Small-Group Discussion in Physics: Peer Interaction Modes in Pairs and Fours

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Abstract

The importance of group discussion in facilitating learning in science is widely acknowledged. At the same time, it is recognized that in the social context of small groups, peers' discussion processes and their subsequent learning are influenced by factors other than students' conceptual understanding. Focusing on the social processes of knowledge construction in group settings, this article investigates the ways Greek secondary school students interacted in pairs and fours while discussing and attempting to explain simple physical phenomena. The study showed that students progressed significantly more in their physics reasoning after participation in fours than pairs. Moreover, the analysis of discourse in the different groupings suggested that the differences in progress were related to the more constrained modes of interaction of pairs.

While the importance of the role of discussion in learning is widely acknowledged, the function that it serves is interpreted within a number of theoretical perspectives. The Piagetian perspective, for example, emphasizes the personal construction of knowledge through the interaction between the individual's knowledge schemes and his or her experience of the environment. From this perspective, the focus is on the psychological process of equilibration. Talk with other people is seen as aiding the process by, for example, helping to create cognitive dissonance. On the other hand, Vygotsky's writings emphasize the construction of knowledge as a social process and stress the fundamental role of language and discourse in shaping meanings. Central to this perspective is that through joint actions and communication with others, children internalize practices and discourse features and transform them to tools of conscious control. Thus, because children's meanings are seen as mainly socially derived, talk with adults or more capable peers is considered to be the basis for any subsequent learning.

In relation to learning in science, it is now accepted that scientific theories and explanations cannot be discovered through personal interaction with phenomena, and talk with both peers and teachers is at the center of children's conceptual understanding (e.g., Driver, 1989; Sutton, 1992). Studies that focus specifically on the construction of knowledge in science classrooms through teacher—pupil and pupil—pupil discourse provide evidence for seeing learning in general and learning science in particular as a process of enculturation into the meanings of

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specialist discourse (Edwards & Mercer, 1987). The importance of student talk in facilitating learning has been demonstrated by research studies (Howe, Rodgers, & Tolmie, 1990) and has been incorporated in pedagogic practices in development projects in science classrooms (Brook & Driver, 1986). These studies suggest that peer talk offers children the opportunity to construct new ways of understanding through a collaborative negotiation of their meanings.

However, studies focusing on the social processes of knowledge construction in group settings show that peers’ negotiation of meaning about the subject matter is linked to the negotiation of their interaction on the social plane. Thus, students’ attitudes and behaviors depend on a variety of social and contextual factors that operate in school classrooms (Barnes & Todd, 1977; Edwards & Mercer, 1987). Investigating the effects of conflict in small groups with primary school children working on Piagetian tasks, Perret-Clermont, Perret, and Bell (1991) found that children’s willingness to acknowledge and deal with situations that may involve social confrontation depend on their perceptions and interpretations of the purpose and the context of the task and the learning situation. Work by Eichinger, Anderson, Palinscar, and David (1991) with mixed-ability, mixed-gender groupings of 11- to 12-year-old students engaged in science group discussions showed that the students who were already skillful in constructing scientific arguments participated more, and thus got practice and feedback. Moreover, students’ difficulties seemed to arise as much by the conceptual demands of the task as by the lack of commonly understood standards of scientific argumentation and peer collaboration. In addition, studies investigating the social dynamics among peers engaged in science group discussions suggest that the existing group dynamics, based on peer influences and students’ perceptions of their own and other’s abilities, affect individual stances and opinion changes and can sometimes lead peers to regress in their reasoning (e.g. Solomon, 1989; Bivens, 1990).

Evidence of correlations between peers’ within-group behavior (i.e., amount of verbal participation, giving and receiving explanations, etc.) and their subsequent learning is also provided by research that focuses on the effects of different interactive conditions on individual learning (Webb, 1989; Bennett, 1991). These studies show that different types of groupings, in terms of ability levels, gender, and number of the participants, affect group discussion modes as well as individual learning.

However, there is lack of consensus in the peer interaction literature about the optimal size of groups. While some studies suggest that pairs function better because peers cannot withdraw and leave the responsibility of the discussion for others (Webb, 1989), other studies argue for larger groupings (e.g., fours) which give students the opportunity to consider a wider range of ideas, hence reducing the possibility of discussion dying out too soon (Needham, 1987).

With these considerations in mind, an in-depth investigation of secondary school students’ group discussions in physics was undertaken. The aim was, first, to investigate the nature of the processes by which students negotiate their ideas in science while discussing and explaining simple physical phenomena, and, second, to investigate any relationship between group discussion processes and the development of individual students’ physics reasoning (Alexopoulou, 1993). In the social context of small groups, it was thought that the number of group members involved would be likely to influence the ways peers negotiate their meanings. Therefore, pairs and fours were used and peers’ modes of interaction were analyzed with reference to group size and group members’ subsequent progress in physics reasoning (based on test results before and after the discussion).

Data Collection

The students that participated in the study were aged 14 to 15 and came from four state schools sited in different socioeconomic areas of Athens. One mixed-ability class was selected
from each school, and a total of 86 students were involved in the study. The intervention took place in students' own classrooms and the students were aware of the purpose of the research. That is, after we were introduced to the students of each class by their physics teacher, she or he left and we told the students that the research was from the university and had nothing to do with their schools and teachers. We also told them that we were interested in finding out how students of their age were thinking about some everyday science phenomena and how they were discussing them among themselves in groups and, thus, helping each other to understand unclear points about the particular topics.

Groupwork is not a common activity in Greek science classrooms; to a certain extent, students are also not used to an open-ended, exploratory type of science questions. Thus, to make the students feel free to express their own views, we told them that it did not really matter whether they could remember the relevant science lessons because we were interested in what they really believed. In introducing the tasks as requiring common sense rather than scientific reasoning, we wanted to prevent students from giving short, cut-and-dried responses based on memory and not understanding. However, because the research took place within a school science lesson, it was acknowledged that this would frame the way students would respond and they would be likely to use science ideas alongside commonsense ones.

Students were pre- and posttested using six qualitative reasoning questions. The questions were from the concept areas of conductivity, change of state, and free fall and were related to topics that students had already studied in their physics course (Table 1).

The conductivity and change of state questions had been used in a previous study to provide insight into the particular ways students conceptualize a number of everyday science phenomena that involve concepts central to students' physics understanding (Brook, Briggs, Bell, & Driver, 1984). The free-fall questions were devised for the purposes of this study. The specific questions were chosen for a number of reasons. First, the content of the questions was related to the

<table>
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<th>Table 1</th>
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<tr>
<td>Physics questions used in the study</td>
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<table>
<thead>
<tr>
<th>Conductivity</th>
<th>Spoons</th>
<th>The question shows two spoons, a metal and a wooden one, which are in a jug with hot water, and asks whether either of the spoons will feel hotter after awhile, and why.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frosty day</td>
<td>The question shows two spoons, a metal and a plastic one, which are placed outside the window on a frosty day and asks whether either of the spoons will feel colder after awhile, and why.</td>
<td></td>
</tr>
<tr>
<td>Change of state</td>
<td>Potatoes</td>
<td>The question shows two pans with potatoes in boiling water. The gas under one is lowered but the water still keeps boiling. Students are asked whether in either one of them the potatoes will take more time to cook, and why.</td>
</tr>
<tr>
<td>Ice and water</td>
<td>The question shows two pans, one with ice and water at 0°C and the other with just water at 0°C, and asks whether either one of the pans will take more time to come to the boil, and why if heated at the same rate.</td>
<td></td>
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<tr>
<td>Free fall</td>
<td>Balls</td>
<td>The question shows a boy that drops two same-sized balls, a metal and a plastic one, from the same height at the same time and asks whether either of them will reach the ground first, and why.</td>
</tr>
<tr>
<td>Ball and feather</td>
<td>The question shows a girl that drops a tennis ball and a feather from the same height at the same time and asks whether either of them will reach the ground first, and why.</td>
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</table>
students' curriculum. Second, the nature of the questions was important. The relevant literature reports that students, despite instruction, face considerable difficulties in dealing with the particular science concepts (Brook et al., 1984; Gunstone & White, 1981). Moreover, the questions were from more than one physics domain, so as to control for the effect of the content on individual performances and group discussion processes. In addition, the questions required detailed explanations by students, because it was the reasoning behind their predictions that was of interest. Finally, the questions were open-ended; this was fundamental for allowing students to express their own ideas and facilitating peer-group discussion.

After completing the individual pretests, students discussed all six questions in self-selected, single-sex groups of either pairs or fours. Each group was asked to write down, when possible, an agreed response and the supporting reasons. If they were unable to agree, they were asked to write down their different responses as well as their reasoning. Group discussions lasted for about 60 minutes and were audiotaped. Posttesting, involving the readministration of the same questions, took place 2–3 weeks later.

Analysis of Students' Pre- to Posttest Changes in Reasoning

To investigate the effect of group discussion on the development of students' physics reasoning, students' pre- and posttest answers in each one of the six questions were first categorized. Typical responses were identified and placed in a hierarchy in terms of the scientific reasoning content. Table 2 gives an example of the coding categories for one of the questions. Then, for each student, his or her pre- to posttest response to each question was identified as showing progress, regress, or no change. The overall numbers and percentages of students' responses that progressed, regressed, or stayed the same across all questions were determined and students' pre- to posttest performances were analyzed in relation to whether they participated in pairs or fours. Table 3 shows students' pre- to posttest changes in their responses in relation to the type of grouping.

As can be seen in Table 3, students participating in fours progressed slightly more than those in pairs (17.4%–16.7% for fours and pairs, respectively). However, students in fours also regressed considerably less than those in pairs (8.3%–14.9% for fours and pairs, respectively). To test the significance of the differences in students' pre- to posttest changes in reasoning following participation in pairs and fours, individual performances across all the questions were scored and an analysis of variance was undertaken. In each one of the six questions, progress in reasoning was scored +1, regress −1, and no change 0, and individual performances across all the questions were calculated by aggregating for each student his or her change scores in all questions. In this scoring scheme, different types of progress, regress, and no change in students' responses were scored in the same way, although they may involve qualitatively different shifts in reasoning patterns. Table 4 shows students' pre- to posttest gain scores in pairs and fours in the four schools from which the sample was selected.

Figure 1 shows students' pre- to posttest gain scores in relation to group size and school. Students' gain scores in fours were higher than those in pairs in all four classes that participated in the study. The analysis of variance test showed significant differences at the 0.01 level for the performances of students participating in pairs and fours. This suggests that group discussion in fours had helped students to progress in their physics reasoning more than group discussion in pairs.

Analysis of Group Discussions

Having identified significant differences in students' performances following participation in pairs and fours, an in-depth analysis of the ways peers negotiated their ideas during group
Table 2

Coding categories for the potatoes question

Students needed to acknowledge that as long as the water was boiling and until the whole of it had changed to steam, i.e., during the change of state, its temperature would remain constant. Therefore, in both pans the potatoes would cook at the same time. Extra heat input does not make the potatoes cook faster, it just evaporates the water more rapidly.

a. Explanations that include accepted ideas about heat transfer and temperature constancy during the change of state
   a1 Students referred to the heat received and temperature constancy during boiling and implicitly to latent heat, e.g., if I’m right, once the water has started boiling, the temperature in the pan is 100°C and it can’t increase. This means that the potatoes will cook equally fast. Simply, the water in one of the pans will evaporate faster.
   a2 Students referred to the heat received and temperature constancy during boiling but they did not explain what happens to the extra heat, e.g., both pans will cook at the same time because the one where we lowered the heat received, as long as it keeps boiling, it’ll be the same as the one where the heat is left the same because the boiling of the water is at 100°C.
   a3 Students referred only to the temperature constancy during boiling, e.g., in both cases, the potatoes will cook at the same time because, as long as the water is boiling in both pans, the temperature of the water is the same.
   a4 Students just said that changes in the heat received did not matter. A few students were also referring to the fact that the water was boiling, e.g., in both pans, the potatoes will cook at the same time because it doesn’t make any difference how much is the heat received.

b. Explanations in terms of alternative ideas about heat transfer and temperature during the change of state
   b1 Students explained the phenomenon by relating the heat received, the temperature of the water, and the cooking time of the potatoes, e.g., the potatoes will cook faster in the pan where the heat has stayed the same because in the other pan, the temperature will slowly fall and more time will be needed for the potatoes to cook.
   b2 Students explained the phenomenon by relating the heat received to the cooking time of the potatoes, e.g., the more the heat received, the faster the potatoes cook.
   b3 Students confused heat (i.e., heat input or gas mark) and temperature (i.e., the ring’s or the water’s temperature), e.g., it doesn’t make any difference whether the fire is low or high because even if we raise it, the fire remains the same and doesn’t change.
   b4 Students explained the phenomenon in terms of everyday experience (i.e., on high heat the potatoes will be burnt or the water will overflow or evaporate, the potatoes are already cooked as long as the water has started boiling), e.g., the potatoes will cook faster in the pan where the heat received has been lowered because in the other one, where the water will boil all the time at high temperature, the potatoes will cook on the surface. However, in the other pan, the whole of the potatoes will cook.

c. Uncodeable responses
   Responses in this category included cases where no answer was given, cases where the response was unintelligible, and restatements of the text or unique responses that could not be categorized within the above set of categories.

Table 3

Students’ pre- to posttest changes in reasoning in pairs and fours ([n]/%)

<table>
<thead>
<tr>
<th>Student</th>
<th>Total Response</th>
<th>Progress</th>
<th>Regress</th>
<th>No Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Responses Total</td>
<td>No. of Responses Total</td>
<td>No. of Responses Total</td>
<td></td>
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<tr>
<td>In pairs</td>
<td>228</td>
<td>38</td>
<td>16.7%</td>
<td>34</td>
</tr>
<tr>
<td>(n = 38)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In fours</td>
<td>288</td>
<td>50</td>
<td>17.4%</td>
<td>24</td>
</tr>
<tr>
<td>(n = 48)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4

Students' pre- to posttest gain scores in relation to group size and school

<table>
<thead>
<tr>
<th>School</th>
<th>In Pairs</th>
<th>In Fours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.84</td>
<td>2.13</td>
</tr>
<tr>
<td>2</td>
<td>0.00</td>
<td>0.12</td>
</tr>
<tr>
<td>3</td>
<td>-0.63</td>
<td>0.31</td>
</tr>
<tr>
<td>4</td>
<td>-0.23</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Discussion was carried out with a view to relating peers' discussion modes in pairs and fours to the development of students' reasoning patterns. All discussions were transcribed and a sample of 16 was selected for an in-depth analysis of discourse on particular questions. The discussion of each group on each one of the six questions was first identified as progressive, regressive, or mixed. Progressive discussions were taken to be those in which one or more of the group members progressed in their reasoning between the pre- and posttests with the other group member(s) giving the same level of response. Regressive discussions were those in which one or more of the group members regressed in their reasoning between pre- and posttesting. (Mixed discussions, where some group members progressed and some others regressed between pre- and posttesting, were not included in the analysis.) Thus, the selection of discussions for analysis was based on the group members' pre- to posttest changes in physics reasoning and not on changes in reasoning during the discussion. The 16 discussions analyzed were selected to include 4 progressive and 4 regressive discussions in pairs (2 with boys and 2 with girls) and 4 progressive and 4 regressive discussions in fours (2 with boys and 2 with girls).

![Figure 1](image)

*Figure 1.* Students' pre- to posttest gain scores in pairs and fours in relation to school.
Group discussion modes were first analyzed in terms of the frequencies of the types of utterances involved in argument construction and social interaction. Then, a time-dependent analysis of the sequencing of discussions was also undertaken to illuminate how peers' efforts to build an argument interrelated in the process of the discourse.

Two sets of codes were used to classify types of utterances: One set related to argument construction in physics, the other to social interaction. The argument construction coding scheme (i.e., making a prediction, giving a justification, providing evidence for the support of assertions, evaluating, applying a scientific principle, changing opinion) mapped peers' scientific reasoning processes and was an adapted form of Barnes and Todd's (1977) categorization of the logical elements of a reasoned argument. The social interaction coding scheme mapped peers' negotiation of meanings on the social level and was devised for the study by listening to group recordings and reading the discussion transcripts. This scheme included peers' explicit discourse moves (i.e., agreeing, disagreeing, asking questions), which have a social element but are directly related to students' scientific reasoning process. However, by listening to group recordings, it became obvious that the modes of discourse were influenced in different ways by peers' explicit comments as well as their implicit ones (shown in many cases by voice intonation or the other group members' reactions to them). Therefore, utterances were also categorized in terms of the contribution they made to the social dimension of the group activity. The categories included being supportive, aggressive, and showing uncertainty or confusion. The frequencies of the different types of codes for the 16 selected discussions were determined and the patterns of discourse in the 16 selected discussions from progressive and regressive groups were compared for pairs and fours.

Group Discussion Modes in Pairs and Fours

Students' progress or regress in physics reasoning appeared to be related to both the forms of argument construction and types of social interaction of the discussion groups. Argument construction in progressive and regressive discussions differed in the extent to which students considered and evaluated their own and their peers' assertions instead of simply presenting their views. Figure 2 shows the ways peers constructed the argument in 4 progressive pairs (Discussions 1–4) and 4 regressive ones (Discussions 5–8) in terms of peers' use of predictions (ProR), justifications (ProC), questions (Que), and evaluations (Ev).

As can be seen in Figure 2, in progressive discussions, peers tended to question and evaluate each other's suggestions, whereas in regressive ones, peers tended to repeat their own predictions and explanations, which made their discussions move in circles. However, in pairs and fours, peers' modes of interaction on the social level seemed to be different; this influenced the patterns of argumentation that were employed in the groups. The main differences in the social interaction modes of pairs and fours are illustrated in the following sections through a number of dialogue extracts from progressive and regressive group discussions. (The study involved single-sex groups and the findings suggested important gender differences in the ways students discussed their views in small groups [Alexopoulou & Driver, in press]. However, this article focuses only on those differences between pairs' and fours' discussion processes that were irrespective of the gender of the participants—that is, were noticed in both male and female groups.)

Interaction Modes in Pairs

The development of students' physics reasoning through small-group discussion seemed to center on the raising of objections and the negotiation of a different perspective. In the case of
pairs, however, the raising of objections and the process of the negotiation of meanings seemed to depend fundamentally on the group members' preexisting attitudes toward the task as well as toward each other. Students who were willing to be open about their thinking and negotiate their ideas and who also saw group interaction as a collaborative rather than a competitive process seemed more likely to progress in their physics reasoning.

The following extract is from the progressive discussion of a male pair on the potatoes question and illustrates how, by attempting to clarify his thinking, 1 of the 2 boys developed his physics reasoning, although his peer was reluctant to engage in the argument. In the pretest, both students reasoned that despite the different heat input, the potatoes would cook equally fast in both pans because the water keeps boiling in both of them. At this point of the discussion, the idea that puzzles one of the students (M) is what happens to the extra heat under one of the pans.

1 V: In both pans the potatoes will cook equally fast because they have reached 100°C as long as they have already started boiling and, no matter whether we turn down the heat under one of the pans, the 100°C will remain.

2 M: In both pans the potatoes will cook equally fast because, as long as the water in both cases is boiling, the temperature will be 100°C . . . . But what I don't understand, Vasili . . . perhaps you can tell me . . . the rest of the heat . . . where does it go? Do you know perhaps?

[Here, it is the latent heat notion that bothers M.]

3 V: No matter whether it goes over 100°C . . .

4 M: It never goes over 100°C, this is known.

5 V: No matter whether it's 100 or 120 . . .

[V seems to have no notion of temperature constancy during boiling.]

6 M: It never goes to 120 . . . unless, of course, the barometric height perhaps . . . no . . . no . . . I think it goes only up to 100.

7 V: In any case . . . this is another issue about the heat . . .

8 M: No! Where does the rest of the heat go?
SMALL-GROUP DISCUSSION IN PHYSICS

9 V: We go beyond . . . we’ll better answer the question itself. We have both reached the same conclusion which . . . we have already reasoned. Let’s not fight as long as we have reached the same conclusion.

[V tries to avoid argumentation on an issue that he is unclear about and seems to perceive M’s efforts for clarification as a social threat.]

10 M: Wait! Where does the rest of the heat go? Yes, we’ve got a disagreement but you don’t know either!

[after awhile] One possible answer . . . it may go to the environment.

11 V: [Thinking for a while] . . . I also believe so. It evaporates and . . . it goes to the environment . . . not that it evaporates . . . but . . . anyway . . .

12 M: Perhaps . . . perhaps it goes to the environment . . .

13 V: . . . all right . . . I believe we’ve said everything about this issue!

As can be seen here, M’s willingness to address a problem at his reasoning during the course of the discussion gives him the chance to clarify his ideas (10). On the other hand, although M’s suggestion seems to make sense to V (11), he remains unwilling to open up the argument and explore his own views (13). In the posttest, V keeps his pretest response, which, despite being scientifically accepted, is not explicit, while M elaborates further his reasoning by implicit reference to latent heat. Therefore, in this pair’s discussion, it seems that M’s openness about his lack of understanding and his willingness to confront the implications of the social conflict helped him to develop his physics reasoning.

The following two extracts from the regressive discussions of a male and a female pair illustrate how the covering up of unclear points as well as the emergence of competitive attitudes prevented students from developing their meanings. In the first extract, the two boys are discussing the spoons question. Both of them agree that the metal spoon will feel hotter after awhile, but they disagree on the reasoning. D explains the phenomenon in terms of conduction, while A uses thermal equilibrium ideas.

1 D: I believe that the heat from the hot water is transferred to . . . to the metal spoon and, then, from the metal spoon which we touch with our hand we . . . we receive the heat more rapidly than from the wooden spoon.

2 A: She asks how the heat is transferred from . . . from the hot water to the spoon . . .

3 D: I think that I’ve answered that.

4 A: How is the heat transferred then? That’s what she asks!

5 D: (to the tape recorder) Because Akis T. didn’t pay any attention when I was talking, I have to repeat the answer.

6 A: After the advertisements I believe . . . after the advertisements. One minute! Beep, beep, beep, beep . . . we continue our program . . . [seriously] Tell it!

[These two boys carry out most of their discussion as though they were presenting a radio show. Their role playing, in most cases, functions as a means to avoid exploring their differences in cases of disagreement. Here, D tries to handle his puzzlement by A’s question (4) by attributing it to a lack of attention on A’s part (5), while A, through role playing (6), tries to diffuse the social tension created by D’s provocative comment (5). However, neither of them directly addresses their differences in terms of physics reasoning.]

7 D: [To the tape recorder] It’s necessary I believe because, as I’ve just said, Akis T. wasn’t paying any attention while . . . some incidents are happening [he looks at the other groups] . . . well . . . the heat follows the metal spoon and we receive . . . receive this heat to our hand which . . . touches . . . when we touch the spoon of course.
8 A: And the heat transfer?
9 D: [Unsure about what A means] Now . . . the heat transfer happens because . . .
   it's a good conductor probably.
10 A: There's a thermal potential difference at the two edges.
11 D: [Role playing] Let's listen to Akis T. The tape didn't take that properly.
12 A: There's a thermal potential difference between the metal spoon and the hot water . . .
13 D: I can't . . . I can't express my opinion for the issue. All right . . . let's go on to
   the next question. We agree to go on to the next question.

As can be seen in this sequence, the two students do not manage to interrelate their ideas. Despite
their differences in terms of physics reasoning, they seemed unwilling to recognize
openly their disagreement and were trying instead to avoid argumentation through role playing.
At the end, this becomes more apparent when D, in an effort to cover his lack of understanding
of A's assertion (12), suggests they go on to the next question (13). An analysis of this pair's
discussion through all the six questions indicated that their interaction problems were due
mainly to their different ability status in the science class. D, who has lower marks in Physics
than A, seems insecure about his responses and, when challenged, uses role playing to divert the
discussion. On the other hand, A confidently comes up with ideas which, although often
incorrect, sound scientific. In this way, A takes the lead of the discussion without paying much
attention to D's views. As far as this particular question is concerned, students regress in their
reasoning in the posttest. A explains the phenomenon in terms of thermal equilibrium ideas
instead of heat transfer ones, while D moves to nonscientific ideas about conduction.

The following extract is from the regressive discussion of a female pair on the ice and water
question. Both students argued that the pan with the ice and water will take more time to come
to the boil because the ice needs to melt first. However, their discussion proceeded as follows:

1   F: So . . . shall I tell you what I believe? I believe that . . . the pan K will need
   more time to boil.
2   V: I also believe the same.
3   F: I'll tell you why. So . . . wait! I'm speaking, not you! So, listen . . . there's
   water in the pan K. Is this water hot or cold? Wait!
4   V: It says here . . .
5   F: [Interrupting V] It's not clear . . . wait!
   [Here, F appears to treat the discussion simply as a chance to think aloud and does not
   welcome V's contributions (3). At first, V allows her to control the discussion, but F's
   lack of cooperation frustrates her, and toward the end of the discussion V fights back.]
6   V: . . . because the pan K will first need to melt the ice cubes and only after
   awhile it'll start boiling whereas the pan L will have already started boiling
6   . . .
7   F: [Interrupting V] Wait! It needs some time for the ice cubes to melt and then
   some more time for the water to boil.
8   V: [Angry because F keeps interrupting her] So . . . we said that in the first pan,
   which contains ice and water, the ice needs to melt first!
9   F: Shall I write down my opinion?
10  V: [Aggressively] I'll dictate my opinion.
11  F: So . . . repeat again 'our' opinion.

As can be seen in this extract, despite their apparent agreement (8), competition and aggression
prevent this female pair from interrelating their ideas. In the posttest, V keeps her pretest
accepted reasoning, while F regresses to a scientifically nonaccepted response.
Therefore, in pairs, the ways peers discussed their views depended a lot on the participants’ individual dispositions and goals during the group interaction task. That is, students’ perceptions of their own ability compared to that of their peers, their competitive or collaborative attitudes toward one another, as well as their interpretations of the purpose of the task (whether it is only about giving a common response or about exploring their meanings) influenced group discussion processes and peers’ subsequent learning. The existence of conflicting perspectives seemed to have helped group discussion only in those cases when one or both peers were willing to acknowledge openly their differences and explore their ideas.

Interaction Modes in Fours

The development of students’ physics reasoning in fours, as in pairs, seemed to center on the raising of objections and the negotiation of the different perspectives. However, in fours, peers’ progress or regress in physics reasoning seemed to depend more on whether the raising of objections turned to personal conflicts. That is, in fours it was more the interrelation of group members’ efforts rather than their preexisting attitudes and goals that seemed to influence discussion processes and learning outcomes.

The following extract is from the progressive discussion of four boys on the spoons question and illustrates how interpersonal tension caused by disagreements was diffused through the social support of a peer and led students to progress in physics reasoning. In the pretest, two of the students (S and T) argued that the metal spoon would feel hotter because metal is a good conductor of heat; the third student (ST) reasoned that the wooden spoon would feel hotter than the metal one because it would absorb water; and the fourth student (G) did not respond to the question.

1. S: So . . . my name is Sergios P. and, in this question, I have chosen that the metal spoon will feel hotter to her as long as she has placed it in hot water because metal, as we know, is a good conductor of heat.

2. T: This is the general opinion of the group for the first question. My name is Thanasis. We go on to the second question.

3. ST: No! Each one of us must say his own opinion first and then we’ll say the general opinion.

[Following ST’s intervention in relation to the task requirements (3), T gives the same justification as S. G agrees with them, without mentioning that he had not responded to the question in the pretest. However, the fourth student (ST), who in the pretest had argued that the wooden spoon would feel hotter because it would absorb water, does not put forward his different view and pretends that he has given the same response. This indicates that in small groups, the need for peer group conformity can sometimes restrict peers from raising their objections if they are at odds with those of their peers.]

4. S: [To the tape recorder] So . . . as you can see . . . all group members have the same opinion; that is, we all agree that the metal spoon is one that will get hotter because it’s a good conductor of heat. We go on to the next question.


6. T: We should have a discussion and not simply each one of us give his answer. We must talk them over.

7. S: Well . . . I think we agree on this question. It’s very obvious.

[Here, it appears that the group has reached an easy agreement. Later, however, the group returns to review their responses and ST opens up the argument by raising his objections.]

8. ST: I disagree! I believe that . . . although the first time I had chosen the metal spoon . . . and although my classmates beside me tell me to shut up! . . . I
believe that the wooden spoon could be the one that has more chances to get hotter because it could absorb the water inside it and the water would raise the temperature, and thus the spoon will be very hot. This is another view, right? I think that we could write down this view as well. [To S] Why do you disagree with me? Why do you disagree with my opinion?

[ST’s initial comment shows clearly how peer pressure can sometimes affect peers’ stances, and thus the flow of the discourse within the group. However, ST resists peer pressure and goes on with his objections.]

9  S: I disagree, right? And I’ll tell you why. It says that Maria left a metal and a wooden spoon in a jug with hot water. However, it says . . . sorry, Stefane, but I disagree . . . which spoon will feel hotter to her when she touches them after a few minutes. Well . . . if she had left them in the water for years, you could have said that the wooden one would have been soaked. But now, after just a few minutes, how is it possible that the wooden one would have absorbed water so as to be hotter?

[S introduces the time factor and this leads the group to a negotiation of its consequences for the relative temperature of the metal and the wooden spoon.]

10  ST: Yes, but there’s still a possibility because it doesn’t specify exactly the time.
11  S: “After a few minutes” . . . a few minutes is at most five minutes!
12  ST: Haven’t you ever put a paper napkin in water?
13  S: The paper napkin is one thing . . . the paper is one thing and the wood quite another.
14  ST: This has nothing to do with it.
15  S: The spoon is not a bath sponge!
16  ST: It depends on the time.
17  S: It says “a few minutes.”
18  ST: Then it could be that the metal spoon would not have felt hotter to her either.
19  T: That’s true!
20  S: [Aggressively to T] Do you agree with him?! Do you agree that there’s any chance that the wooden spoon could have felt hotter to her?
21  T: I agree that within a few minutes there’s a chance that the metal spoon wouldn’t have felt hotter to her as well. Of course, I don’t agree that the wooden spoon would have felt hotter after awhile! However, in any case, I don’t take sides on this issue.

[T’s clear statement of his view as well as his equally clear refusal to take sides (21) and, thus, turn the dispute in terms of physics reasoning into a majority vote, seems to resolve the social tension caused by S and ST’s confrontation as is shown by ST’s follow-up comment.]
22  ST: You’ve persuaded me . . . all right . . . you’ve persuaded me. I think that . . . it may have sounded a bit irrational . . . all right . . . my opinion wasn’t rational . . . but now I believe that you’re right.

As can be seen in this extract, the fact that ST raises his objections (8) and there is a discussion of the different views rather than a social confrontation on the winning view seems to have helped him to clarify his ideas (22). In the posttest, ST moves to an accepted reasoning that refers to the relative conductivities of metal and wood, while S and T give more elaborated accepted responses. The fourth student (G), who did not participate much during this group’s discussion despite his peers’ efforts to get him involved, again does not respond to the question. This extract shows clearly how social factors can sometimes prevent peers from raising their objections in small groups. However, once differences were acknowledged, it was through the
skillful intervention of one of them that peers managed to avoid social tension and resolve their differences.

The following extract is from the regressive discussion of four boys on the potatoes question and illustrates how, by turning their differences in physics reasoning to personal conflicts, peers failed to clarify their meanings. In the pretest, one of the students (M) argued that the potatoes will boil first in the pan on high heat. The other three students (A, S, and N) reasoned that because the water in both of pans is boiling, the potatoes will take equal time to cook.

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1 N: They’ve already started boiling at 100°C.
2 M: Yes, but . . . at first, they boil at certain degrees and then you lower it.
3 S: [Interrupting M] You fool . . . you lower it so the potatoes do not burn!
4 A: Because the potatoes will be burnt otherwise.
5 N: Since we know that the boiling point of the water is 100°C, how can it ever exceed that? It can never go to 300! Therefore, if both of them are at 100°C, they’ll both cook at the same time.

[Here, it is apparent that N, S, and A’s agreement was based on a superficial consideration of the problem. N justifies his response in terms of temperature constancy during boiling (1, 5) while S (3) and A’s (4) reasons are based on everyday ideas. However, the students make no effort to clarify what appeared to be different perspectives.]

6 M: Yes, but the heat under one of them is the same all the time whereas, under the other pan, the heat changes and decreases. Therefore, the potatoes in the second pan won’t cook at the same time as the potatoes in the first pan.
7 N: [To A and S] You two, you better talk as well because . . .
8 S: What can we say since he doesn’t understand it?
9 A: Come on! What do you mean, “he doesn’t understand it”? Why are you saying “he doesn’t understand it”? He may have a different view. That’s all right, isn’t it?!

[S’s socially provocative comment about M (8) provokes A’s reaction (9) but rather than being followed by an argument relating to the different perspectives, this is followed by S’s suggestion to put down both competing views.]

10 S: All right, all right . . . maybe he’s correct. Put down both views. [To the tape recorder] We’ve thought about it but we disagree. We can’t agree. Three of us agree but the fourth one disagrees!

As can be seen in this extract, M’s objections (2, 6) seem to be taken to be a challenge to the group’s easy agreement, and thus, peers are led to personal conflicts (3, 8). However, although A’s intervention about the discussion norms (9) have prevented the group members from explicit social tension, S still seems to feel the need to point out to an external audience that M’s view is a minority one (10). In the posttest, A and S regress to scientifically nonaccepted responses. The other two students keep their pretest answers, M a scientifically nonaccepted explanation, and N an accepted one.

In fours, the process of the negotiation of meanings depended more on the interrelation of group members’ efforts to avoid the raising of objections turning to personal conflicts rather than on peers’ individual perceptions and interpretations of the situation, as was the case with pairs. At the same time, efforts to avoid arguments and to resolve disputes over the physics reasoning through, for example, unconvincing agreements, majority voting, or quick decisions to write down the competing views appeared to lead students to a lack of progress in physics reasoning. Once again, it seems that the existence of conflicting perspectives helps peers only in those cases when they are willing to explore them openly without turning their disagreements to interpersonal conflicts.
Implications for Teaching and Further Research

The findings of the study showed significant pre- to posttest differences in students' performances as a consequence of whether they participated in discussions in pairs or fours (with fours being more beneficial than pairs). The analysis of group dialogue suggested that peers' modes of interaction on the social level were more constrained in pairs than in fours. That is, in pairs students seemed to face more difficulties in negotiating their views and in dealing with their disagreements. It also seemed that pairs found it more difficult to overcome the notion of right or wrong responses to explore their meanings. On the other hand, in fours, difficulties in peers' social interaction seemed to be more easily diffused through the social support system that operated in these settings. In addition, it appeared that in fours, students recognized that different people could have different views which, in turn, diverted attention from the search for the right response toward a negotiation of meanings.

For students to progress in their reasoning, a willingness to be open about their thinking and to raise their disagreements in terms of physics reasoning was more important than equal participation in the discussion. However, because peers' stances and modes of argumentation were regulated to a great extent socially, the balance between students' cognitive activity and social dynamics was a fragile one. That is, in many cases peers seemed unwilling to confront the social implications of possible disagreements and preferred not to raise their objections. Therefore, the mere existence of conflicting perspectives in small groups seemed not to be an adequate prerequisite for conceptual change in science. The ways in which peers exchanged and interrelated their ideas during the course of their interaction seemed more important in relation to group discussion processes and individual learning outcomes. In this respect, the findings of the study point more toward fours than pairs for group discussion in science, as the social interaction in fours seems to function more effectively.

However, because peers' modes of interaction on the social level played such an important part in the process of the construction of knowledge in group settings, whether students want to work together seems to be of fundamental importance. Thus, at least for the purposes of everyday classroom interactions, this may suggest that there could be advantages in using self-selected groups, as was the case in this study, rather than groupings on predetermined factors (e.g., ability levels).

The difficulties that peers face in coping with disagreements and reaching shared understandings when working in groups raise the issue of how to help students explore and interrelate their ideas and hence enhance their learning outcomes from group discussion. Some researchers argue for an explicit portrayal of skills for discourse, either through interventions designed to teach norms of argumentation and social collaboration in advance of peer interaction, or through direct assistance when groups are in operation (e.g., Eichinger et al., 1991; Cohen, 1994). The benefit of role playing in coping with conflict in small groups has also been recognized. That is, students seem to find it easier to enter argumentation and discuss their conflicting perspectives through role playing than when it is their own ideas that are under dispute. The findings of this study suggest that role playing might be particularly fruitful for pairs where peers appear to have the more difficulties in regulating their interaction on the social plane.

However, openness about their views and willingness to negotiate them alongside alternative ones require a supportive classroom atmosphere and a model of science learning by the teacher in such terms. Implicit messages that are conveyed through everyday classroom interactions can have powerful effects on students' perceptions of what is accepted and valued as well as on their interpretations of the nature of the learning process in general and learning science in particular. In this respect, meaningful group discussions also seem to ask for a different balance
of power in classrooms, one that will provide to students the security needed for exploring their ideas.

This study involved only an hour’s intervention with peer discussion. A longer intervention might well have shown a development of students’ interaction modes over time. However, the findings of the study indicate that there is a complex interrelation of conceptual, contextual, and social factors which influence the collaborative sharing and building of meanings in science classrooms. Issues such as whether and how peers raise and handle their disagreements, what happens when they challenge each other in different ways, and the reasons for which peers change their views are fundamental when group discussion is used as a means for facilitating learning. In this respect, this study showed that groups of fours functioned better than pairs in terms of both group discussion processes and peers’ learning outcomes in science. This was due to the various ways in which discussion is constrained in the interaction between pairs.

References


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