Explanatory Activity with a Partner Promotes Children's Learning from Multiple Solution Methods

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Abstract: This study examined how explanatory activities prepare children to learn from multiple solution methods to mathematics problems. We conducted an experiment involving 124 fifth-grade students using a 2 × 2 comparison design (Factor 1: *self-explanation* versus *collaborative explanation*; Factor 2: *a formal solution method only* versus *informal and formal methods*). The results showed that the condition under which paired children were presented informal and formal methods and were required to explain why each method would solve the problem was most effective for promoting learning from multiple solutions.

Introduction

To clarify easy and effective ways to introduce CSCL into ordinary classes, we examined whether and how paired student discussions promote their understanding of others' solutions presented to the class. In Japanese mathematics class, students work on a task for the day, present multiple solution methods, and engage in discussion to build a consensus on which method is good and why. In this case, not only formal but also informal methods can be presented. We often observe that the informal methods are incomplete, yet intuitively appealing enough to provoke heated discussion. Yet, it is unclear how to design and foster such heated discussions. For example, whole-class discussion immediately after the presentation of multiple methods is the most popular way. However, this intervention method does not allow students, except for the academically successful children, sufficient time to understand each method, often leading teachers to just state which method is the formal one without discussing its validity. CSCL research tells us that self-explanation (Chi *et al*., 1994) and collaborative explanation (Miyake *et al*., 2007) are promising approaches to examining informal and formal methods. Yet, such explanations are often applied to normative worked-out examples, text, or lectures which do not include obscure content. Thus, we do not yet know whether these methods work for other content. Therefore, we conducted a 2 × 2 comparison, with *self-explanation* versus *explanation in pairs* of two problem-solving approaches, *a formal solution method only* versus *informal and formal methods*, to determine whether explanatory activities promote learning of multiple solutions and how this is achieved.

Methods

The participants were 124 children from four fifth-grade classrooms in Japanese public elementary schools. The subject matter was density as an example of intensive quantities. The participants had received no instruction for comparing intensive quantities prior to the experiment.

Four classes were randomly assigned to one of four intervention conditions. The conditions were varied in terms of the kinds of solution methods presented to the children by video clips and the activities required of them after watching the video clips. Children under the IF-pair condition watched both informal and formal methods with a partner and then explained why each method would solve the problem. Children under the FF-pair condition watched two versions of the formal method with a partner and then explained why each method would solve the problem. Children under the IF-solo and the FF-solo conditions performed the same procedures except they did them alone. With this experimental design, we aimed to replicate in a controlled setting a natural situation in which students present informal and formal solutions and reflect upon them. All children completed the pretest and post-test, which consisted of density-comparison problems, before and after the intervention. For example, the children were asked to compare the density of a flowerbed that had an area of 5 m^2 and 25 flowers with that of a flowerbed that had an area of 7 m^2 and 28 flowers. The problem can be solved by calculating the unit values (the number of flowers per square meter) for the flowerbeds and comparing those values to identify which flowerbed is more dense (unit strategy; Fig. 1a). However, children often use an informal strategy to solve this kind of problem, i.e., they calculate the difference within each dimension and compare these two values (subtraction strategy; Fig. 1b).

All problems were presented in the form of worksheets. The children were asked to decide which flowerbed was denser and to justify their conclusion using algorithmic and/or diagrammatic explanations. In the post-test, children were also required to solve a transfer problem to assess their understanding of equal distribution. In the transfer problem, they were asked to judge whether a worked-out example of a density comparison problem (7 flowers /3 m^2 vs. 10 flowers /5 m^2) was correct. In the worked-out example, a hypothetical child drew the diagram shown in Fig. 2 and chose the second flowerbed as more dense by comparing the number of flowers in the far left, 1-m^2 area. This is an incorrect answer based on a misunderstanding of unit strategy. We calculated the number of children who answered that this solution was wrong with an explanation of the need for equal distribution.

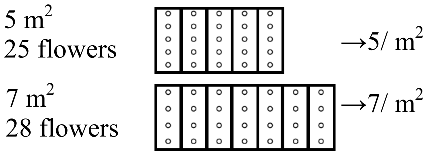

Figure 1a. The Unit Strategy.

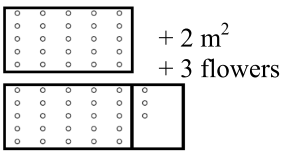

Figure 1b. The Subtraction Strategy.

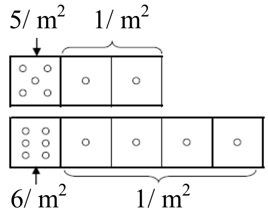

Figure 2. The Transfer Problem.

The procedures were the following. The children were asked to solve one density comparison problem, which they had not learned (pretest). Then, they watched two types of video clips wherein other children explained their solution methods. After watching each clip, the children were given 7 minutes to explain why the methods would solve the problem on a worksheet using the panels presented in Fig. 1 (explanatory activity). Finally, they were asked to solve a similar density comparison problem again and a transfer problem (post-test).

Results and Discussion

First, results on the post-test showed that IF-pair group provided justification for the formal method at a higher rate than did children under the FF-solo condition (χ^2 (6) = 20.4, p < .01). As shown in Fig. 3, FF-solo group applied the unit strategy formula without explaining it (white-colored portion), whereas children under other conditions applied this strategy and accompanied it with an explanation of its meaning (black-colored portion). The conditions that fostered such explanation included at least either the presentation of multiple solutions or collaborative explanatory activities, the former of which enriched variety in solution types and the latter of which fostered alternative viewpoints on solutions. Furthermore, results on the transfer problem showed that IF-pair group rejected the incorrect solution method and detected the deficit in that method at a significantly higher rate of 30.8% than the other groups (χ^2 (3) = 8.15, p < .05; FF-pair: 4.4%, IF-solo: 12.9%, FF-solo: 9.7%). Thus, both experiencing and discussing multiple methods with a partner was necessary for improved performance on the transfer task. The overall results indicated that a collaborative discussion of multiple solutions increased the conceptual understanding of the unit strategy. Finally, we examined the conversation of the IF-pairs as they were explaining the formal method. We found that, when at least one member of the pair completed the transfer problem correctly, they were more likely to refer to equal distribution than were the other pairs in their conversations (t (8) = 1.94, p < .05). This result suggests that they interpreted the subtraction strategy based on the principle "the more space there is available, the less dense it is" and applied this principle to explaining the unit strategy. Thus, they understood that the difference in the space per 1 m^2 was consistent across all 1-m^2 units.

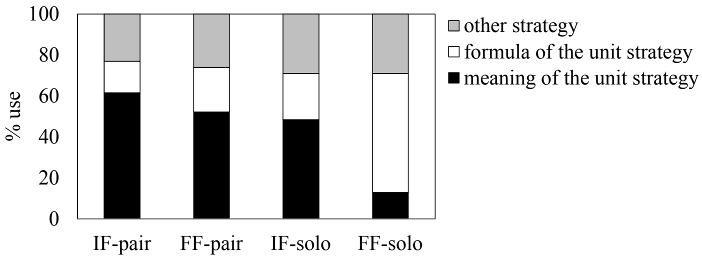

Figure 3. Percentage of Children Who Applied Each Strategy by Condition.

These findings imply that constructing explanations collaboratively requires that children make others' informal method comprehensible and coherent by seeking some rationale, that they make sense of the formal method in the light of that rationale to differentiate the core unit of the solution procedure from its irrelevant units, and that they appreciate the essence of the formal method. Although it may be unusual to ask children to explain both informal and formal methods presented by others, such an opportunity could help them develop their own understanding while distinguishing the components of each method. This might be an important process of learning from multiple solution methods. Yet, this result might be due to our deliberate selection of the "informal method." Much work needs to be done to increase the generalizability of the results.

References

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