Process Gain: A Task on Which Real Groups Outperformed Individuals Modeled Under Perfect-Knowledge-Sharing Assumptions

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An experiment with university students examined effects of two versions of a statistics task on individual versus group learning. Using a novel measure of transfer, groups were found to outperform, on average, individuals modeled as groups under perfect-knowledge-sharing assumptions. To my knowledge, this is the first result of its kind, and it suggests a characterization of naturally productive collaborative tasks.

Process loss occurs when a group performs worse than their capability due to a member with the correct answer being silent or ignored by the other group members (Steiner, 1972). The idea is that something in the group process must have caused the group not to recognize and take up the correct answer even though it was available to them. This is a pattern frequently noted in small group interactions (e.g. Barron, 2003), and it continues to be a concern of educators and researchers looking to implement effective collaborative learning activities.

If groups performed up to their potential, then ideally, every member within a group would perform at least as well as the best member of their group. One way that this could occur is if the students in a group selected the top performer in their group to do every problem and explain the answers until everyone in the group understood them. I am not suggesting this is an ideal form of cooperation; far from it. Instead, it seems like an important and attainable benchmark. Currently, most-competent-member levels of performance are rare and noteworthy (e.g. Laughlin, Zander, Knievel, & Tan, 2003).

Even top performers are wrong sometimes, so their performance can be surpassed. If every member of a group shared their knowledge perfectly with one another, and they could all recognize a correct solution when they saw it, then they would outperform or at least equal the top individual. This hypothetical scenario reflects what should happen under perfect-knowledge-sharing, and it is known as the *truth-wins* scenario. Unlike the most-competent-member model, whenever *any* individual in the group has the correct answer, it is assumed that the whole group will take up that answer. Ideally, collaborative activities would naturally promote perfect-knowledge-sharing amongst group members such that truth-wins levels of performance were achieved.

Of course, we would like groups to be able to construct new understanding by building upon each member's insights and incomplete conceptualizations. This achievement is known as process gain because something in the group interaction leads students to a new understanding that no individual had before working together. When process gain occurs, it is possible for groups to exceed even truth-wins levels of performance. Such results have been obtained in group performance tasks. For example, Schwartz (1995) found that dyads were more likely to make a conceptual shift on a gear modeling performance task than individuals modeled under truth-wins assumptions. On learning tasks, case studies have shown instances of building insight and knowledge construction between group members (Yackel, Cobb, & Wood, 1991); however, to my knowledge no study has shown a task on which the average group member exceeded truth-wins levels of performance.

Finding and characterizing a type of learning task that naturally yielded process gain could be theoretically and educationally significant. According to recent survey results, despite many teachers knowing of means of structuring productive collaborations, they often do not implement them because they are already so busy (Antil, Jenkins, Wayne, & Vadasy, 1998). Below is a study of a statistics task for college students designed on the innovation and efficiency framework of Schwartz, Bransford, and Sears (2005). It was hypothesized that tasks with an opportunity for innovation followed by efficient instruction might yield naturally productive interactions and, thereby, process gain.

Methods

Participants—Seventy-six university students with little or no background in statistics were randomly assigned to one of two conditions: Innovation or Efficiency. Participants either worked alone (40) or in same-sex pairs (36). Forty-eight women (24 in dyads) and 28 men (12 in dyads) participated.

Materials—A nine-page learning packet about the chi-square formula and a seven-item posttest made up the materials for this experiment. The learning packet consisted of three units about different aspects of the chi-square formula. Each unit contained three pages: a Lesson page, a Problems page, and a Final Practice Example page with answers provided at the bottom of the page. For Innovation, the sequence of pages for each unit was: 1) Problems, 2) Lesson, and 3) Final Practice Example. For Efficiency, the sequence was: 1) Lesson, 2) Problems, and 3) Final Practice Example. In other words, Innovation had to try to figure out a formula before getting the canonical solution while Efficiency received the formula and had a chance to apply it.

A key feature of these materials was that the Problems pages had contrasting cases designed to highlight key features of the formula(s). For example, if students did not divide by the expected value for the problems in the first unit, then two of the three contrasting cases would yield the same value. Not many students would spontaneously realize the need to divide by the expected value, but when they were shown to do so in the lesson, they should recognize its importance. It was expected that participants in the Innovation condition would be more likely to notice and learn from these contrasts than those in the Efficiency condition.

Time participants spent on the learning packet and time on the posttest was recorded. The posttest consisted of seven problems of three types. Two problems required calculations of the chi-square formula, three involved comprehension questions about where and how the formula works, and two involved a difficult transfer to the related statistics topic of inter-rater reliability. An important feature of these far transfer measures was that they were designed in PFL fashion (Bransford & Schwartz, 1999; Schwartz & Martin, 2004). The first problem introduced the new type of problem while the second provided a more difficult case in which those same principles applied. The PFL idea is that only participants who were prepared to learn from the first problem, the resource problem, would be able to answer the second one, the target problem, correctly. This approach allows one to estimate what kinds of instruction are better at preparing students for future learning.

Procedures—Table 2 summarizes the procedures. To keep participants from blurring the distinction between conditions, they were told to complete each page in the packet before going to the next page and to look back only if necessary (such as to recall the formula). The experimenter instructed participants to spend 25 minutes on the posttest, that it was difficult, to try their best, and to work alone. Some participants finished early, and none took longer than 30 minutes. No significant differences between conditions were found on time taken for the learning packet or the posttest.

Table 2: Procedures

<table>
<tr><th>Step</th><th>Context</th><th>Innovation</th><th>Efficiency</th><th>Time</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Alone / Dyads</td><td colspan="2">9-page Learning Packet on the Chi-Square Formula</td><td rowspan="2">35 to 65 min.</td></tr>
<tr><td>1) Problems (invent)
2) Lesson (instruction)
3) Final Example (reinforce)</td><td>1) Lesson (instruction)
2) Problems (apply)
3) Final Example (reinforce)</td></tr>
<tr><td></td><td></td><td colspan="2">Short Break</td><td>~5 min.</td></tr>
<tr><td>2</td><td>Alone</td><td colspan="2">Posttest (done individually)
(7 problems: 2 calculations, 3 comprehension, 2 far transfer)</td><td>25 min.</td></tr>
</table>

Results

Each of the seven problems on the posttest had multiple components that could receive points. For example, did the participant divide by the expected value? Did they calculate the expected value and the chi-square formula correctly? Did they show negative transfer by applying the chi-square formula blindly where it did not belong? The coding scheme showed high inter-rater reliability (93% agreement, minimum agreement of 80% on any item, Cohen's Kappas above 0.81 for each type of question: calculation, comprehension, and far-transfer). The reliability of the test was also high (alpha = .81).

As expected, participants in the Innovation condition outperformed those in the Efficiency condition on the far transfer problems while performing similarly on the calculation and comprehension problems, as shown in Figure 2. Some may argue that the better performance of the Innovation condition on the transfer problems was simply due to "greater messing around." The data suggest otherwise. Innovation participants made fewer negative transfer errors than their Efficiency counterparts ($\chi(1) = 5.40$, $p = .020$). In other words, they were better at adapting their knowledge to solve novel problems, and they better understood when the chi-square formula did *not* apply. Perhaps most importantly, on the preparation for future learning (PFL) measure the Innovation condition not only outperformed the Efficiency condition, the Innovation dyads outperformed their individual peers—both on average, and under truth-wins assumptions. These results are shown in Figure 3 where Innovation "nominal" dyads' and Efficiency "nominal" dyads' scores were calculated based on the performance of the individuals from the Innovation and Efficiency conditions, respectively. Those interested in how the truth-wins calculation was performed can contact the author.

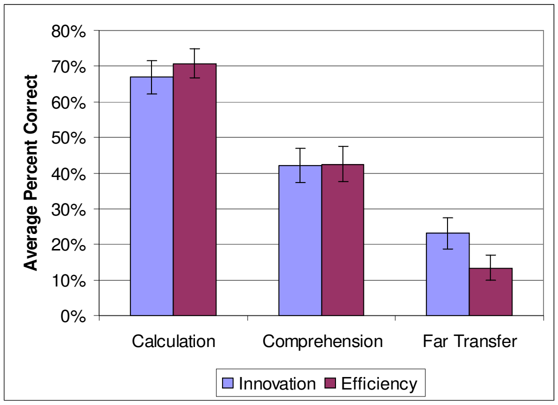

Figure 2. Performance under Innovation versus Efficiency learning conditions on learning and transfer measures.

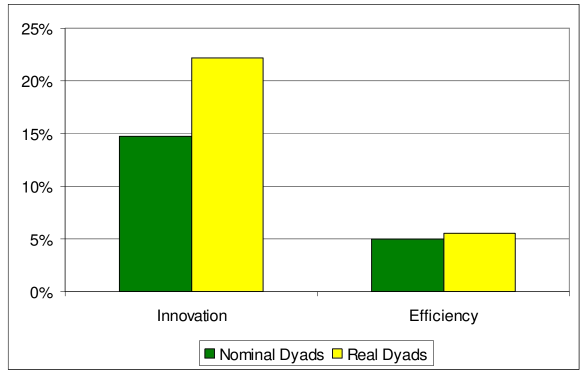

Figure 3. On the target question, real Innovation dyads exceeded all others.

Conclusion

In the field of collaborative learning, many important discoveries have been made about effective methods for obtaining educational benefits from group work. Teachers often do not implement some of the research-based structures for making collaborative activity effective (Antil et al., 1998). This study took an alternative approach, examining what types of tasks might naturally support productive collaboration. Using the innovation and efficiency framework of Schwartz et al. (2005), two versions of a statistics task for college students were developed. The efficiency version followed traditional lesson-then-practice methods while the innovation version included an opportunity for inventing solutions to contrasting cases prior to receiving the lesson. The innovation condition significantly outperformed the efficiency condition on far-transfer problems, and innovation dyads exceeded the performance of their individual peers modeled as dyads under perfect-knowledge-sharing assumptions.

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