Computer Support for Pupils Collaborating: A Case Study on Collisions

Denise Whitelock, Eileen Scanlon, Josie Taylor, and Tim O'Shea

Institute of Educational Technology, The Open University, U.K.

Abstract

This study set out to investigate collaborative learning in pairs of students solving physics problems with a computer. It tested the hypothesis that peer facilitation effects are improved ifparticipants have conflicting models of the task. Subjects working inpairs were more likely to improve their post test scores and to succeed in the problem solving exercise thansubjects working totally alone or alone yet in the presence of others. Ourmain result, which is surprising, suggests that pairs with 'similar' pointsof view did best.

Keywords — Classroom discourse processes, collaboration andconceptual change, collaborative composition.

1. Introduction

This paper reports the results of a study focusing upon the effects of peercollaboration, peer presence and peer absence when subjects are engaged incomputer based physics problem solving activities. We wished to understandmore clearly what were the benefits of working with a partner, i.e. can they all be attributed tointeractional processes? The influential work of Doise and Mugny [1], has given particular impetus to the study of group composition and theirwork predicts that group-generated conflict stimulates the jointconstruction of a more advanced concept which is then individuallyinternalised. This study set out to investigate collaborative learning between pairs of students solving physics problemswith a computer. It tested the hypothesis that peer facilitation effectsare improved if participants have conflicting models of the task. Theresearch takes its direction from Piagetian theory which holds that conflict creates disequilibrium which canthen lead students to attempt the construction of new knowledge. If thetheory is correct, it should follow that peer collaboration should provesuperior to individual learning or situation.

Although there is a body of research focusing on the benefits of peerinteraction in the context of computer use (e.g. Howe et al [2], Light andBlaye [3] and O'Malley [4]), there is now a growing interest into theeffects of social facilitation in computer based learning. Studies with children have foundthat peer presence facilitates problem solving (Joiner et al [5]) and thatgender too has a mediating effect (Loveridge et al [6]).

In the light of this work we were interested in investigating threeissues:

1. Does socio-cognitive conflict maximise learning withinpairs?
2. Do pairs perform better than individuals?
3. What effect does working alone, yet in the presence of others, have uponperformance?

The results from our study indicate that subjects interacting together as pairs do performsignificantly better than subjects working totally alone. However, pupilsworking simply in the presence of others also exhibit a superiorperformance to subjects left to struggle alone. The pupils working alone, yet in the presence of others adopted amore systematic investigation of the domain than subjects working totallyalone. This observation suggests that peer presence has a motivationaleffect while interaction within a pair served to draw attention to critical instances in the simulation whichcould aid further understanding in a domain of known conceptualdifficulty.

2. Method

2.1. Subjects

The pupils, involved in these studies comprised of a selection of fifteenyear olds (mean age = 15.1 years, sd = 0.67) from an 'all-ability' schoolin Hoddesdon, serving a mainly working-class catchment area. Pupils allstudied a double science G.C.S.E. course, which was taught in a modular fashion. The pupils who took part in the collaborative study were paired according to whether they had similaror different views about the motion of pucks sliding on ice after acollision, (data obtained from pre test questionnaire). These groups werebalanced in terms of ability level by the class teachers. We chose to study single sex dyads as this was thecurrent practice for teaching within the school. The subjects who workedalone were randomly assigned to the 'coactive' (i.e. used the computer inthe presence of others) or the 'single' (used the computer totally alone) condition. The numbers in each groupare shown in Table 1 below.

2.2 Procedure

The pupils were firstly pre tested with an extended version of thequestionnaire developed by Whitelock et al [7]. This included a predictiontask where subjects were asked to predict the subsequent motion of two icepucks after collision for the following three cases:

Case 1: Puck A is small and light; Puck B is largerand heavier.

Case 2: Puck A is large and heavy; Puck B is smaller and lighter.

Case 3: Puck A and Puck B are identical.

N.B. Puck A always hits a stationary Puck B.

The subjects were questioned about theirunderstanding of kinetic energy and momentum. Most of these laterquestions were taken from, or adapted from, the APU Science in schools: Age15 report, (Welford et al [8]).

Table 1. Numbers of pupils who worked in the'paired' or "single" condition when using the PuckLand program.

PUPIL GROUP	n
BOYS 'SIMILAR'	22
BOYS 'DIFFERENT'	18
BOYS 'COACTIVE"	12
BOYS 'SINGLE'	14
GIRLS 'SIMILAR'	22
GIRLS 'DIFFERENT'	16
GIRLS 'COACTIVE'	9
GIRLS 'SINGLE'	9

The pupils were taken (in pairs or as singles) to a sixth formteaching room where a Macintosh SE computer was set up on a table. In the'coactive' condition i.e. where subjects worked alone yet in the presenceof others, the sixth form teaching room contained seven Macintosh computers. and subjects could see each other'sscreens. Only the pairs were videotaped.

2.3 The Computer Simulation

The PuckLand simulation was written in Hypercard 2 for use with the AppleMacintosh computer. It used a direct manipulation approach, (Shneiderman[9]) which allowed students to investigate a series of collisions betweentwo ice pucks. It consisted of a pair of pinball-style flippers on either side of the screen with whichsubjects could flick pucks. The amount of force with which the flippershit the pucks could be varied, as could the mass of the pucks. The icepucks, ranging from 1 to 100 units of mass, could be dragged into position ready to be struck by theflippers. The initial velocity of the collision was controlled by directlymanipulating the angle of the flipper from 90 to 180 degrees in the vertical plane. When the "Go" button was activated the pucks moved towards each other on the screen and wereanimated with a speed proportional to that set by the initial angle ofimpact executed by the flipper.

After the pucks collided they moved away fromeach other with a speed which was calculated from the correct physics formalisms. This meant that theprinciples of conservation of momentum and kinetic energy were obeyed andagain the apparent screen velocities of the pucks was proportional to theircalculated values. At the bottom of the screen was a grid which provided numerical information about theamount of energy and momentum that the system had initially, and then,subsequent to being run, it showed what the effect of the collision was onthese two factors. Every experiment attempted by users of the simulation was automatically logged by thecomputer.

2.4 . Using the Simulation

All the subjects, whether they worked in pairs or alone, had access totheir paper and pencil task predictions about the motion of the ice pucksafter collision. They were asked to think about their predictions interms of what sorts of experiments they would like to try with the simulation. Subjects who worked in pairs wereasked to actually discuss their predictions with each other and to try and sort out any differences between them before running their experimentson a Mac SE. All subjects then had access to the computer simulation,where they had time to check out their predictions and to experiment withany other situations which interested them. The subjects working as individuals were also actively encouragedto predict their original predictions against the results given by thesimulation. (N.B. The length of session for each group was notconstrained).

Once the subjects felt they had learnt all they could by experimenting without help with thesimulation they were asked to solve three different problems, which wereposed in order of difficulty. These problems required the subjects not topredict the result of a collision but to state the original conditions for a given outcome. The problems were asfollows:

1. What initial conditions arė needed to send thep-ucks travelling away from each other at the same speed?

2. What initial conditions are needed to make one puck stop after impact?

3. What initial conditions are needed to make puck-sof unequal masses move away, after impact, at the same speed?

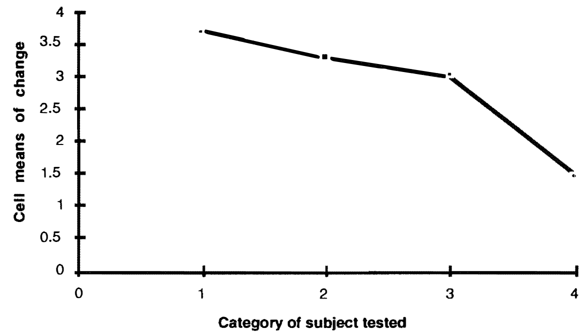
The purpose of the final phase of the experiment was to ascertain whatthe pupils had learnt and so they were asked to describe he most importantfactors that should be taken into account in order to perform thep-rediction task correctly. Since the pupils working alone could not discuss their results they completed awritten summary of their conclusions on their instruction sheet, where they had also recorded their answers to the problem solvingexercises. All subjects were post tested, with the same problems and underidentical conditions as used in the pretest, 3-4 days after they had usedPuckland.

3. Results

The key finding from this experiment is that, of all the groupstested, pairs do best in terms of post test gain. The plot of changescores versus group category (see Figure 1) illustrates that both thesimilar paired condition and the different paired condition perform better than subjects in the single condition. However,the coactives i.e. the pupils who worked alone yet in the presence of others did better than those in the single condition. A one way ANOVAperformed on the pre-post test change scores revealed no overall difference according to condition but apostoripairwise comparisons revealed a significant difference between the changescores of pupils working individually and those working in similar pairs(Fishers protected LSP $p<0.05$). Pupils working in similar pairs made a greater pre to post test improvementthan those working alone. There were no significant differences between'-girls similar' and 'boys similar' post - test scores but the 'similargirls' pretest ($t = 3.2$, $p=0.1$) was significantly lower than the others. The dialogues led us to suspect thatthe girls had less experiential knowledge of collisions than the boys andthis affected their predictions, (i.e. they did not play snooker, footballor even hockey and did not use analogies from any sporting experiences to make predictions). This findingis similar to that reported by (Johnson and Murphy [10]).

As well as looking simply at improvement on pre to post test scoresit was possible to investigate problem solving success when subjects wereusing the simulation alone and in pairs (See figure 2). The three problemswere given in order of difficulty and all the pupils in the paired condition were able to answer question1. This was not the case for 'boys coactive' and boys and girls working alone. In fact the single condition for problem1 is significantly different from that of the 'similar' , 'different' and'coactive' conditions (Fishers protected LSP $p<0.05$).

Figure 1. Graph to illustrate change scores versusgroup category.



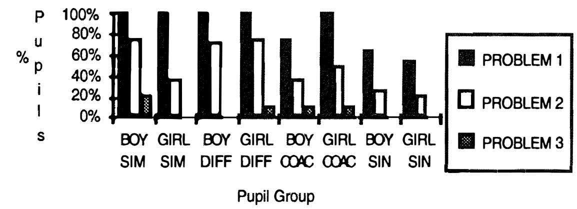
Key: 1 = 'similar', 2 ='different', 3 = 'coactive', 4 = 'single' .

For problem 2 and 3 there were no significantdifference across groups. In fact Problem 3 proved to be too difficultfor most of the subjects. This data supports the Piagetian hypothesis that working in pairs should besuperior to working alone. However we have also found that pupils workingin the presence of others have better scores than those working totally alone. Therefore further analysis of the number and range of experiments performed with Puckland wasundertaken to find reasons for these group differences.

The pupils in the single condition spentsignificantly less total time using PuckLand, (Fishers protected LSP $p<0.05$) than those in the 'similar, 'different' and 'coactive' conditions . Thereis no significant difference between the time spent by pairs in theexploratory phase but significant differences between the pairs andthe single condition and the pairs and the coactive conditions in this phase. The pairs, like the coactives,spent longer exploring the domain before they wanted to complete theproblem solving tasks. These results suggest that one of the factorscontributing to problem solving success with this simulation is allowing enough time to become familiar with thedomain before rushing into the problem solving.

One very interesting finding from the analysis is that the girlsbenefited more than the boys from the 'coactive' condition. Theypersevered longer with the experimental phase than the boys in the'coactive' condition. They were more conscious of what their peers were doing throughout the whole experiment, making use of theauditory clues provided by the simulation. For example when the sticks hit the puck there is a sound which is followed by a loudernoise when both pucks collide. They used this cue to assess how theirpeers were progressing and hence continued with the work while theyunderstood others were persevering with the task in hand.

Figure 2. Percentage of pupils who solved each ofthe Puckland problems.



Key: Sim = 'similar' partner, Diff ='different' partner, Coact = 'coactive' (working alone but in the presence ofothers), Sin = 'single'

To summarise: the pairs investigated all the scenarios where our previous work hasshown pupils experienced conceptual difficulty. The 'coactives' and'singles' did not exhibit an identical behaviour but unlike the pairs thecoactives experimented with limiting conditions cases. The lack of investigation of critical events by pupilsworking alone suggests that a partner can draw attention to unexpectedphenomena. This aspect was the missing ingredient from the 'coactive' and'single' conditions. It is suggested that working in pairs can encourage a "predict, observe and explain"modus operandi which in turn can facilitate subjects "seeing" theunexpected phenomena.

4. Conclusion

The results indicate that on this computer-based investigation subjectsworking in pairs were more likely to improve their post test scores and tosucceed in the problem solving exercise than subjects working alone. However there was no significant difference between the pairs. The Video analysis of the interaction between thepairs revealed more instances of conflict among the different pairs however,there were far fewer conflicts than expected, in fact only 28 in total with16 recorded among the different pairs. All subjects however, tried toresolve these conflicts but only one remained unresolved among the similar pairs and three were unresolved amongthe different pairs. Two separate strategies were employed to resolveconflict these were achieved by appealing to the computer for the correctanswer and secondly by talking the problem through by themselves. Resolution of conflict by the computer wasused more frequently by 'different' pairs and the other strategy of talkingthrough the problem was used more by the 'similar' pairs. This resultsuggests that co-operative construction of shared meaning maybe a more important consideration than conflictin successful collaboration (Barbeiri and Light [11]).

We found that subjects working in the 'coactive'or 'single' condition perform more experiments than the pairs. However, it was not the number but type of experiments investigated that was animportant factor in understanding the nature of collisions. Both the pairsand the singles spent more time exploring the domain before attempting theproblem solving exercises. Not only were the range of experiments different within the groups but moreimportantly the approach. It appeared that the pairs did better becausethey adopted a "predict, observe, explain" modus operandi which was notattempted by the pupils working as individuals in the 'coactive' or in the single condition. This observationsuggested that peer presence had a motivational effect and that anxiety waslowered when subjects worked in the presence of others. This appeared areasonable conclusion since two subjects in the single condition were so stressed they abandoned theexperiment less than half way through. The 'coactives' performed betterthan the singles and also felt they had learnt more as revealed by theircomments at the end of the experiment.

Similar' pairs did perform significantly better than pupils workingtotally alone and although they performed better than the 'coactives', there was a benefit not only from peer interaction but also from peerpresence. In our case peer presence prevented subjects from giving up, they felt more relaxed and persevered in aproductive fashion exhibiting less trial and error behaviour than thesingles. The magnitude of such peer presence effects is controversial. (e.g. Light et al [12], and Mevarech et al [13].

Our results suggested that a "predict, observe, explain" methodology(see e.g. Champagne et al [14], aids subject understanding of a domain. The adoption of this strategy has proved to be successful when used by bothHennessy et al [15] and Howe et al [2]. Although Howe's work has found that most benefits occur whenmembers of a pair have different views we have found that children canprogress without necessarily having reached a more advanced solution duringinteraction. An important finding from our study is that the performance gains by the 'coactive'group suggested that it was not just the interaction but the physicalpresence of others sharing the same task which lowered anxiety levels andincreased subject motivation although we did not collect measures of these, our results are based on observationsof subject behaviour. To conclude our main result is surprising and doesnot support one popular view of the benefits of collaboration. Oursubsidiary results cast light on the role of experiments in developing pupils conceptual understanding, modes ofcollaborative working and the design of interactive learningenvironments.

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Authors' Addresses

Denise Whitelock, EileenScanlon, Josie Taylor and Tim O'Shea: Institute ofEducational Technology, Open University, Walton Hall, Milton Keynes, MK76AA, England. email: d.m.whitelock@open.ac.uk.