Transfer Of Argumentation Skills In Conceptual Physics Problem Solving

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Abstract. We investigate the integration of argumentation in a physics course for future elementary teachers. Students were divided into two groups – construct and evaluate – to solve conceptual physics problems using corresponding forms of written argumentation. After training in small teams, each group received tasks that required transfer of skills to new problems requiring a different form of argumentation i.e. students trained to construct arguments were now required to evaluate arguments and vice versa. The process was repeated after three weeks during which more training was provided. Results indicate no significant improvement of argumentation on team training tasks over this period, but a statistically significant improvement on individual transfer tasks. Thus, three weeks of training did not improve students' performance on the team tasks, but it prepared them to \transfer these skills to individual argumentation tasks.

Keywords: argumentation, transfer of learning, physics, problem solving.
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INTRODUCTION

Argumentation is a key skill used to logically make decisions and solve problems [1-4]. An emphasis on argumentation is consistent with the goal of improving students' scientific reasoning and proficiency in advancing, critiquing and justifying claims [5]. Bing and Redish [6, 7] investigated the claims and warrants that students used while arguing in a group about physics problems using mathematics. However, there have been no studies regarding argumentation on conceptual physics problems requiring qualitative reasoning rather than mathematical computation.

We investigate argumentation skills of students in a conceptual physics class for pre-service elementary teachers. Students received training and feedback on how to construct and evaluate arguments. On the exam, they were required to transfer their argumentation skills to problems that were different in terms of both the underlying physics concepts as well as the kind of argumentation needed. Further, they were also expected to transfer their skills from a team task to an individual task. We address the following research questions in this study.

1) To what extent can students trained to construct (evaluate) arguments transfer skills to tasks requiring them to evaluate (construct) arguments? How does transfer compare between these two conditions?

2) To what extent can students transfer their argumentation skills from a team (construct or evaluate) task to an individual (evaluate or construct) task?

3) How do students' argumentation skills on training and transfer problems change over time?

THEORETICAL BACKGROUND

Two areas of theory are relevant to this study: scientific argumentation and transfer of learning.

Argumentation

Argumentation is the process of making a claim and providing justifications for the claim using evidence [4]. Toulmin's argumentation pattern enumerates the elements of an argument: claim, data, warrants, backing, and rebuttals [8]. Claims are conclusions or assertions, data are facts that provide foundation to the claim, warrants are the proposed reasons (e.g. rules or principles) that connect the data and claim, backings are assumptions to justify the warrant, qualifiers are conditions when a claim is true, and rebuttals are conditions when it is not true [1].

There are two forms of written argumentation – construction and evaluation of arguments [9]. Successful argumentation requires a problem solver to develop a solution, support the solution with evidence, and consider alternatives [4, 9]. Students have difficulty constructing or evaluating arguments [10]. Specifically, they have difficulty writing arguments, citing evidence, and evaluating and rebutting counter-arguments [11, 12]. They need to be prompted to construct arguments to justify their solutions [13].

Transfer of Learning

Vertical transfer of learning occurs when a learner abstracts knowledge or skills in a learning context and reconstructs them in a new transfer context [14]. It requires learners to adapt their expertise to a new situation. This transfer paradigm is relevant as we investigate whether learners trained in teams on one type of argumentation skill can transfer their argumentation skills to a problem requiring a different kind of argumentation skill. The first problem that learners solve in a team using one type of argument skill is the training problem. The second, that they solve individually using a different kind of argument skill is the transfer problem.

Another aspect of transfer of learning relevant to this study pertains to how learners transfer skills from a team task to an individual task. Olivera and Straus [15] investigated effects of group collaboration on individual learning. They tested the hypothesis that group tasks facilitate transfer of learning to individuals task. Students first completed tasks either individually, in groups, or individually while observing a group. After that all participants completed an individual transfer task. Results seemed to indicate that participants in the group condition or observing group condition outperformed the participants in the individual condition on the transfer task. Olivera and Straus [15] adapted the theoretical framework of O'Donnell and Kelly [16] who take into account both cognitive perspectives (such as Piaget and Vygotsky) and socio-cultural perspectives. The latter includes motivation toward group goals [17] and social-cohesion [18]

METHODOLOGY

Students (N = 107) enrolled in a conceptual physics course for pre-service elementary teachers participated in this study. They received no prior instruction on argumentation before this study and they had taken no prior course on argumentation.

Argumentation Training & Practice

Starting week three, students received 40 minutes of instruction via a lecture in class describing the criteria for a good argument, which has proved to be successful in promoting students' argumentation skills [19]. Then we randomly divided them into two groups to practice argumentation on conceptual problems in teams of two or three. 'Construct' and 'evaluate' groups received written prompts for each problem task (Table 1) by Manson & Scirica [20] and Jonassen [9] respectively. In the next class period, students received written solutions and argumentation strategies [19]. The There were no other differences between the control and evaluate conditions.

TABLE 1. Training prompts to scaffold argumentation

Construct Prompts	Evaluate Prompts
What is your answer? Construct an argument to justify it. Remember to consider: • What evidence supports your answer? • One of your classmates may disagree with you. What might their alternative be? • What reasons would your classmate provide to support their conclusion? • What would you reply to your classmate to explain your position is right?	Which statement do you agree with? Or do you have another answer? Explain your solution. Remember to consider: • What evidence supports your selection? • Explain your reasons for not choosing the alternative. • How might a classmate supporting the other solution disagree with your preferred solution? • What would you reply to your classmate to explain your position is right?

Data Collection

On each test students in the construct and evaluate groups participated in both team and individual tasks each, with two conceptual problems. Examples are shown in Fig. 1. We collected students' written solutions to the problems on each test.

Construct: Two kids that you are babysitting are playing with spring loaded toy cars that can bounce off each other. Ryan picks up a truck and Sam picks up a car that is lighter than the truck. They push them against each other in the center of the living room on the wooden floor ready to let go. Before they do that, you ask: "Which one will get to the reach the wall on their side faster?

Evaluate: Two kids that you are babysitting are playing with spring loaded toy cars that can bounce off each other. Ryan picks up a truck and Sam picks up a car that is lighter than the truck. They push them against each other in the center of the living room on the wooden floor ready to let go. Before they do that, you ask: "Which one will get to the reach the wall on their side faster?"
Ryan: "They will get there at the same time, we are starting from the middle of the room and the walls are equally far, so it will take the same time to get to the wall on either side."
Sam: "Not quite! Your truck is slower than my lighter car, so my car will get to the wall much sooner than your truck."

FIGURE 1. Examples of construct and evaluate tasks.

Table 2 shows the format for each test and Fig.2 shows the design of the complete study. In the training and feedback session, students collaborated in teams, but wrote their own solutions. The team tasks on tests used the same format as the training including the prompts, but without verbal feedback. The individual tasks on the tests had the same level of difficulty as the team task. They required vertical transfer from the team tasks because we provided no prompts and the tasks required different argumentation skills. After Test 1, over the next three weeks, the class covered new topics, and another training session before Test 2.

TABLE 2. Format for the Tests

Task (2 problems) (Duration)	Construct Group	Evaluate Group
Team Task (20 minutes)	Construct Task with prompts	Evaluate Task with prompts
Individual Task (15 minutes)	Evaluate Task no prompts	Construct Task no prompts

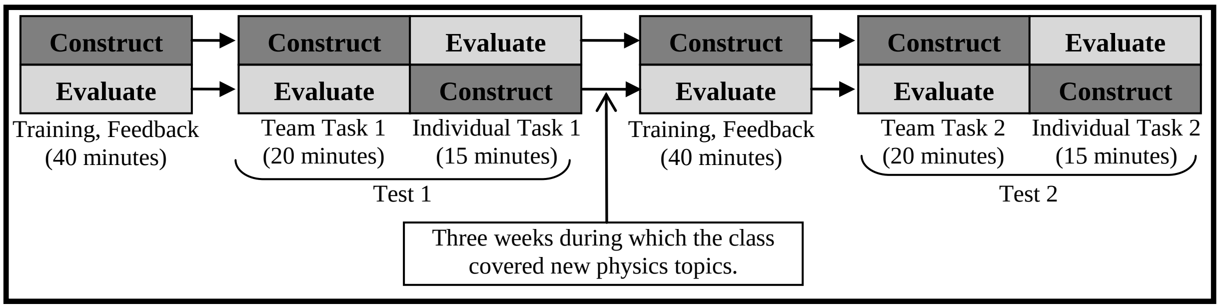

FIGURE 2. Design of the complete study.

DATA ANALYSIS

Students' solutions to each test problem were coded using a rubric adapted from Sadler and Fowler's [21] based on Toulmin [8]. Our adaptation of this rubric (Table 3) accounted for both scientific correctness and grounds for justification, counter-position and rebuttal, with a maximum score of 8 points. Inter-rater reliability was 100% after discussion between two raters

TABLE 3. Scoring rubric for conceptual test problems

Scientific Correctness	Grounds Provided
0-Incorrect, with no justification	1-No grounds
1- Incorrect with justification	2- Single grounds
2-Correct, with no justification	3-Multiple grounds
3-Correct, with justification	4-Single/Multiple grounds, with counter-position
	5-Single/Multiple grounds, with counter-position and rebuttal

For research question 1 we completed a within subjects analysis using a paired t-test to compare team and individual task performance for each group. For research question 2, we completed a between subjects analysis using a two-sample t-test (assuming unequal variances) for each task for the two treatments. Finally, for research question 3, we completed repeated measures ANOVA to compare performance between tests.

RESULTS & DISCUSSION

A within subject analysis of the data (see Table 4) for Test 1 showed a significant decline in means scores from the team task to the individual task for both the construct ($t(46) = 6.25$, $p = 0.000$) and the evaluate group ($t(57) = 9.44$, $p = 0.000$). We found no significant difference in scores of the team task versus the individual task for either group on Test 2.

TABLE 4. Mean ± S.D. on each task for both groups

Test	Group	Team Task	Individual Task
Test 1	Construct	12.28 ± 2.80	8.72 ± 3.50
	Evaluate	12.10 ± 2.55	7.74 ± 4.24
Test 2	Construct	12.28 ± 1.68	12.23 ± 3.14
	Evaluate	11.76 ± 1.65	11.53 ± 2.63

A between subjects analysis using a two-sample t-test showed no significant difference between the two groups either on the team task or on the individual transfer task for either Test 1 or Test 2.

The repeated measures ANOVA showed no statistically significant improvement from Test 1 to Test 2 on the team task [Wilks' $\Lambda = .996$, $F(1, 103) = .395$, $p = .531$]. However, we observed a statistically significant improvement on the individual task from Test 1 to Test 2 [Wilks' $\Lambda = .557$, $F(1, 103) = 81.83$, $p < 0.001$].

A repeated measures ANOVA with a Greenhouse-Geisser correction determined that mean scores differed statistically significantly between tests [$F(1, 103) = 81.83$, $p < 0.001$]. The between groups test indicated that treatment effect is not significant on the individual task from Test 1 to Test 2 [F(1, 103) = 2.41, p = 0.124]. There was no significant test-treatment interaction on either of the tasks.

CONCLUSION & IMPLICATIONS

The study began with only 40 minutes of training on argumentation prior to Test 1. Students' argumentation performance on the individual transfer task on Test 1 was significantly worse than their performance on the team training task for both the construct and evaluate group. Thus, we conclude that students in both groups were unable to transfer their argumentations skills from the training task (team) to the transfer task (individual) on Test 1. .

On Test 2 we found no significant difference between students' performance on the team and individual tasks for either the construct group or the evaluate group. Thus, we conclude that students in both groups were successfully able to transfer their argumentation skills from the training task (team) to the transfer task (individual) on Test 2.

Another interesting result in our study is that we found no significant differences between the two -- construct and evaluate -- conditions either on the training (team) task or on the individual (transfer) task, on either Test 1 or Test 2. Thus, we conclude that training students to construct an argument would prepare them to evaluate an argument on a physics problem as well as the converse. The implications are that both kinds of training are equally successful in preparing students to apply their skills to problems requiring different kinds of arguments, including those that we had not previously trained them on. An alternative explanation for these results is that after taking Test 1, students got accustom to the format of the test. They anticipated the team and individual task components and therefore improved their performance on Test 2.

Finally, we found an improvement on scores from Test 1 to Test 2 on the individual task, but not on the team task. We can perhaps attribute this result to a ceiling effect. Students had already scored around 12 of 16 points on the team tasks on Test 1, not leaving much room for improvement. Even though students did not improve their team task performance on Test 2 relative to Test 1, they were able to transfer their from team to the individual tasks on Test 2 more successfully than on Test 1. It appears that training on argumentation between the two tests may have prepared them to learn to transfer these skills from the team to the individual task on Test 2. Thus, the training provided between the two tests did not improve students' performance on the team tasks, but it prepared them to learn from their team tasks and transfer these skills to their argumentation tasks.

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