Impact of a discussion method on high school students’ understanding of kinematics concepts

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Abstract: Despite of its importance for future physics learning, Kinematics is a field where students’ misunderstanding is the most pronounced. Our research aims to test the use of the discussion method allows students on the high school students’ understanding of kinematical concepts. Our study consisted of four classrooms of a total of 122 French-speaking students of a 12th grade physics course given in three different high schools in Canada. To determine if the discussion had an effect on the understanding of the pupils, a repeated measures analysis of the variance was performed to determine if the increase of understanding according to the number of periods of the discussion method is linear. A positive and significant linear trend in students’ understanding was present in two groups out of four where the discussion method had been implemented. In the two groups where there were no significant results, it appears from notes in the researcher’s diary that the discussion method had not been implemented as planned. Our research therefore concludes with recommendations for future research to go further.

Keywords: Discussion method, conceptual understanding, kinematics concepts

Introduction

If there is a domain which causes a lot of difficulties to the pupils, it is kinematics, defined as the study of the motion of objects without being concerned about its causes (Arons, 1997). There are two main reasons put forward by the researchers: alternative schemas which the pupils already have on the properties of motion and the emphasis put on the mathematization of its properties in the teaching of kinematics. Firstly, the pupils have, before arriving in the physics course, a broad experience about the properties of motion which they have acquired in their interactions with daily events. These experiences allowed them to construct schemas with which they can interpret the phenomena of motion (Knight, 2004). Particularly, these schemas resemble those developed by historical figures such as Aristotle (Espinoza, 2005). These schemas are completely adapted to the common life tasks: drive a bike, catch an object, etc. However, these schemas may differ from scientific concepts. In certain cases, these schemas may even interfere with learning, especially if the teacher does not take them into account. In that case, there is great danger that the pupils differentiate school knowledge, which works in the school (for instance, in the laboratory), of daily knowledge, who allows them to react with effectiveness to events of the common life (Arons, 1997). Secondly, during laboratory activities, kinematics is often approached with the aid of a mathematization to which the pupils are not accustomed. For instance, a common pedagogic technique consists in bringing the pupils, at the beginning of the study of kinematics, to the laboratory where they measure different properties of motion which they then put in graphs. Back in class, they analyze their results and perform calculations with the aid of mathematical expressions to get the values of the speed and acceleration. And yet, it appears that the pupils perform these various operations without a real understanding of what they are doing (De Vecchi, 2006).

These different sources of difficulty have led researchers to make improvements to daily teaching practices. First, the study of everyday phenomena has been suggested because they are likely to let emerge students’ thinking patterns (Knight, 2004). Hence, study of everyday phenomena occurs mainly either in teacher demonstrations of physics phenomena or in laboratories where students are grouped into small teams. In particular, labs are mainly used to check the content covered in the course. Indeed, the traditional approach in laboratory is very structured. The objectives of the experience and methods are selected in advance by the teacher. The main students’ activities consist of executing procedures, collecting and analyzing data. Students’ participation is passive and at low cognitive level (De Vecchi, 2006; Hofstein&Lunetta, 2004). So it is not surprising in this context that some researchers found that there is little difference in terms of potential cognitive gains between demonstration by the teacher and practical activities by students (Roth, McRobbie, Lucas &Boutonné, 1997). As such, it seems that the distinction between the demonstration and the laboratory is essentially based on whom of the teacher or students, controls the activities. Indeed, in the laboratory, students exert more control over the selection, organization and pace of learning while in the demonstration, it is the teacher who controls the flow of activities. However, it may be that the aspect of "Who controls the manifestation of the phenomenon? "is less important, with respect to understanding, that the opportunities for students, when using a given method, to build a coherent representation of the phenomenon (Roth, McRobbie, Lucas &Boutonné, 1997).
In addition, various factors have been invoked to explain the lack of conclusive results of either demonstration or the laboratory. Taking into account the influence of these factors has led researchers to propose more complex teaching strategies to promote student understanding while research uncovers their multiple influences on understanding (Brown & Hammer, 2013). From what precedes, one must infer that the mere presentation of phenomena in demonstration or experimentation in laboratory experimentation does not seem sufficient to enable students to change their way of understanding (Roth & al., 1997). Indeed, it may be that the phenomena presented by the teacher during the demonstration or reproduced by the students in the laboratory do not call into question students’ conceptions. It is for this reason that many researchers have proposed to choose the phenomena that destabilize students contradicting their initial conceptions (Vosniadou, 2013). The objective of this procedure is to induce conceptual conflict when the student realizes that his conceptions are insufficient to explain or predict phenomena. In this method, the teacher guide and support students in their efforts to change their conceptions so that they appear fruitful, intelligible and plausible. Nevertheless, research has shown that the introduction of phenomena specifically chosen to undermine students' ideas is rather ineffective to change them. One reason for this failure lies partly in how students react to data that seem to contradict the ideas they maintain about the physical phenomena (Niaz, 2008). In fact, students can adopt different behaviors in order to safeguard the "hard core" of their conception, that is to say, the ideas that constitute their most fundamental beliefs (Chinn& Brewer, 1993). To help students become aware of the gap between ideas and the phenomena, authors recommend that students discuss with each other about the phenomena studied and verify their ideas with experiences. Indeed, a discussion with peers provides students with various feedbacks about their ideas, confront them to other ways of interpreting the phenomena and prevents premature closing by boosting awareness of their deficiencies in understanding. The student and would come to gradually adopt a more coherent and adequate representation of phenomena (Inagaki and Hatano, 2013).

However, if most authors agree that discussion encourages the expression of students' ideas about the phenomena and the evaluation of their merits, it is not certain that the discussion leads to a more thorough understanding of scientific concepts. Hence, the link between the discussion and understanding of concepts has not been established through research in a clear way. Indeed, various proposed strategies such as discussion often consist of several educational interventions, the discussion is only one element, so that the effect of the discussion of comprehension is difficult to assess. In addition, the discussion as a teaching method is poorly defined and often associated with exchanges between students (Dillon, 1995). Therefore, in this research we aim to achieve the following objectives. The first and second objectives are concerned with the conception (1) and identification of the conditions of implementation (2) of a discussion method about the properties of kinematical phenomena which takes into account students’ alternative schemas. The third objective (3) is concerned with assessing the effect of such a strategy on high school students’ understanding of kinematical concepts.

**Conception of the discussion method**

From what precedes, it appears that to promote understanding of motion, discussion should focus everyday phenomena of motion, for at least three reasons. First, complex phenomena require the student to iteratively engages in a process of understanding where it is more likely to gradually occupy increasingly complex levels of understanding (Miyake, 2013). Second, the use of daily phenomena helps develop cognitive schemas that the student has motion, which facilitates their review and modification. Moreover, since the demonstration and the laboratory give equivalent results, we chose to use, for practical reasons, the demonstration rather than the laboratory to introduce students to the phenomena. In addition, using the demonstration, the teacher can further guide students’ approach to understanding. To avoid looking for a single solution and to facilitate students’ expression of their ideas, the discussion should focus on problems or physical situations involving qualitative reasoning. Finally, to avoid premature closure of the debate on an erroneous explanation, discussion should focus on cases that challenge students’ ideas. In addition, to encourage students to generalize their results, the discussion should focus on a set of cases covering all aspects of kinematics.

To establish and maintain the discussion, the teacher should focus on discussion animation and management and refrain to give his opinion about the phenomena studied. To this end, the teacher gives instructions to follow during the discussion, sets or revises the rules of operation, describes the objectives, establish limits and constraints, and creates an organization promoting interactions between students. To keep the discussion in line with its objectives, the teacher must summarize and clarify students’ remarks, assess whether students have talked enough and are ready to switch to another theme, focus on a specific point or extend the field of investigation, redirect the group's efforts towards the objectives of the discussion. The teacher creates a safe environment where all students can express their ideas in a climate of trust and acceptance. The teacher invites silent members to express themselves and avoids discussion time is monopolized by some members. To promote the participation of the largest number of students and facilitate interactions between them, they should be divided into small groups of four to five students. The seats are arranged in circle, forming small islands, so that all participants can see and hear each other, and facilitating exchanges. These islands are distributed in a circle around the experimental set up so that all teams can distinctly see the teacher's demonstrations. However, to ensure that students receive the whole class feedback, we also expected that the results of the deliberations of the teach team are regularly discussed with the whole class group under the supervision of the teacher. This class discussion allows the teacher to synthesize the results of the

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exchanges between students in teams. Choosing a team spokesman allows the group to express the consensus reached within the group. In the class discussion, the teacher makes sure to tour the teams and to get students to comment on the ideas of the other teams. In addition, he challenges students by asking them to test their ideas by suggesting changes to the set up.

In this regard, it is important that the activities offered to students in small groups are structured to channel their interactions towards the achievement of learning objectives. In addition, a better framework for discussions between students empowered them and therefore facilitates teacher’s management of activities. To this end, an activity guide is distributed to each student, containing the objectives of the method of discussion, the way forward, the description of montages, the structure of activities, questions to answer, expected results, etc. In addition, the specification guidelines are likely to overcome students’ lack of communication skills. The guide contains concrete physical situations highlighting various properties of the movement. In each situation, activities (questions to answer, graphics profile, etc.) are proposed to facilitate students' modeling of the properties of movement. We call "case" such a design. In addition, the tasks proposed to the student should allow him to use his cognitive patterns to accomplish the scientific functions of predicting, describing and explaining scientific phenomena. To this end, the POE tasks allow students to develop their scientific understanding in a structured way. POE task is composed of three parts: 1) a physical situation is shown to the students and the teacher describes the experience he wants to achieve with this arrangement; 2) the teacher asks students to: a) predict the outcome of the experiment described; b) to write a justification of their prediction; 3) the experience is then made to students and the teacher asks them to describe their observations and explain the difference, if any, between predictions and observations (Dekkers, 1997). For example, one of the phenomena studied concerns the uniform motion (see Figure 1). This phenomenon can be represented by the motion of a ball rolling on a straight horizontal track. Regarding uniform straight motion, the first case subjected to the pupils is represented in the guide in the following way: « A ball is thrown on a horizontal rail. The circle in grey points out its initial position at the time of launching. The circle with symbol 1 inside points out the position of the ball after 1 second (see fig. 1) ».

![Figure 1. Motion of a ball traveling a horizontal rail](image)

During the observation phase, the teacher stands in front of the set up and describes the experience he intends to do. Once students have registered their predictions in their notebook, the teacher asks students to observe the product phenomenon. He can repeat the demonstration several times to ensure that students have had the opportunity to observe the various characteristics of the phenomenon. Subsequently, the teacher asks students to discuss in teams. During this discussion, students answer questions from the guide. They compare their predictions with each other and try to explain any difference between their predictions and observations. Thereafter, when the teacher finds that students have sufficiently discussed in teams, he began a discussion with the whole class, where each team, through his spokesman, explains and defends its position. The role of the teacher at this time is to encourage the participation of the largest possible number of students, to clarify and summarize what have been exchanged and classify the ideas into categories and to get students to offer tests to verify their ideas. When he believes the students have sufficiently understood the phenomenon, the teacher chooses the next case in the guide and until all situations of motion have been studied.

**Methodology**

To assess the attainment of our three research objectives, we used a mixed methodology combining qualitative and quantitative methods (Creswell, 2009). The first two research objectives concerning conception and study of the conditions of implementation of the discussion method is treated by qualitative methods, namely the diary, and semi-guided interviews with teachers engaged in the study. The third research objective concerning the evaluation of the effects of the learning sequence on students’ understanding of kinematics concepts will be treated by quantitative methods in a quasi-experimental research design (Shadish, Cook & Campbell, 2002). Our study consisted of four classrooms of a total of 122 French-speaking students of a 12th grade physics course given in three different high schools in Canada. The first two groups come from the same school. This is a private secondary school located outside the metropolitan area of Montreal. It differs from the public sector in that the schedule is based on a five-day cycle rather than a nine-day cycle so that students taking the introductory course physics at the same time from one cycle to another. Students in the third and fourth groups are studying in public school in a secondary school in the suburbs of Montreal. These are public high schools whose schedule are based on a nine-day cycle, that is to say, the different courses are spread over a period of nine days. The first teacher teaches introductory physics to the first two classes of students. The second and third teachers teaches physics to the third and fourth classes respectively. The main researcher replaced the third
To prove our research hypothesis, it is necessary for us to determine if every opportunity of measure is superior to the previous measure so that the increase of understanding according to the number of periods of discussion method introduces a linear tendency. An analysis of the variance of repeated measurements performed with the aid of orthogonal polynomials allow to test separately linear, quadratic, cubic, etc., tendencies (Howell, 2008). To measure the evolution of understanding according to the number of periods dedicated to the use of the discussion method, we conceived a test of kinematics motion after a literature review on the subject (Trudel, Parent & Auger, 2008).

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\[
\log \left[ \frac{P_{nijkl}}{P_{nijkl-1}} \right] = (B_n + T_i) - (D_j + F_k)
\]  

where:

- \(P_{nijkl}\) is the likelihood that the pupil ' \(n\) ' sees itself granted a level ' \(k\) ' at occasion ' \(i\) ' when he answers question ' \(j\) '.
- \(P_{nijkl-1}\) is the likelihood that the pupil ' \(n\) ' sees itself granted a level ' \(k-1\) ' at occasion ' \(i\) ' when he answers question ' \(j\) '.
- \(B_n\) is the skill of the pupil ' \(n\) '.
- \(T_i\) is the more or less easiness with which the pupils answer at occasion ' \(i\) '.
- \(F_k\) is the difficulty linked to the jump of level \(k-1\) at level \(k\).

The various properties of the Facets model make it an appropriate tool for our analysis. Firstly, the various parameters calculated by the model from observations have the properties of an interval scale. Secondly, the model allows the calculation of values for all pupils during all occasions of measure, including missing data, which increases the power of the statistical tests used. In order to do so, the model calculates for every pupil a value of the logarithm of its likelihood to produce a correct answer to the question subjected to each of the periods of the experimentation. To determine if the discussion method had an effect on the understanding of the pupils, a repeated measures analysis of the variance was performed of the computed values. This analysis allows us to compare the results of the pupils between the different occasions of measure and to determine if one of these results differs significantly from the others. This comparison can take a specific form called contrast. To prove our research hypothesis, it is necessary to determine if the increase of understanding according to the number of periods of the implementation of the discussion method is linear. As such, it is possible, with the aid of orthogonal polynomials to separate the
contribution from the linear tendencies and higher polynomials (quadratic, cubic, etc). Besides, these elements of variance being independent to each other, they can be separately tested (Howell, 2008).

**Presentation, analysis and interpretations of results**

In this research, we aim to verify the following hypothesis: “The discussion method as described previously has a positive impact on high school students’ understanding of kinematic concepts”. Moreover, since we are interested in checking out our hypothesis in various settings to increase external validity, we have chosen four different school environments, urban and suburban, private and public. Therefore, we will also describe the characteristics of each classroom context that may throw some light to explain the results obtained for each group from 1 to 4. With respect to first group, Table 1 shows the results of the omnibus test for the three phases: before using the method of discussion (BEFORE), while using the method of discussion (DISCUSSION) and after the use of the method of discussion (AFTER). We report in Table 1, the value of the F ratio, the degrees of freedom of the numerator (source of variation) and denominator (error term) of the F ratio and the degree of significance of each phase of the experimentation.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>3,213</td>
<td>5 ; 175</td>
<td>0,008**</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>1,971</td>
<td>3 ; 105</td>
<td>0,123</td>
</tr>
<tr>
<td>AFTER</td>
<td>1,097</td>
<td>3 ; 105</td>
<td>0,354</td>
</tr>
</tbody>
</table>

Note : **: significant to alpha level of 0,01

The study of Table 1 shows that the null hypothesis of "no difference in understanding between different opportunities of measurement" is rejected at the "BEFORE" phase only. Therefore, in the prior phase, the average value of comprehension is significantly different. Since the omnibus test rejects the null hypothesis of no difference between means in the phase BEFORE we check the linear trend in understanding in this phase only. The result of this analysis is shown in Table 2. We report in Table 2, the value of the F ratio, the degrees of freedom of the numerator (source of variation) and denominator (error term) F report and the degree of significance of each phase of the experiment.

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>0,017</td>
<td>1 ; 35</td>
<td>0,897</td>
</tr>
</tbody>
</table>

From Table 2, the results of phase "before" did not identify significant linear trend in understanding based on the number of measurement occasions. Moreover, since the result of the omnibus test does not allow us to reject the null hypothesis of "no difference in understanding between different measurement occasions" during the discussion, we conclude that the discussion did not have a significant effect on understanding in the first group. In the first group, we found the absence of a significant linear trend in all phases of the experiment. This absence can be explained in different ways. First, various field observations lead us to believe that the discussion method had not been implemented as planned in this group: 1) low participation of students, especially girls, in the discussion; 2) pattern of interactions between students and teachers more like a recitation; 3) Quick covering of cases by the teacher that does not facilitate discussion among students. From our observations, this low participation can also be explained by a negative class climate which makes it difficult for students to express their ideas. It is also possible that students did not understand the role they should play in the discussion so they did not follow the rules thereof (Costa, 1990).

As regards the second group, a linear trend, positive and significant, was highlighted during the implementation of the method and also after removal of the discussion (see table 3). As with the first group, we need to check for a given phase, if there is an average score of understanding of the second group at a given opportunity that is significantly different understanding of the values obtained on other occasions. Omnibus test values for the three phases are shown in Table 3. In examining Table 3, we
find that only the phases of "DISCUSSION" and "AFTER" discussion allow us to reject the null hypothesis of no difference between the average values of the understanding in the different occasions of measurement.

**Table 3.** Test omnibus of each phase of the second group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degree of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>0.328</td>
<td>5 ; 130</td>
<td>0.896</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>11.505</td>
<td>3 ; 78</td>
<td>0.000**</td>
</tr>
<tr>
<td>AFTER</td>
<td>10.177</td>
<td>3 ; 78</td>
<td>0.000**</td>
</tr>
</tbody>
</table>

Note : ** : significatif au seuil de 0.01

From Table 4, we find that the initial phase does not produce a significant linear increase understanding. For cons, the phase associated with the discussion demonstrates that understanding is linearly related to the number of discussion periods and that this trend is significant at the alpha level of 0.05. Similarly, in the AFTER phase, the linear trend in understanding is significantly related to the number of periods of this phase.

**Table 4.** Analysis of linear tendency of results of each of phase of the second group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISCUSSION</td>
<td>12.38</td>
<td>1 ; 26</td>
<td>0.002**</td>
</tr>
<tr>
<td>AFTER</td>
<td>9.556</td>
<td>1 ; 26</td>
<td>0.005**</td>
</tr>
</tbody>
</table>

Note : * : significant at the alpha level of 0.01

These results for the second group may be explained in several ways. First, it is possible that the method of discussion has a positive impact on students’ understanding, given the fact that it was implemented largely as planned according to our classroom observations. In support of this view, we observe that the teacher involved is concerned about student learning and, in his practice, he does not hesitate to use active teaching methods to engage students, even "take risks "as he himself admits in an interview. For example, he does not hesitate to challenge his students by asking them problems they have to find the solution by experiments. As such, he was the most involved teacher in the practice of the discussion method before the research began. However, the absence of a decline in this understanding, following the withdrawal of the method of discussion, does not allow us to exclude the possibility that this increased understanding is rather associated with the presence of a fluctuation in student achievement in the comprehension test.

As regards the third group, no significant linear trend could be demonstrated either before or during the implementation of the discussion method. Moreover, after the withdrawal of the discussion method, we could not get enough measures of understanding to determine a linear trend. As with the first two groups, we need to check for a given phase, if there is an average of the understanding of the group at a given opportunity that is significantly different from the average values of understanding obtained on other occasions. The omnibus test values for the first two phases of the third group are shown in Table 5. By studying Table 5, we find that only Phase "BEFORE" allows us to reject the null hypothesis of no difference between the values of mean understanding at various occasions measure.

**Table 5.** Test omnibus of the first two phases of third group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>7.471</td>
<td>7 ; 203</td>
<td>0.000**</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>1.041</td>
<td>3 ; 87</td>
<td>0.379</td>
</tr>
</tbody>
</table>

Note : ** : significant at the alpha level of 0.01

Therefore, we will check whether the data of phase "BEFORE" have a linear trend. From Table 6, we find that the initial phase does not produce a significant linear increase in understanding. In summary, the analyzes that we conducted, we can not reject
the null hypothesis of no linear trend in the relationship between the number of periods for discussion and understanding in the case of the third group.

**Table 6.** Analysis of linear trend of the results of the first phase of third group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>0.738</td>
<td>1 ; 29</td>
<td>0.397</td>
</tr>
</tbody>
</table>

Note : * : significatif au seuil de 0.01

With respect to those results of the third group, the analysis of our field observations and analysis of transcript of interview lead us to conclude that certain requirements of the discussion method were not followed: 1) the teacher was not well prepared to manage the discussion; 2) the pattern of interactions between students and the teacher was more like a recitation rather than a discussion; 3) few students expressed opinions on the phenomena presented and comments from students were rarely on ideas expressed by other students. Regarding the lack of teacher preparation, it is possible that not having time to be familiar with the experimental set-up, he did not know how to operate it effectively, so that opportunities for students to gather information on the motion phenomena or to verify their ideas were restricted (Hatano & Inagaki, 1991; Viennot, 2003). In addition, the teacher often sought to impose the correct solution rather than giving students the opportunity to debate.

With regard to the fourth group, we note that in the phase preceding the implementation of the discussion method, there were no significant linear trend. In the opposite way, we note the presence of a linear, positive and significant trend in understanding during the implementation of the discussion method while following its withdrawal, students’ understanding decline significantly. Table 7 verifies, for each phase, the null hypothesis of no difference between the values of the average student understanding at different measurement occasions.

**Table 7.** Test omnibus of each phase of the fourth group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>10.65</td>
<td>4 ; 112</td>
<td>0.000**</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>9.822</td>
<td>2 ; 56</td>
<td>0.000**</td>
</tr>
<tr>
<td>AFTER</td>
<td>5.224</td>
<td>6 ; 168</td>
<td>0.000**</td>
</tr>
</tbody>
</table>

Note : ** : significative to alpha level of 0.01

The study of Table 7 shows that the null hypothesis of "no difference in understanding between different occasions measure" is rejected in three phases. Therefore, the linear trend will be tested in all three phases. The results of these analyzes are shown in Table 8. From Table 8, we find that the initial phase does not produce a significant linear increase in understanding. For cons, the phase associated with the discussion demonstrates that understanding is linearly related to the number of discussion periods and that this trend is significant at the alpha level of 0.01. Similarly, in the AFTER phase, understanding is linearly related to the number of periods of this phase and this trend is significant at the alpha level of 0.05.

**Table 8.** Analysis of linear tendency of the results of each phase of the fourth group

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>F</th>
<th>Degrees of freedom (source of variation ; term of error)</th>
<th>Degree of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEFORE</td>
<td>0.03</td>
<td>1 ; 28</td>
<td>0.863</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>12.15</td>
<td>1 ; 28</td>
<td>0.002**</td>
</tr>
<tr>
<td>AFTER</td>
<td>10.78</td>
<td>1 ; 28</td>
<td>0.018*</td>
</tr>
</tbody>
</table>

Note :
* : significant to the alpha level of 0.05
** : significant to the alpha level of 0.01
This lack of linear trend before the introduction of the method of discussion is surprising in our view, given that students have covered, with their teacher, all the concepts of kinematics during this phase. Moreover, this teacher has extensive experience of teaching physics and uses various methods to facilitate student learning, such as lectures, problem solving sessions and labs. We may conclude from these results that the positive significant trend in understanding during the implementation of the method of discussion and the following decline may be caused by the implementation followed by the withdrawal of the discussion method. However, it is also possible that this increase is the result of an interaction between the method of discussion and teaching methods used by the teacher before the implementation of the method of discussion (Nelson, 1973).

Discussion and conclusion

By checking the impact of the method of discussion on understanding in four secondary five classes in schools in the Montreal area, we found a significant positive linear trend during the implementation stage of the discussion in the second and fourth groups. According to our observations, the discussion method was implemented in part as planned in the second group and fully as expected in the fourth group. Therefore, it is possible that the method of discussion has produced a significant impact on student understanding. Nevertheless, changes to our research design in the second and fourth groups have not ruled out the possibility that other factors may be responsible for the gradual rise of understanding in both groups during the implementation of the discussion. Thus, in the second group, it is possible that the positive linear trend (and significant) may be a reflection of a cycle or a fluctuation in the data. In the fourth group, it is possible that the positive linear trend (and significant) is the product of an interaction between previous learning and discussion method itself.

In both groups where no significant linear trend was highlighted, it is not possible to confirm or refute the research hypothesis. First, this negative result may be partly linked to the difficulty of establishing a class discussion, especially in science. In addition, the method of discussion we have developed consists of a set of requirements that must be followed to ensure the effectiveness of this method to promote understanding of science students. If any of these requirements are not fulfilled, it may affect the fulfillment of other requirements, as we have shown in the first and third groups, so that no impact is observed on understanding. The complexity of the sources of influence, which may affect the effectiveness of teaching methods such as discussion promote understanding, has already been emphasized by various authors (Brown & Hammer, 2013). Secondly, we must also mention that the method of discussion, as conceived, perhaps did not produce any impact on the understanding of these two groups. For example, the method is perhaps not conducive to the establishment of exchanges between students, mainly because it is too much under the control of the teacher. It also may not permit in a sufficient way the verification by the students of their ideas, as only one set up is available for the entire class. In conclusion, the results of our analyzes suggest that the method of discussion, when applied as directed, allows students to further link the information provided in the problems of our kinematics test. This conclusion is subjected to the reservation that our description of the implementation of the discussion reflects the events that took place there.

Comparing our results with other studies, we note that some of their results confirm our findings, such as the method of discussion allows students to better link their knowledge together. By cons, this research also highlight other impacts of the method of discussion that have not been studied in ours. Particularly regarding reciprocal teaching, Brown and Campione (1990) mention the retention of knowledge, the ability to classify information into categories, development of strategies for the student to learn by himself. With respect to another discussion method named hypothesis-experiment-instruction method, it wouldallos, according Hatano and Inagaki (1991) the development of better explanation, conceptual change, greater success at mass conservation tasks. Finally, regarding the usefulness of a discussion after a laboratory, Nelson and Abraham (1976) suggest that the method of discussion allows students to produce more inferences, and of better quality, than informal lecture.

Regarding the implementation of the method of discussion in schools, it seems it raises difficulties, as mentioned by various authors (Gall and Gall, 1990; Dillon, 1994). As such, Brown and Campione research tells us about the difficulties encountered in the application of reciprocal teaching method, which proved effective in controlled conditions, but not in the school environment where the control of variables is more difficult. Thus, the example shows that some details of teaching methods such as discussion can have an important influence on subsequent student learning, details thatViennot (2003) calls "critical". For example, the replacement of the large board by smaller ones in the previous research resulted that students could not share their solving approaches, neutralizing the role of the latter as a place for exchanges between students. In light of these observations, it seems appropriate to take another look at what happened in our research with respect to the groups where no significant linear trend was found.

Thus, in the first group, the lack of impact on the understanding can be explained by the negative climate that prevailed there, but it is also possible that the modification of a detail of the discussion method by the teacher has changed other method parameters, thus neutralizing its effectiveness in promoting understanding. Indeed, we have already mentioned that the teacher, perceiving his students as gifted, covered quickly the various cases, leaving little time to students to discuss the phenomena presented. Therefore, it is possible that students, who have not had the time to develop a prediction or explanation of the
phenomenon, did not dare to speak, so that the entire class did not benefit from exchanges that could have otherwise changed their ways of understanding. In the case of the third group, it may be that the teacher did not have time to become familiar with the set-ups and thus could not operate them effectively, for example by drawing the attention of the student on some conceptual difficulties or modifying assembly to provide more opportunities for students to test their own ideas. These two examples seem consistent to the notion of “critical details” exposed by Viennot (2003). According to the latter, teachers modify the methods they appropriate, which may explain the relative ineffectiveness of our discussion method in the first and third groups.

In conclusion, a distinctive result of our research concerns the fact that the method of discussion seems to have an impact on student understanding as long as it is implemented properly and provided that the description we have made of the implementation of this method in groups represents really what happened. Specifically, and without prejudice, the method of discussion seems to help students make connections between the information they collect about phenomena or between knowledge they already have on them, so they are progressively better able to answer questions at greater level of understanding. Furthermore, it appears that our study further clarifies the role of certain aspects associated with the implementation of the method of discussion on the effectiveness of the latter to promote understanding in science: difficulty for science teachers to appropriate the method of discussion, influence of some implementation details (eg, the transformation of the method of discussion by the teacher) on the other components of the method of discussion, interaction between certain contextual characteristics and course of the discussion. Given these various sources of influence, our research is important in that it examines the effectiveness of the method of discussion where it is likely to be used, that is to say, the school environment.

Regarding the limitations of our research, the selection of teachers, and therefore of classes of students, was done on a voluntary basis. Therefore, the link, we have confirmed between the method of discussion and understanding, cannot be generalized to the entire population of secondary students who take an introductory course in physics in Canada. In addition, factors associated the context in which the research hypothesis was checked, could not be controlled. Using a diary and interviews of the analysis carried out with the teachers involved have allowed us to identify some potential factors and to assess the possible impact on our results. These factors are the degree of teacher preparation to use the method of discussion, class climate, and possibly fatigue of students. With respect to recommendations for future research, we first suggest that in order to increase the efficiency of the method of discussion, teacher training in the discussion should be given special attention (Costa, 1990). It may be also appropriate to train students in discussion by preparing preparatory sessions where students learn to master the skills of discussion, such as the operating rules of discussion (Costa, 1990). With regard to improving the discussion method used in this research, each team could have its own experimental set-up so that students could be more in contact with the motion phenomena studied. Thus, they could follow a path of their own and they would, therefore, have more opportunities to modify the set-up to test their ideas. The teacher would summarise with the class after the teams study several cases. The discussion therefore would emerge enriched of all those contributions from the teams’ various pathways. Finally, due to the limited number of classrooms involved, further research is required, extended to many classrooms in diverse contexts, to establish in a more objective way the effect of the discussion method proposed here upon students’ understanding of kinematical concepts.

References


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