Collaborative learning, mental deficiency and causal reasoning

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Abstract
The aim of our research is to assess in what a collaborative learning can modify the quality of the causal reasoning. In the sphere of causal reasoning, we focus on the functioning of a bicycle. The subjects concerned are twenty-two mentally retarded children (IQ < 75), aged between 8 to 11 years. Three measures allow to estimate the performances of the subjects (a pre-test, a test (collaborative learning) a post-test). The results show that: (i) the collaborative learning allows to increase the performances of the subjects (ii) This improvement is stable in the time.

Keywords: causal reasoning, mental deficiency, bicycle, collaborative learning.

Résumé
L’objectif de ce travail est de montrer l’effet d’un travail en interaction sur la qualité du raisonnement causal et, plus particulièrement, sur la représentation du fonctionnement de la bicyclette, chez 22 enfants de 8-11 ans présentant une déficience intellectuelle légère d’étiologie indéterminée. Deux tâches sont demandées aux sujets : dessiner une bicyclette et expliquer comment elle fonctionne. Trois tâches permettent d’évaluer les performances : un pré test de connaissances initiales, une tâche de production (travail en interaction) et un post test. Les résultats montrent que le travail en interaction favorise le développement des performances des sujets. Cette amélioration est stable dans le temps.

Mots-clés : raisonnement causal, retard mental, bicyclette, interaction.

1. Introduction

The purpose of this research was to investigate how collaborative learning influences the quality of causal reasoning. More specifically, the present work focuses on the functioning of a technical artifact (the bicycle) and was conducted with 10- to 11-year-old children with mild mental deficiency of undetermined etiology.

The first part deals with studies on causal reasoning applied to how bicycles work and is followed by a presentation of research that examines the effect of collaborative learning on causal reasoning quality.

2. Bicycle functioning

Bicycle functioning has been studied within both the didactics of the physics framework (Favers, 1979; Jones, 1970; Kirshner, 1980; Lowell & Mekell, 1982) and the genetic psychology framework (Forman, 1993; Jamet, Legros & Déret, 2000a, 2000b; Jamet, Legros, & Es-Saïdi, 2003; Jamet, Legros, & Pudelko, 2004).

In didactics of physics, research work focused primarily on the stability of the representation of bicycle functioning through different prototypes that were characterized by either the front fork or the gyroscopic effect modification (Favers, 1979; Jones, 1970; Kirshner, 1980; Lowell & Mekell, 1982).

In genetic psychology, Piaget was the first to write an entire chapter on children’s representations of bicycle functioning. According to Piaget, the evolution of the comprehension of bicycle functioning involves four stages. At stage I, the child is able to identify the different parts which participate in the system functioning (i.e., pedals, gears, drive chain and gearwheel) but considers them to be useless. At stage II, the child evokes the necessity of these parts. At stage III, the attempt to explain bicycle functioning – which still is not entirely right – is based on the representation of the actions that can be performed with the different elements. It is only at stage IV that the description of the bicycle’s functioning becomes relevant. This stage is reached when the child is about 8-9 years old.

In the same book, Piaget (1927) also described protocols of “mentally deficient” subjects, showing that their performance corresponds to stages I and II. For subjects with the highest performance, the bicycle motion results from global links. The action of elements that are implied to be in motion does not follow an antecedents-consequences order. Figure 1 is a drawing by a 9-year-old deficient child presented by Piaget (1927).

![Figure 1: A level II bicycle produced by a 9-year-old mentally deficient child](image)

For Piaget, this drawing shows a typical case of synthetic disability. The drive chain, gear and pedals, placed between the wheels, are aligned without any relationship between them. The child’s clinical interview confirmed this representation consisting of juxtapositions only: “The pedals serve to make the rear wheel work”, “The drive chain serves to make the pedals work”, “The rear wheel so it moves” etc.
The child is unable to create coherence links between the components of the system.

It was not until Forman’s work in 1993 that children’s representation of bicycle functioning was investigated again. In this research, Forman studied not only the representation but also its construction. More precisely, the author’s purpose was twofold: first, to describe how a child represents a bicycle, and second, to show how the drawing activity and explanation about what is realized can be a help to causality learning. Within Piaget’s clinical and critical methodology framework (Ducret, 2005), Forman asked a 7-year-old child first to draw a bicycle without a model and then to compare his drawing with a real bicycle. The child was informed in advance of the two situations (with and without model). The two tasks were performed in interaction with the experimenter, who reminded the child of the objectives of the task being performed and encouraged him to explain why and how he was doing such or such a thing. The different steps of the drawing were written down. The child started by drawing the top tube, then the head tube, handlebars, saddle leg, saddle, gear, a pedal, fork, front wheel, seat stay, rear wheel, lower seat stay, gearwheel and drive chain. The author analyzed both the verbal productions and gestures. The analyses showed that after 4 minutes and 30 seconds, the child was able to describe the system that makes it possible to transfer the energy from foot motion (i.e., pedaling) to the pedals, which in turn drive the rear wheel by means of the gear, drive chain and gearwheel.

Using the bicycle functioning task proposed by Piaget (1927), Jamet, Legros, and Déret (2000a, 2000b) asked 6- to 11-year-old children to draw a bicycle and then to explain how it works. The results showed that the bicycle functioning representations observed were consistent with four levels of reasoning (L-IV, L-III, L-II, and L-I). Each level is composed of: (1) elements and (2) one or two relations. The elements are the essential pieces that participate in the functioning of a bicycle. There are six of them: the wheels, frame, gear, pedals, drive chain and gearwheel. Two relations are also necessary: the “frame” relation and the “chain” relation. The “frame” relation implies the fact that the wheels make contact with the frame; the “chain” relation refers to the relation between the pedals and the gear, which is related to the gearwheel by means of the drive chain, the gearwheel being in the center of the rear wheel. A level IV drawing (see appendix) includes the six elements and the two relations. At this level, the causal reasoning can be described as follows: action on the pedals leads to the rotation of the gear, which results in the drive chain motion, which in turn causes rotation of the gearwheel. The latter is in contact with the rear wheel and makes it spin around. A level III drawing consists of the six elements and one relation, the “frame” relation. The causal reasoning is the following: action on the pedals leads to the rotation of the gear, which in turn causes the motion of the drive chain. This is how a bicycle works. Level II is characterized by the “frame” relation and at least three elements, one of which is mandatory (the pedals). The subject’s reasoning is as follows: it is action on the pedals that makes the bicycle move. Finally, level I includes a minimum of two elements (the wheels and the frame). For a level I subject, a bicycle moves by means of the feet. Levels I and II can have different profiles, with from three to six elements. These four levels are comparable to Piaget’s four stages: levels I to IV correspond to stages I to IV.

Jamet et al. (2000a, 2000b) observed that the four levels defined above make it possible to explain the performance of the 6- to 11-year-old children. An effect of gender on drawing performance was also observed, boys’ performance being higher than girls’. Overall, it was easier for children to draw a bicycle than to explain how it works.

In 2003, Jamet, Legros and Es-Saïdi designed a study to assess whether these four levels could explain the performance of 10- to 11-year-old children with mild intellectual deficiency. The task and procedure were identical to the 2000 study. The results showed that the four levels account for deficient children’s performance as well. More specifically, the data indicated that most of the deficient children are at level II (65.5%), whereas ordinary children of the same age are almost equally distributed from level II to level IV (35%, 35% and 20% for level II, level III and level IV respectively). It is worth noting that there are twice as many ordinary children at level IV as deficient children (19.5%). The interaction between the type of children (deficient vs ordinary) and the level of development was reliable ( 2 = 13.76; p = .003; df = 3). However, this difference between ordinary and deficient children was observed for girls ( 2 = 12.67; p = .005; df = 3) but not for boys ( 2 = 4.52; p = .210; df = 3). The results showed that 85% of the deficient girls were at level II, whereas deficient boys were distributed from level II (50%) to
level IV (36%). Thus, as for the ordinary children, a gender effect was found. Because of the poorness of the verbal explanations, the difference between the quality of the drawings and that of the explanations has not been studied.

3. Collaborative learning

Researchers’ interest in collaborative learning activities came first from observations made “in the field”, but more recently has increased with the development of new systems of communication (Hoareau, Legros, Gabsi, Makhlouf, & Khebbeb, 2006; Legros, Maître de Pembroke, Makhlouf, & Talbi, 2001; Legros, Maître de Pembroke, & Talbi, 2002; Legros, Pudelko, & Crinon, 2001). Collaborative learning can be seen as both a pedagogical method and a psychological process.

Roschelle and Teasley (1995) defined collaboration as “a synchronic and coordinated activity that results from a continuous attempt to construct and to maintain a shared conception of the problem” (p. 70). The authors also highlight the importance of negotiation. When participants work in collaboration, their interactions are bound to engage in continuous negotiation. Indeed, collaborative work implies a mutual engagement of the participants in a coordinated effort in order to perform the same task. These verbal interactions between partners on the same domain and with the same goals – acquiring knowledge – promote the co-construction of knowledge (Brna, Baker, Stenning, & Tiberghien, 2002).

It is now well known that individuals have limited cognitive capacities, such as working memory and attention resources. Nevertheless, human cognitive resources remain highly overestimated in general. Without external help, individuals have insufficient memory and reasoning capacities to solve problems or accomplish complex tasks. These tasks require help from peers or from external systems that can constitute knowledge sources, activity organizers and extensions of individual cognitive resources (Norman, 1993).

Collaborative work could help to develop cognitive education in promoting the intrinsic-interpersonal functioning modality for deficient individuals. Nevertheless, this methodology constitutes a conception of learning that contrasts with the dominant pedagogical models, which are still mainly based on the behaviorist paradigm that does not take into account the “black box” content. In neglecting cognitive system, tenants of the behaviorist approach ignore the cognitive processes and structures on which they operate when new information is processed and knowledge is constructed. The risk in not taking into account all the characteristics of the learner’s functioning is that of obtaining an incomplete analysis of the causes of learning failure, especially for deficient individuals. Because children’s problems and difficulties are not treated on their cognitive dimensions, the teacher can intervene only on contextual factors of the learning situation. This conception, still widely dominant in several pedagogical approaches, cannot be efficient for pupils’ cognitive and meta-cognitive development, and more particularly for mentally deficient children.

The purpose of the present experiment was to examine the performance of children with mild intellectual deficiency of undetermined etiology in two tasks – drawing and explaining a physical object – as a function of the modality of task performance (i.e., collaborative work vs individual work situations).

Hypothesis H1. Performance should be better when the task is performed in a collaborative situation than in an individual situation.

Hypothesis H1.1. Performance in the post-test session should be higher than in the pre-test session (Kitcher, 1990; Wertsch, 1985; Wertsch, 1991).

Hypothesis H1.2 Performance in the post-test session should not differ from performance in the collaborative work session.

Hypothesis H2. Subjects’ performance should be better in the drawing task than in the explanation of bicycle functioning task (Jamet, Legros, & Déret, 2000; Jamet, Legros, & Pudelko, 2004). In this experiment, the text production task activates two types of mental models in parallel, an intentional model and a functional model, both of which are characterized by a specific causality system.
works have shown that intentional causality is easier to process than causality relating to the physical world (Jamet, Legros, & Pudelko, 2004; Legros, Baudet, & Denhière, 1994).

Hypothesis H3. Performance of the tasks (drawing vs explaining) should vary as a function of the work situations (collaborative vs individual). In the drawing task, an improvement in performance was expected in the collaborative work situation compared to the individual work situation. However, since the explaining task is a highly complex task for children in our sample, no effect of the work situation modality was predicted for this task.

4. Method

4.1. Participants

Participants were 22 children from CLIS classes1 with a mild intellectual deficiency. Their ages ranged from 8 years, 9 months, and 27 days to 11 years, 8 months, and 8 days. Intellectual deficiency was measured by two tests of average 100 and standard deviation 15 (WISC-III or K-ABC). The children’s IQs were between 50 and 70.

4.2. Procedure

The experimental paradigm was based on the one used in previous experiments (Jamet, Pudleko, & Legros, 2000a; Jamet, Legros, & Déret, 2000b; Jamet, Legros, & Es-Saïdi, 2003; Jamet, Legros, & Pudelko, 2004; Salvan, 2000) Children were asked to perform two tasks: the first consisted in drawing a bicycle with a view to explaining how it works; in the second, children had to describe verbally the functioning of the bicycle. The experimenter wrote down the whole discourse.

The experiment was composed of three sessions: an individual pre-test session, a collaborative work session and an individual post-test session. For each session, children had as much time as they needed to perform the tasks. Because previous studies have shown that the order in which the two tasks are performed has no effect, the order of the tasks was not considered as a factor to counterbalance. Thus, in each session, participants first performed the drawing task and then were asked to explain the bicycle’s functioning verbally.

The pre-test session was designed to classify participants according to the four levels previously defined (L-I, L-II, L-III, and L-IV; Jamet, Legros, & Déret, 2000b; Jamet, Legros, & Es-Saïdi, 2003). The classification criterion was a relevance cue obtained by computing the ratio between the number of objects and relevant relations given by the participant and the number of objects and relevant relations of the system. For example, a level IV child is a child who has a total of eight points in the drawing task: the six objects necessary for a bicycle to function (i.e., wheels, frame, pedals, gear, drive chain, gearwheel) as well as the two causal relations (i.e., the “frame” relation and the “chain” relation). So the level IV child has a ratio equal to one. The collaborative work session (test session) took place eight days later and consisted in the same tasks: drawing a bicycle in order to show how it works, and then explaining how it works. The difference with respect to the previous session was that the children performed the tasks in a collaborative work session. Two children of different levels were grouped together (L-I with L-II, L-II with L-III, etc.). They were asked first to discuss the matter and then, after a few minutes, to draw one bicycle only. Then they had to explain together verbally how a bicycle works. Children were reminded that they needed to agree on the quality of the drawing and explanations. The third and last session (i.e., post-test session) took place a week later. Children were again asked to perform the two tasks, but in an individual work session. The goal of this post-test session was to assess the stability of individual performance in comparison with performance in the collaborative work session.

1 CLIS classes are French special education classes.
5. Results

Two analyses were performed. The goal of the first analysis was to compare the drawing content (i.e., the number of bicycle components represented in the drawing) to the content of the explaining discourse (i.e., the number of components mentioned in the explaining text) in the three sessions (i.e., pre-test, test and post-test sessions).

The purpose of the second analysis was to analyze the number of sentences produced that describe an action (i.e., relations between an agent and a relevant element of the bicycle) and the number of sentences that deal with events (i.e., relation between two events). Because collaborative work had been shown, during the planning phase, to facilitate activation of the knowledge necessary for production and hence of children’s long-term memory reorganization (Alamargot, Lambert, & Chanquoy, 2005; Suthers & Hundhausen, 2003), an increase in the number of sentences produced (actions + events) during the collaborative work situation and a stabilization of these results in the post-test session were expected.

5.1. Analysis of the drawing and explaining text contents in the three sessions

An Anova was performed on the number of components mentioned with subjects as random variables and sessions and tasks as within factors. All analyses reported are significant at the .05 alpha level unless otherwise indicated.

A main effect of session was observed, F(2, 42) = 21.76. Planned comparisons revealed that: (1) the number of components mentioned is higher in the collaborative work session than in the pre-test session (3.65 vs 2.18), F (1, 21) = 39.42. This result indicates an effect of the collaborative work situation on the quality of the children’s reasoning. (2) There were no reliable differences in performance between the collaborative work session and the post-test session (3.65 vs 3.33), p > 1. (3) More components were mentioned in the post-test session than in the pre-test session (3.33 vs 2.18), F (1, 21) = 23.96.

The effect of task was also significant, F (1, 21) = 13.79. The data show that production of the representation is easier in a figurative form (3.53) than in a verbal form (2.57).

The session*task interaction was reliable, F (2, 44 ) = 9.57 (see figure 2). It shows a smaller difference in performance between the drawing and explaining tasks in the pre-test (2.4 vs 1.95) and collaborative work sessions (3.9 vs 3.4) than in the post-test session (4.3 vs 2.4). This larger difference in the post-test session is mainly due to the fact that performance in the explaining task declined compared to the collaborative work session, whereas performance in the drawing task remained as high as in the collaborative work session. It is worth noting, however, that performance in the explaining task remains higher than in the pre-test session. Thus, these results indicate that the benefit of collaborative work is still present when the participants performed both tasks individually and so suggest that collaborative work has a long-term effect. Even though collaborative work mainly increases drawing performance, the explaining task also benefits from it.
5.2 Analysis of action and event sentence production

An Anova was performed on the number of sentences produced, with subjects as random variables and both session and type of sentence (action vs event) as within factors.

Again, a main effect of session was observed, $F(2, 42) = 3.07$. Planned comparisons indicate that the number of sentences produced is higher in both the collaborative work (1.0) and post-test (0.96) sessions than in the pre-test session, $F(1, 27) = 5.11$. There were no differences in the number of sentences produced between the collaborative work and post-test sessions, $p > 1$.

The effect of type of sentence was also significant, $F(1, 21) = 53.50$. The data show that participants produced action sentences (1.70) but did not produce event sentences (0.00).

The session* type of sentence interaction was reliable $F(2,42) = 3.07$. It reveals that the difference between the number of action and event sentences produced is smaller in the pre-test session (1.18 vs 0.00) than in both the collaborative work (2.00 vs 0.00) and post-test sessions (1.91 vs 0.00). These larger differences are explained by an increase of the number of action sentences produced in the collaborative and post-test sessions.

Overall, these results confirmed the first analysis in showing that collaborative work has a long-term effect. Furthermore, they reveal that participants did not produce any information about events and thus demonstrate that participants are unable to create causal relations between the components of the bicycle micro-world.
6. Discussion

The results show that performance in the collaborative work situation was better than in the first individual work situation. Thus, they are consistent with the assumption that collaborative work can help to compensate for reduced processing capacities. As shown in figures 2 and 3, the collaborative work situation allows pupils to make significant progress. In addition, the benefit of the collaborative work situation on the quality of causal reasoning is demonstrated; when children subsequently performed the tasks individually again, performance remained as high as in the collaborative work situation. This stabilization in performance indicates a beneficial reorganization of knowledge. The fact that better performance was obtained in the post-test session than in the pre-test session shows that verbal interactions between children seem to promote and/or strengthen knowledge construction.

As expected, the results also indicate that the drawing task was easier than the verbal task. One explanation for this advantage of the drawing task could be that it allows the child to visualize mentally the relevant elements and so to activate and represent the link between those elements. This mental visualization translated to the sheet of paper makes it possible for the child to work from a visual support.

However, the difference between the two tasks is smaller when children are in a collaborative work situation than in an individual situation, probably because collaborative work requires children to share their points of view and thus enrich their representations, which are then verbalized. It is worth noting that the children’s weak linguistic knowledge – such knowledge being necessary to verbal description of their representations – affected the explaining task and can account for children’s difficulties in this task. It seems that the negotiation – about their knowledge – that took place during the collaborative work situation allowed them to overcome difficulties that occurred when they worked individually. Without this activity of disagreement verbalization and mental regulation processes, the child alone would not have been able to question some of his mistaken ideas.

The observation of peer interactions, which will be further investigated in subsequent work, leads to a better understanding of how the negotiation process between two partners facilitates activation of the knowledge needed for the figurative and verbal productions. The collaborative work situation improves sentence production, indicating that negotiation between peers facilitates activation of knowledge about the bicycle micro-world. This knowledge remains available when the child is subsequently placed in an individual work situation again. However, participants activate only intentional causal relations, that is, relations between an agent and an object of the bicycle micro-world. They are only capable of producing processes that describe actions and seem unable to produce processes that describe events, that is, causal relations between components of the bicycle micro-world.
7. Conclusion

Consistent with previous research in the field (Jamet, Legros, & Es-Saïdi, 2003), the present results provide evidence that the population studied is characterized by difficulty in representing the causal relations between world objects and components of micro-worlds. Although these children are able to construct and thus to activate intentional causal relations, they seem to experience considerable difficulties in changing point of view and producing a coherent representation of the world objects’ meaning. It appears that verbal productions do not facilitate reorganization of verbal contents, as previous studies have shown (Eigler, Jechle, Merziger, & Winter, 1991). For those children, production of a text does not seem to enrich the referential knowledge base of the writers. Further research on the knowledge construction and production processes are necessary in order to develop new lines of research and hypotheses (Hoareau & Legros, 2006).

The primary observations of verbal interactions in the collaborative work situation seem consistent with the assumption concerning the learning effect of verbal interactions. According to Scardamalia and Bereiter (1991), in order to reach his communicative goal, the writer constantly reconsiders and adjusts the content of his text (Alarmagot, Favart, & Galbraith, in press; Pudleko, Georget, & Legros, 2002). The collaborative work situation may help subjects take into account the communicative goal and thus may facilitate activation and restructuring of knowledge. This constitutes one interesting line of research – among others – that needs to be investigated further.
8. Bibliography


