them that ΔxA represents the action force (for a target) and ΔxB denotes the reaction force (for an effect).

7. Have the students relate their conclusions to the activities of Phase-2 and Phase-3.

8. Conclude the role of NTL for not only a continuous force but also an impulsive force.

9. Discuss arguments raised in Phase-1.

10. Extend the discussion to other iterations of the impulsive force (e.g., an apple falling to the ground, a hammer striking a nail, a bird crashing into a window, a large magnet exerting a force on a smaller magnet, etc.).

By this phase, it is sufficient to alter the students' views related to our and others' research findings. To determine why the action force is equal to the reaction force and how this can be explained, we may continue to Elby's Pair.

e. Phase-5: Refining with Elby's Pair

Elby's pair is illustrated in Figure G.

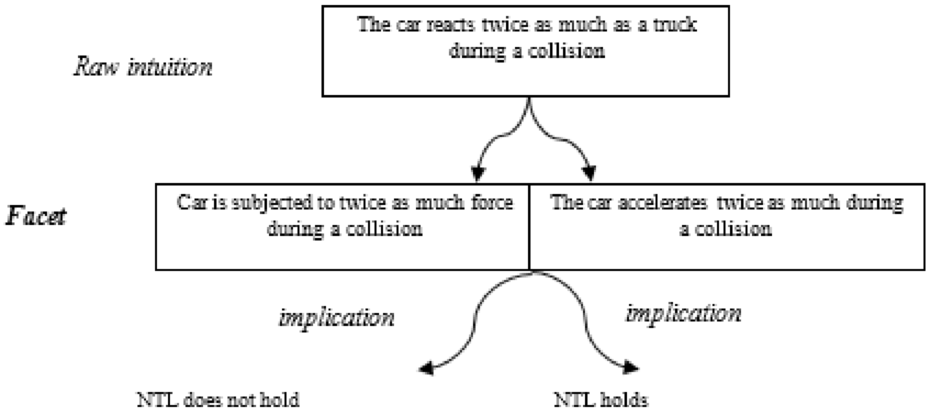

Figure G. Two Possible Outcomes (Facets) Related to NTL and Its Implications.

1. Discuss the collision case of Phase-4 or introduce a case from the case illustrated in Figure F.
2. Consider the raw intuition derived from Phase-1 and compare it to the raw intuition illustrated in Figure G.
3. Discuss the two possible lines of reasoning and their implications.
4. Encourage the students to consider the results of the demonstration illustrated in Phase-4.
5. Draw a conclusion based on a discussion of the two lines of reasoning and of their implications.