

An investigation of the classroom use of prediction-observation-explanation computer tasks designed to elicit and promote discussion of students' conceptions of force and motion.

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Paper presented at the 2000 National Association for Research in Science Teaching Annual Meeting, April 28 – 31, 2000, New Orleans, LA, USA.

ABSTRACT

This paper reports on the results of a case study of two Physics classes using an interactive multimedia computer program. The program used digital video clips to encourage student discussion about their own ideas and to elicit their preconceptions prior to instruction in physics in Year 10 and 11. The video clips showed difficult, expensive, time consuming or dangerous demonstrations of real, observable events, primarily focussing on projectile motion. A predict-observe-explain (POE) format supported the students' interactions with the program. In this computer learning environment, students worked in pairs and were required to type full sentence responses that were recorded by the computer for later analysis by the researchers and teachers. In addition, the students were required to make pencil and paper drawings during some tasks. Other data sources for this study included interviews with selected students and their teachers, classroom observations, and student questionnaires. This paper reports on the findings from the study with a focus on the student conversations whilst using the program. The findings have implications for the effective use of multimedia to enhance meaningful learning in physics classrooms.

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BACKGROUND

The constructivist view of learning suggests that learners construct their own knowledge, strongly influenced by what they already know. In this way, each learner builds his or her own individual sense of 'reality' (Tobin, Tippins & Gallard, 1996). Constructivism encourages teachers to recognise these strongly held preconceptions which children bring to the classroom and provide experiences that will help them build on their current knowledge of the world (Duit & Confrey, 1996).

Social constructivism acknowledges that learning is a social activity in which learners are involved in constructing consensual meaning through discussions and negotiations. During these discussions, students can identify and articulate their own views, exchange ideas and reflect on other students' views, reflect critically on their own views and when necessary, reorganise their own views and negotiate shared meanings (McRobbie and Tobin, 1997, Prawat, 1993, Solomon, 1987). Although individuals construct their own understandings, it is not done in isolation but in a social context.

From a social constructivist perspective, the development of understanding by writing and discussion of ideas with peers is an essential element in learning... (McRobbie & Tobin, 1997, p.199)

Probing student understanding

If students are to experience meaningful learning they must review and if necessary reform their strongly held personal views. Hence, the elicitation of student ideas is central to any teaching approach informed by constructivism (Driver & Scott, 1996). Student interviews, concept maps, student journals and diagnostic multiple choice tests are techniques which have been used as probes of student understanding for these purposes (Treagust, Duit, & Fraser, 1996). As well as identifying preconceptions, these processes of eliciting ideas can also offer an opportunity for student learning (Duit & Confrey, 1996). From a social constructivist perspective, if students' ideas are elicited in a social setting, they receive an opportunity to articulate and clarify their own preconceptions, reflect critically on their own and others' ideas and possibly co-construct reformulated ideas.

The predict-observe-explain (POE) strategy

White and Gunstone (1992) have promoted the predict-observe-explain (POE) procedure as an efficient strategy for eliciting students' ideas and also for promoting student discussion about their ideas. This strategy involves students predicting the result of a demonstration and discussing the reasons for their predictions; observing the demonstration; and finally explaining any discrepancies between their predictions and observations.

Whether used individually or in collaboration with other students, POE tasks can help students explore and justify their own individual ideas, especially in the prediction and reasoning stage. If the observation phase of the POE task provides some conflict with the students' earlier prediction, reconstructions and revision of initial ideas is possible (Searle & Gunstone, 1990; Tao & Gunstone, 1997).

The use of POE tasks has been reported extensively in the literature. The procedure was developed at the University of Pittsburgh (Champagne, Klopfer & Anderson, 1980) and has been used to investigate student ideas in studies by Baird and Mitchell (1986), Gunstone, Champagne and Klopfer (1981), Gunstone and White (1981), Liew and Treagust (1995) and Palmer (1995). The POE technique has been discussed in Driver (1983), Driver, Guesne and Tiberghien (1985), Gunstone (1990, 1995), Gunstone and Champagne (1990), Searle (1995), White (1988), and White and Gunstone (1992).

Using POE tasks within a computer environment

A computer environment permits more intimate, small group interactions with the POE tasks, giving students control of the demonstrations and allowing the teacher more time to interact with students. This is in contrast to the more common strategy of using whole class, teacher-led POE tasks. These collaborative small groups encourage the social interactions and personal reflections which are so important in the social constructivist classroom.

A computer environment can support the sequencing and presentation of POE tasks. For example, the program used in this study did not allow the students to view the video of a demonstration (the observation phase) until their predictions and reasons were completed. (Indeed it was not possible to change these responses after viewing the video clip.) A computer program can also automatically and efficiently place students' written responses into a database or text file for future teacher reference.

A computer environment can also support the use of the digital video medium to present the physical scenarios which are the focus of the POE tasks. Digital video clips allow events to be slowed down, played 'frame by frame' or replayed numerous times, creating more sophisticated ways of observing events. The video clips also allow students to view accurate replications of demonstrations.

The digital video clips can provide realistic contexts for the students to consider as they engage in the POE tasks. The clips can show dangerous, difficult, expensive or time consuming demonstrations not normally possible in the classroom. For example, one clip used in this study shows footage of an astronaut on the moon. Such real-life scenarios can make science more relevant to the students' lives (Duit & Confrey, 1996; Jonassen & Reeves, 1996), and help students build links between their prior experiences and abstract models and principles of physics (Escalada & Zollman, 1997).

Previous studies of POE tasks in a computer environment.

The use of POE tasks within a computer environment has been reported sparingly in the literature. Tao and Gunstone (1997) used computer supported POE tasks to investigate whether and how collaborative learning at the computer fosters conceptual change. The students' responses were written on paper and the POE tasks were presented as abstract computer simulations. Students had to predict what would happen if certain changes were made in their 'Force and Motion' microworld.

Two other recent studies used computer programs to promote student predictions and observations of various events in physics, although they did not specifically refer to the POE strategy. Gorsky and Finegold (1992) made a conceptual change study in Mechanics whilst Goldberg and Bendall (1996) reported on a program used for facilitating learning in geometrical optics. In this program, students were presented with a situation where they made a prediction about certain optics problems. They then observed what happened on the computer simulation, evaluated their observation and compared it with their prediction.

However, the use of digital video (within a computer program) to present 'real life' demonstrations within a POE framework has not been reported in the science education literature.

THE STUDY

The findings discussed here are from an interpretive study of a Year 11 physics class and a Year 10 science class using 16 POE computer tasks incorporating digital video clips of real life events. Students used the program in collaborative pairs at the beginning of their study of motion for the purpose of eliciting and promoting discussion of students' preconceptions of force and motion. The study does not attempt

to address conceptual change issues but rather focuses on the use of the program to promote discussion, reflection and probing of students' science views.

The study adopted a social constructivist perspective to investigate the students' conversations as they used the POE computer tasks (the focus of this paper). The study also set out to understand the students' and teachers' individual interpretations of their experiences with the computer program; as well as to investigate the actual force and motion preconceptions elicited by the program. An interpretive methodology was used in the study (Guba & Lincoln, 1989).

Research Questions relevant to this paper

The main research question that this study investigated is "To what extent do the POE computer tasks promote discussion about students' science ideas?"

Three subsidiary questions were:

To what extent do the students articulate, justify and reflect on their own ideas?

To what extent do the students reflect on the viability of their partner's ideas?

To what extent do the students co-construct ideas and negotiate shared meanings?

Participants

The two classes which participated in this research were primarily chosen because of the interest expressed by the teachers associated with them. Both teachers were highly respected by their peers and were considered to be highly skilled teachers. They were both familiar and comfortable with constructivist teaching strategies and appreciated the value of students discussing and reflecting on their science conceptions in collaborative settings. Each teacher had over 15 years experience teaching science.

Each class was familiar with cooperative group work and POE tasks in a normal, non-computer environment. The first class was a Year 11 physics class following the Higher School Certificate (HSC) physics course in NSW, Australia. The class consisted of 19 girls and their female teacher. The second class was a Year 10 advanced level science class from a different school and consisted of 27 boys and their male teacher. (N.B. gender differences were not a focus of this study.)

Computer program used in this study

Sixteen POE tasks were used in this study (see Table 1 for brief description of each task). They were created by the first author within a computer environment using the multimedia authoring software: Macromedia Authorware. Demonstrations within the POE tasks were presented using digital video clips. About half of the video clips were filmed by the first author and the other half were obtained from commercial VHS tapes after copyright permission was granted. The demonstrations consisted mostly of events which presented 'real world' contexts to the students, although a few featured laboratory equipment which would be difficult or time consuming to set up. Where the outcomes of the demonstrations were limited, students made their predictions using a multiple choice format. When pathway predictions were needed, students made drawings for both their predictions and observations. Reasons for predictions, observations and explanations were always required to be typed using full sentences. All multiple choice selections and written responses were recorded on the computer.

Domain of study

The topic of motion (mainly projectile motion) was chosen as the domain for the study for three reasons. Firstly, there was ample literature on student alternative conceptions in mechanics to aid construction of the POE tasks and for use in later analyses of students' elicited preconceptions. Secondly, motion is an essential part of all introductory physics courses. Finally, there were sufficient numbers of digital video clips available for the program.

Alternative conception research on mechanics (Caramazza, McCloskey & Green, 1981; Clement, 1982; Eckstein, 1997; Fischbein, Stavy & MaNaim, 1989; Halloun & Hestenes, 1985a,b; McCloskey, 1983a,b; McDermott, 1984; Millar & Kragh, 1994; Twigger, Byard, Driver, Draper, Hartley, Hennessy, Mohamed, O'Malley, O'Shea & Scanlon, 1994; Whitaker, 1983) informed the selection and creation of the video clips. Common misconceptions emerging from this literature also informed the design of the multiple-choice options offered in the prediction stage of the POE tasks. Most video clips were designed to elicit different variations of pre-Newtonian alternative viewpoints. Where possible, abstract situations discussed in the literature were adapted to an everyday context for the video clips used in this study. For example, the pendulums discussed in Caramazza et al. (1981) and McDermott (1984) were adapted to a child on a swing (Task 8). In some cases, similar contexts could be created. For example, the scenario of a running person dropping a ball as discussed in McCloskey (1983a) was adapted to the video clip of a walking child trying to drop a small ball into a cup on the ground (Tasks 10 and 11). In other cases, contexts were changed to become more familiar with the students. For example, the canon ball discussed by McDermott (1984) was adapted to a soccer ball kicked into the air by a boy (Task 7). Speed variations (Tasks 4 and 5) and mass variations (Tasks 5 and 6) were incorporated into some of the tasks to help elicit student views relating to 'impetus' theory.

Three video clips (in Tasks 1, 2 and 9) were related to vertical motion only. They were designed to elicit alternative viewpoints relating to one-dimensional motion. The remaining videos covered both half flight and full flight projectiles. Projectiles used in the video clips covered both active and passive launches (Millar & Kragh, 1994).

Data collection and brief description of lessons

The following data sources were used in the study: participant observation, collected documents, audio and video recordings, semi-structured interviews and questionnaires.

The students and the teacher initially completed two background questionnaires that provided some quantitative data for the project. The first was devised for the purpose of becoming familiar with the students' background and previous experience using computers. The second, a revised version of the Constructivist Learning Environment Survey (Taylor, Fraser, & White, 1994), was used to gain an insight into the students' and teacher's perceptions of their normal classroom learning environment.

The study mainly employed qualitative research techniques for collecting data. Classes were observed both before and after the computer sessions. There were frequent informal interviews with the teachers and documents were collected during visits to the classes. For example, the Year 11 students did some teacher directed POE tasks using ticket tape during a lesson leading up to the computer sessions. Their responses during these tasks were collected.

The students worked in pairs with the program for two lessons at the beginning of their unit of study in Motion. During this time they completed 16 POE computer tasks. The typed responses were automatically stored in a text file on the computer as a source of data for the study. Student drawings completed during the computer sessions were also used as a data source. Student conversations and teacher discussions with groups were recorded on audiotape. Sample group interactions of students using the program were filmed using a video camera.

Immediately after completing the computer sessions, all students and their teacher completed a questionnaire about their experiences during the computer lessons. These were completed individually. Several days later, some students and their teachers were formally interviewed. Students were selected for these interviews by means of 'purposeful sampling' (Bogdan & Biklen, 1982) based on their questionnaire

responses, observations of group dynamics and teacher recommendations. They were interviewed in pairs, using the same groups that worked together during the computer sessions.

Table 1. Description of the 16 predict-observe-explain (POE) computer tasks.

<i>Task Number & Name</i>	<i>Motion Type (Type of Launch)</i>	<i>Description (from Introduction Screen)</i>	<i>Prediction Question and Given Options (from Second Screen)</i>	<i>Related Literature</i>
1. Falling Ball	Vertical (Passive)	The child in the photo is holding a ball. She is about to release the ball so it will fall.	What happens to the motion of the ball as it falls? a) It will get faster. b) It will slow down. c) It will fall at a constant speed. d) Other.	Halloun & Hestenes, 1985, p1049; Hestenes et al., 1992, p156; Champagne et al., 1980; Driver et al., 1994, pp163-165.
2. Rising Ball	Vertical (Active)	The child in the photo is holding a ball. She is about to throw the ball upwards.	What happens to the motion of the ball as it rises upwards? a) It will get faster as it rises. b) It will slow down as it rises. c) It will rise at a constant speed. d) Other.	McDermott, 1984, p30; Halloun & Hestenes, 1985, p1049; Enderstein et al., 1996, p490, 491; Clement, 1982, p67; Driver et al., 1994, pp163-165.
3. Ball Throw	Half Projectile (Active)	Flight A tennis ball is about to be thrown by a person from left to right. The ball will initially be thrown horizontally as shown by the green arrow in the photo.	What is the shape of the pathway that the ball follows while it is in the air? Paper drawing required.	Halloun & Hestenes, 1985, p1062; McCloskey, 1983, p116; McCloskey, 1983, p305; Halloun & Hestenes, 1985, p1058; Hestenes et al., 1992, p156 (FCI Q16); Eckstein et al, 1997,p1065.
4. Slow Ball Jump	Half Projectile (Active)	Flight A tennis ball is about to roll off the table as shown in the photo. The ball is travelling SLOWLY from left to right. <i>Note: The projectile is launched in a different way from Task 3</i>	What is the shape of the pathway that the SLOW ball follows while it is in the air? Paper drawing required.	See McCloskey, 1983, p116; McCloskey, 1983, p305; Halloun & Hestenes, 1985, p1051; Halloun & Hestenes, 1985, p1058; Hestenes et al., 1992, p156 (FCI Q16); Eckstein et al, 1997,p1065.
5. Fast Ball Jump	Half Projectile (Active)	Flight A tennis ball is about to roll off the table as shown in the photo. The ball is travelling FAST from left to right.. <i>Note: The velocity of the projectile has increased from Task 4.</i>	What is the shape of the pathway that the FAST ball follows while it is in the air? Paper drawing required.	See McCloskey, 1983, p116; McCloskey, 1983, p305; Halloun & Hestenes, 1985, p1051; Halloun & Hestenes, 1985, p1058; Hestenes et al., 1992, p156 (FCI Q16); Eckstein et al, 1997,p1065.
6. Car Launch	Half Projectile (Active)	Flight The HEAVY car in the photo is about to be driven off the cliff while travelling quite fast. It is travelling from left to right. The cliff is approximately 20m high. <i>Note: The mass of the projectile has increased from Tasks 4 & 5.)</i>	What is the shape of the pathway that the HEAVY car follows while it is in the air? Paper drawing required.	McCloskey, 1983, p116; McCloskey, 1983, p305; Halloun & Hestenes, 1985, p1051; Halloun & Hestenes, 1985, p1058; Hestenes et al., 1992, p156 (FCI Q16); Eckstein et al, 1997,p1065.
7. Soccer Ball	Full Projectile (Active)	Flight The soccer ball in the photo is about to be kicked ""downfield" (from left to right on your screen) by a soccer player. The ball will travel through the air (not along the ground).	What is the shape of the pathway that the soccer ball follows while it is in the air? Paper drawing required.	McCloskey, 1983, p114B; McCloskey, 1983, p308; Halloun & Hestenes, 1985, p1063.
8. Ball & Swing	Half-Full Projectile (Passive)	Flight The person is riding on a swing. He is holding a tennis ball in his outstretched hand. On the next swing forward, the boy will release the ball (while continuing to move forward on the swing) at the point marked "X" on the screen, just BEFORE he reaches his maximum height.	What is the shape of the pathway that the ball follows while it is in the air (after the boy releases it)? Paper drawing required.	Caramazza et al., 1981, p117; McCloskey, 1983, p311)

9. The Astronaut	Vertical (Passive)		The astronaut in the photo is on the moon. He has a hammer in his right hand and a feather in his left hand and will release both objects at the same time. Both objects are held at the same height above the moon's surface.	Which object will hit the moon's surface first? a) The feather. b) The hammer. c) Both at the same time.	McDermott, 1984, p30; Halloun & Hestenes, 1985, p1049; Enderstein et al., 1996, p490, 491; Clement, 1982, p67; Driver et al., 1994, pp163-165.
10. Heavy Ball & Cup	Half Projectile (Passive)	Flight	The student is walking at a constant pace from left to right. There is a cup placed on the ground ahead of her. She has a HEAVY ball in her hand and will release it (while walking) when her hand is directly above the cup.	Where will the HEAVY ball land? a) It will land behind the cup (at A). b) It will land in the cup (at B). c) It will land in front of the cup (at C).	McCloskey, 1983, p114A & 122; Halloun & Hestenes, 1985, p1062; Hestenes et al., 1992, p157 (FCI Q23); McCloskey, 1983, p303; Fischbein et al., 1989, p71.
11. Light Ball & Cup	Half Projectile (Passive)	Flight	The student is walking at a constant pace from left to right. There is a cup placed on the ground ahead of her. She has a LIGHT ball in her hand and will release it (while walking) when her hand is directly above the cup. <i>Note:</i> The mass has decreased from Task 10.	Where will the LIGHT ball land? a) It will land behind the cup (at A). b) It will land in the cup (at B). c) It will land in front of the cup (at C).	McCloskey, 1983, p114A & 122; Halloun & Hestenes, 1985, p1062; Hestenes et al., 1992, p157 FCI Q23; McCloskey, 1983, p303; Fischbein et al., 1989, p71.
12. Sailing Boat	Half Projectile (Passive)	Flight	The boat in the photo is moving from left to right at a constant speed. There is a ball attached to the top of the mast. The ball will be released and fall while the boat continues to move with the same speed.	Where (on the moving boat) will the ball land after it falls? a) It will land to the left of the mast. (at A). b) It will land directly below the mast (at B). c) It will land to the right of the mast (at C).	McCloskey, 1983, p114A & p122; Relate to Millar & Kragh, 1994, p29; et al., 1992, p156 (FCI Q23).
13. Falling Balls	Half Projectile (Active)	Flight	The two balls in the photo are at the same height above the ground. They will be released at the same time. The ball on the left will be launched horizontally to the left. The ball on the right will be released from rest and fall vertically down.	Which ball will hit the ground first? a) The ball on the left. b) The ball on the right. c) Both will land at the same time.	McCloskey, 1983, p116; Halloun & Hestenes, 1985, p1052.
14. Cart & Ball I	Full Projectile (Active)	Flight	The cart is moving horizontally from left to right at a constant speed. There is a small ball in the tube at the centre of the cart. The ball is about to be launched vertically upwards out of the tube (while the cart continues to move at the same speed to the right).	Where will the ball land? a) To the left of the cart. b) To the right of the cart. c) Back in the cart.	Millar & Kragh, 1994, p28.
15. Cart & Ball II	Half-Full Projectile (Active)	Flight	The cart is "falling" under gravity from left to right down the slope. There is a small ball in the tube at the centre of the cart. The ball is about to be launched out of the tube (while the cart continues to move down the slope).	Where will the ball land? a) To the left of the cart. b) To the right of the cart. c) Back in the cart.	
16. The Hose	Full Projectile (Active)	Flight	The person in the photo is holding a hose. In photo A, the hose is held between 0 and 30 degrees to the horizontal. In photo B, 30 to 60 degrees. In photo C, 60 to 90 degrees.	What angle will produce the largest horizontal range of the water? a) 0 to 30 degrees. b) 30 to 60 degrees. c) 60 to 90 degrees.	

FINDINGS

The outcomes of this investigation are presented as four assertions and are supported by quoted learning conversations that represent critical incidents which occurred during the computer sessions. All names used in the following findings are pseudonyms.

Assertion 1: The POE computer tasks encouraged students to articulate and justify their own conceptions.

Most groups of students attempted to reflect on and articulate their ideas and thoughts as they made their predictions and reasons for the POE tasks. The rich contexts encouraged the students to think about and articulate their ideas relevant to the problems posed.

Articulation

Dave explained his thinking to his partner when predicting which ball would hit the ground first in Task 13. In this task, two balls are launched from a given height simultaneously. One is launched horizontally and the other falls vertically from rest. Dave tried to support his explanation with his own theory about the fastest route between two points:

Dave: That one I reckon, don't you?
Paul: Yes, the ball on the right.
Dave: Because that one (ball launched horizontally) has been propelled upwards and then it can go down where as that one (the ball falling vertically) is just going straight down and is less...and also I reckon the fastest gradient between two points is a straight line...
Paul: I agree.

Although Paul was very much the dominant partner in this group, he seemed to respect that Dave had made such an effort to articulate his thoughts.

Sam reflected on the amount of gravity on the moon in Task 9. In this task, an astronaut on the moon drops a hammer and a feather from shoulder height. Sam initially believed that that the hammer would hit the ground first but was unsure of the conditions on the moon. Sam paused to think about and question his ideas on the amount of gravity on the moon:

Laurie: What do you think?
Sam: Oh - the hammer!
Laurie: I say both.
Sam: Is this on the moon?
Laurie: Yeh.
Sam: OK - both at the same time. Because there's no gravity on the moon.
(Pause).
There's no gravity?
Laurie: Yes - a little bit.
Sam: Oh that's right.

Sam reflected on his initial intuition that there was no gravity on the moon. He questioned his partner about this and needed little persuasion to reconsider his preconception.

Alison and Jessica tried to find a reason (although a partially incorrect one!) for their prediction that the ball would land back in the moving cart in Task 14. Interestingly, Jessica starts the 'meaning making' by asking her partner to "explain it", but then proceeds to form her own explanation.

Alison: It'll go back into it, do you think? Back into the tube. Do you think?
 Jessica: Probably. (uncertain) Explain it!
 Alison: Oh, I don't know how to explain it. Because
 Jessica: (Interrupting) Because the cart's moving and the ball is moving
 Alison: (Interrupting) No, because
 Jessica: (Interrupting) Because the cart is exerting a force on to the ball!
 Alison: Yeh, yeh.
 Jessica: Yeh. Until the gravity acts on it and pulls it back down again.

Although Alison's contribution is minimal here, her mere presence seems to initiate some more 'deep thinking' about the problem by Jessica.

Justification of ideas

Students often disputed each other's ideas, giving group members a chance to justify and defend their views. This usually occurred during the prediction or observation stages of the POE strategy.

Laurie chose to justify his reasoning in Task 12 after his partner disagreed over the prediction that the ball falling from the moving sailing boat would land at the foot of the mast. However, Sam remained unconvinced with Laurie's ideas:

Laurie: It's B.
 Sam: Well, the boat's still moving (disagreeing with Laurie's prediction)
 Laurie: Yeh, but the ball is part of the boat. Like the ball will move (forward) as well. (Defending his own views)
 Sam: I reckon it will fall, because the boat is moving faster. I'm going to predict A.

Cath and Michelle disagreed with each other in Task 8. In this task, a boy is moving forward on a swing and passively releases a ball. After stating her disagreement with her partner, Cath defends her view by explaining her reasons:

Michelle: I think ... so he's travelling up, then just lets it go so I think it'll just go straight down wouldn't it?
 Cath: Even though he's not ... the whole swing motion has been executed...
 Michelle: But he's not throwing it; he's bringing it forward and letting it go ... but it'll go forward so it'll go like this wouldn't it? (Michelle shows Cath the drawing of her predicted pathway.) Maybe a bit sharper.
 Cath: No I don't think that's right. Because the swing is still moving so its giving the ball a bit of (forward) velocity. (Defending her own views)
 Michelle: OK. (In agreement)

Paul and Dave had a small dispute over the drawing of their predicted pathway of a slow ball rolling off a table in Task 4. Dave's disagreement with Paul's prediction eventually caused Paul to justify and defend his view:

Paul: ...it's going to go down more than out.
 Dave: No. My prediction is its going to go down heaps faster. It'll go out a little bit and then go down. Not much though. How do you like that? (Dave makes a draft drawing)
 Paul: But the thing is its going slowly...go back a bit...I reckon its going a lot slower than that Dave.
 Dave: Like that? (Dave now edits the drawing.)
 Paul: Yeh - I reckon its more like that Dave.
 Dave: Oh yeh - ok. (not quite convinced)
 Paul: It's going so slow, it'll only get pushed out from the table a little bit before it goes down. (Defending his own views)

Many of the tasks requiring students to respond in a drawing format initiated rich discussions. Perhaps this was due to the challenging task of describing these

trajectories in the students' everyday language or perhaps it was because the outcome required close analysis and interpretation of the video clips. The high incidence of students editing their drawings was testimony to these meaningful discussions. This occurred both during the prediction and observation stages. (There were numerous incidents where groups changed their drawing up to three times!)

Students' limited science vocabulary sometimes restricted the extent of students' articulations

Although many students attempted to explain their views, choosing the correct science jargon in order to articulate ideas and views was a real challenge for many groups. Anne had trouble finding suitable words as she tried to predict which ball would hit the ground first in Task 13:

Anne: This one (will land first), the ball on the right.
Jane: Yep
Anne: Because it has downward motion where as the other one has sideward motion which is slowing it down; downwards, that way. (laughter)
Jane: I know what you mean! Well that's going to take longer because its acceleration is horizontal
Anne: (interrupting) where as the other one's acceleration is downwards...Yes I know what I mean. I just don't know how to say it.
Jane: Yes I hate that.

As these students were at the start of their Physics course they had little experience in attempting to describe two dimensional motion. Without realising it, Anne chose the words 'downwards' and 'sideways' to represent the vertical and horizontal motion respectively but still had trouble describing her prediction.

The term 'range' was introduced to students in Task 16 on the introductory slide. Jilly and Rochelle eventually used this new word in the context of this task. As Jilly was searching for the correct word to describe the horizontal distance covered by the water emerging from the hose, her partner helped her with the dilemma:

Jilly: Should we talk about how it decreased. After that angle, it decreased.
Rochelle: The angle decreased.
Jilly: After C, the length of the water
Rochelle: Ah the...
Jilly: The...
Rochelle: The range
Jilly: Yes the range

It must be noted that the author of the program was very careful to use words in the program that the students would be familiar with. For example, the terms 'speeding up' or 'slowing down' were used instead of the word 'acceleration' in the program. Indeed one of the cognitive outcomes of this program was that students received an opportunity to 'talk science' and use the 'register of science'. However this outcome is not the focus of this study.

Student perceptions relating to articulation and justification of ideas

Students generally perceived a high quality of discussions occurring during the computer sessions. As shown in Table 2, on items 1 and 2 in particular, students were emphatic that the POE computer tasks encouraged them to talk about and debate their ideas.

Table 2. Responses to items about student perceptions relating to articulation and justification of ideas from the questionnaire: ‘My experiences with the POE computer tasks’. (n=46)

<i>Item</i>	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i>	<i>Agree</i>	<i>Strongly Agree</i>
1. The computer tasks encouraged us to talk to each other about our ideas	1	1	1	27	16
2. We sometimes argued about our responses.	1	7	8	27	3
28. Talking to my partner during the program helped me to clarify my own ideas about motion.	0	3	5	31	7
49. I often explained my own ideas to my partner.	0	1	9	29	7

Indeed the responses to item 28 from the survey indicated that all students really appreciated the opportunity to work with a partner in order to clarify their own thoughts on ‘Force and Motion’.

Assertion 2: The POE computer tasks encouraged students to reflect on the viability of their partner’s conceptions

Students were very enthusiastic in listening to and evaluating their partner’s views. Both teachers valued and used group discussions frequently in their normal classes and students generally demonstrated mature and thoughtful listening skills.

Jessica and Alison conducted an in-depth conversation about the outcome of Task 1. Although the task was probably the most simple of all 16 tasks in the program, they both made meaningful reflections concerned with the scenario of a ball being dropped to the ground from a height of about 2 metres. In the process of trying to articulate a reason for their prediction, they changed their actual prediction three times! (N.B. This was a common occurrence with many groups who were frequently seen using the ‘back’ button to change and edit their responses.) Jessica initially challenged Alison’s prediction that the ball would speed up:

Jessica: What are our reasons for this prediction (the ball speeds up)?
 Alison: I know but I can’t explain it. Its because it falls and gets faster (laughter)
 Jessica: Why doesn’t it go at a constant speed? Because if I drop my pencil case. Look. (Alison repeatedly drops her pencil case on to the floor!)

Jessica performed a mini experiment at this point to check the viability of her partner’s ideas. She repeated this numerous times and both students reflected thoughtfully on what they saw. Alison began to make analogies with phenomena in space! Jessica again reflected on the viability of her partner’s ideas here by asking pertinent questions to her partner:

Alison: Because it’s getting closer to the ground. And there’s more gravity.(stated in an excited tone)
 Jessica: Is there?
 Alison: Yeh well there’s more gravity closer to the ground than there is further away from the ground. That’s why you ‘spaghettify’ when you fall in a black hole.
 Jessica: Right, OK. I know that up there in space there’s not. But just because - does that mean that there’s more gravity where my feet are compared to where my knees are?
 Alison: Yep.
 Jessica: Really?
 Alison: That’s why you ‘spaghettify’ when you fall in a black hole; because the gravity is so strong - you go whoop! Because there’s so much more gravity here than there is

here (pointing to her knees & feet).
Jessica: Oh, ok (she says reluctantly) Well. We need to give a reason, lets see.

Jessica is still not satisfied at this point. She wants to go back to the prediction page and change their response to 'Constant Speed'. She eventually makes this change, at which point Alison reflects on the viability of Jessica's ideas!

Alison: I don't know, I'm not sure why.
Jessica: I think it would go at the same rate.
Alison: Well change it then. (Alison seems to becoming a little uncertain of her own Black hole theory now!)
Jessica: OK. We'll change it then. (They then go back to their prediction & choose constant speed instead. Alison is reluctant!)
Alison: Why would it fall at constant speed but?
Jessica: Because its not a very long distance?
Alison: (Reluctantly) All right.
Jessica: No no. We'll talk about it. If you disagree with me..
Alison: I don't get it but. I'm not sure..I don't know why would it fall at a constant speed?
Jessica: I don't know. (Pause.) Um....well I guess the acceleration will get faster. You know.

After all this interrogation by both group members, they now change their answer back to 'speeding up'. Jessica tries to articulate her thinking as she types in her response:

Jessica: The ball will get faster because the acceleration will increase because of the gravity as its gets closer to the ground. (Reading as she types.)
Alison: That sounds good. Is that alright with you?
Jessica: Yeh. (In an unconvinced tone of voice)

As they proceeded to the movie, Jessica reveals the sense of anticipation of finding out the 'correct' answer.

Jessica: Either way this could be a learning experience - we'll find out why! (Still unsure about the prediction)

This rich conversation from Alison and Jessica focussed on a very simple scenario of a child dropping a ball! In the course of this conversation, the students changed their prediction three times, performed a 'mini experiment', hypothesized about the nature of gravity on earth, asked each other many questions and interrogated one another's views!

Dave reflected strongly on the views of Paul during the prediction and reasoning stage of Task 12. The task involved predicting how a ball would fall after being released from the top of a mast of a boat moving at constant speed. Students were asked whether the ball would land behind, below or in front of the mast.

Dave: You really don't know because it'll go forward and it'll drop down
(Pause)
Paul: Yeh. But it (the ball) is going at the same speed (as the boat) Dave.
Dave: Yeh (listening carefully)
Paul: If its going at the same speed as the boat, as it falls, it should land at B.
Dave: Yeh but as it falls like ...
(Pause)
Paul: It won't fall backwards (sensing Dave's thoughts)
Dave: Does it lose any (horizontal) speed as it falls?
Paul: No it won't
Dave: As it goes forward? (continuing thoughts from previous question). I reckon A (behind the mast).
Paul: No way. We'll soon see.

After strong consideration of his partner's views, Dave decides to disagree and stay with his intuitive ideas that the boat will continue to move forward and 'leave the ball

behind' during the flight of the ball. Although there was no negotiated meaning making here, there was evidence of both students listening and reflecting on each other's views.

Student perceptions relating to reflection on their partners' ideas

As shown in Table 3, responses to Item 17 indicated that most students felt they had learned something from listening to their partner's views. Indeed, most students felt that they listened attentively to their partner's ideas during the computer sessions.

Table 3. Responses to items on student perceptions relating to reflection on their partners' ideas from the questionnaire: 'My experiences with the POE computer tasks'. (n=46)

<i>Item</i>	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i>	<i>Agree</i>	<i>Strongly Agree</i>
6. My partner's views were of no interest to me.	25	16	3	1	1
15. I often challenged my partner's ideas.	1	8	12	22	3
17. I learned a lot from listening to my partner's views.	2	5	14	22	3
34. I tried to change some of my partner's ideas	1	14	4	24	3
57. I listened carefully to my partner's ideas.	1	2	1	37	5

Although item 34 attracted 'mixed results', it was significant that the majority of the students felt that they had tried to persuade their partner to change their ideas!

Assertion 3: The POE computer tasks encouraged students to reflect on the viability of their own conceptions

Students reviewed their experiences from previous POE computer tasks to reflect critically on their own ideas

Students sometimes recalled previous tasks to help them formulate responses to a task. It was difficult to assess if students had actually accomplished some meaningful learning from these previous tasks or if they were simply 'rote learning' previous task outcomes. The following conversation would indicate the former. During their reflections in Task 12, Cath and Michelle cleverly compared the passive launch of this task with the context of the 'Cup and Ball' tasks (Numbers 10 and 11) completed previously. Michelle initiated the comparison with the cup and ball tasks before Cath elaborated further. Cath and Michelle reflect and build on each other's ideas in the following dialogue.

Michelle: I reckon it'll land in position C (stated confidently)
 Cath: Wouldn't it hit the mast? I say A (behind the mast); the boat is moving forward.
 Michelle: But so was the girl! (from tasks 10 and 11)
 Cath: Oh OK.
 Michelle: Well the other two (tasks 10 and 11) were wrong and we said B.
 Cath: Maybe B then. Because ok, the boat's moving. Before (in tasks 10 and 11) the ground wasn't moving (she says excitedly) and it landed there. Here the boat is moving so it is going to land there. It (the ball) is going to move that way (forward) but the boat's going to move forward too. You know what I mean? B is going to be like C on the ground before (in tasks 10 and 11).
 Michelle: OK. Choose B choose B. I know what you mean, I know what you mean.

It is interesting to note here that Cath and Michelle initially disagreed with each other over the outcome of this task. Michelle's remark comparing task 12 to previous tasks seemed to change Cath's views considerably, to the point where she was elaborating on Michelle's original 'hypothesis'!

Surprising outcomes encouraged students to reflect on the viability of their own ideas

The observation phase of the POE Tasks often produced the stimuli for students to critically review their ideas, especially if their predictions had been incorrect. Leigh and Joan were very surprised when they saw the hammer and the feather reach the moon's surface at the same time in Task 9. Leigh was inspired to review her thoughts:

Leigh: What do you know!
Joan: That's amazing! Obviously the gravity isn't that strong.
Leigh: Does everything fall at the same rate in a vacuum? Does it?
Joan: Yeh - because it (the moon) doesn't have gravity.

Unfortunately Joan compounded the problem by giving an incorrect reason here. In the context of this study, such incidents were most valuable (especially if they were recorded as written responses), as they provided an opportunity for the teacher to assess common 'alternative conceptions'.

After the initial surprise, Anne reviewed her thinking quite accurately after seeing the ball land back into the cart in task 14.

Anne: Oh-there is something wrong about this!
Jane: OK
Anne: Oh yeh. Because the cart's going 'bip' (forward) so that the ball's actually moving at the same forward motion of the cart.
Jane: Oh yeh

Students often used gestures and performed mini experiments to enhance their reflections

A real feature of the students' use of the POE computer tasks was the frequent use of 'off computer' mini experiments by groups. Objects such as coins, pencil cases, pencils and pieces of paper were constantly being thrown into the air, dropped on to the floor or rolled off tables! Melissa, Belinda and Joanna were the only group of three in the study. (They had to form a group of three simply due to a shortage of computers in the room.) Their discussion in task 2 was typical of their dynamic and meaningful conversations conducted throughout the computer sessions. During the prediction phase of this task, Belinda performs a mini experiment to help them predict the motion of a ball thrown vertically into the air.

Melissa: It'll go faster then it will stop at the top and then fall down
Belinda: I don't think it will go faster
Joanna: I think it'll go very fast at the beginning and then slow down and stop before it comes down. I don't know.
Melissa: I think it definitely won't because
Joanna: (Interrupting) Which one should we type?

(Belinda performs an impromptu mini experiment by tossing her pencil case vertically up into the air. This is followed by much laughter)

Belinda: Oh! What did that look like? What did that look like?
Melissa: Do it again

(Belinda repeats again tosses up her pencil case. This time all students look closely.)

Belinda: What did that look like?
 Joanna: It sort of looks like it didn't keep still and then it stopped and came down
 Melissa: Yeh. It came down really fast
 Joanna: Type 'other' (option)
 Belinda: Yeh

Although this was a relatively simple task considering motion in one dimension, this group devoted a lot of time and consideration to their prediction here. After some conjecture over the outcome, Belinda's repeated mini experiment seemed to focus the group's thinking. (Indeed most mini experiments occurring within other groups were also repeated at least twice!) It was also interesting to note that although these students were considering this motion for the first time, Joanna was observant enough to see that the motion comes to 'rest' as the object reaches its maximum height!

Just as noticeable was the use of hand gestures by students as they articulated and reflected on their thoughts. This was particularly evident during tasks requiring the prediction and drawing of pathways. The conversations occurring at these times indicated that students were using these gestures to enhance reflection on their ideas.

Both Jean and Kirstie used hand gestures to help them predict what would happen when a ball rolls slowly off a table in Task 4:

(Using the real table in front of her, Jean repeatedly traces the imaginary path of a ball rolling off it.)

Jean: It's the exertion of the force of gravity on it
 Kirstie: Yeah, but it's got the table too – before it falls to the ground. (Kirstie also uses hand gestures to trace out in the air an imaginary path of a ball falling from a table)
 Jean: (Speaking slowly and thoughtfully) Um – because – it's only got the force... OK there's a little force placed on it from that direction (sideways) which means that the force of gravity will have more effect on it, so it will go straight to the ground.
 Kirstie: Yep. I agree. (Still tracing their predicted pathway with her hand)
 Jean: It'll go straight to the ground because it's got more force on it.

Student perceptions relating to reflection on their own ideas

Only one item from the survey was related to this section (see Table 4). Significantly, a large majority of students felt that they had changed some of their ideas as a result of the learning conversations with their partner.

Table 4. Responses to items on student perceptions relating to reflection on their own ideas from the questionnaire: 'My experiences with the POE computer tasks'. (n=46)

<i>Item</i>	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i>	<i>Agree</i>	<i>Strongly Agree</i>
3. I changed some of my own ideas after talking with my partner.	1	3	5	33	4

Assertion 4: The POE computer tasks encouraged students to co-construct new ideas and negotiate shared meanings with their partner

Although there were many examples of strong reflection on students' ideas, examples of genuine co-construction and negotiation of new ideas were less frequent. This may have been because of the time constraints on the students or perhaps a general lack of confidence in the language or 'register' of science, needed to undertake such a collaborative process. However, a few groups did provide strong evidence of student negotiation and reformulation of ideas.

Negotiated meaning making during the Prediction and Reasoning Phases of the POE tasks.

Alison and Jessica conducted an in depth discussion over their predicted outcome of Task 12. Many groups were challenged by this task and some interesting discussions emerged here.

Alison initially reflected on the viability of her partner's comments before expressing her disagreement over the possibility of a force exerted on the ball as it is released from the mast. Both students then tried to justify and defend their own views:

Jessica: It'll go that way.
Alison: Yep-it'll fall in the back of the boat. (Pause). Because, the ball is falling straight down but the boat is moving
Jessica: (Interrupting) the boat is moving, which exerts a force on to the ball which makes it go back.
Alison: No it doesn't!
Jessica: Yes it does!
Alison: It's not exerting a force on the ball, it's just moving so that by the time the ball hits it, it's moved over. Yes?
Jessica: No!
Alison: Yes! Because if it exerted a force on the ball it would go that way...
Jessica: No but if it hits at a speed, it goes (She uses her hands to gestures her predicted path of the ball)

At this point Jessica struggled to explain her thoughts, a struggle which many groups encountered (as mentioned previously):

Alison: What, no. But if the ball just goes like that...
Jessica: You type then because I don't know how I would express it.

However, Jessica soon overcomes this lack of confidence in her expressions to take part in an effective 'co-construction' of their written response:

Alison: OK. Because..
Jessica: That the boat is moving
Alison: (Paraphrasing) That the boat is moving
Jessica: (Interrupting) So it will fall
Alison: (Interrupting) No...so by the time
Jessica: (Interrupting) it'll be on the left
Alison: (Interrupting) Yeh, by the time
Jessica: (Interrupting) The time it reaches - yeh - I get you!
Alison: By the time the ball reaches the boat, the boat will have
Jessica: (Interrupting) Will have moved!
Alison: Will have moved along (forward). Yeh, that makes sense.
(Pause)
Jessica: Yes, it does.

Dave and Paul collaborated in a similar fashion when they tried to predict the outcome of Task 10. In this task, students considered a person walking at a constant speed. The person releases an object at the moment they are directly above a cup lying on the ground. In the following extract each person is obviously listening attentively to their partner. This attentive listening and collaboration is most obvious in the last few sentences when the students continue to elaborate on the previous speaker's thoughts:

Paul: If she lets it go at X then while she's walking, it should land at C (in front of the cup)
Dave: Yeh
Paul: It won't land in the cup because...the ball continues to move forward

Dave: Like Kinetic Energy or something?
Paul: Yeh - she's applying a force to it as she's walking.
Dave: Yeh - because she's walking, it'll go at the same speed as her.
Paul: Yeh - the ball is going the same speed she is so it will keep travelling forward.

Although the technical language of physics was an obstacle for Dave as he articulated his ideas, he and his partner were able to create some 'shared meaning making'.

Anne and Jane 'bounced ideas' off each other in the process of formulating a reason for their predicted pathway of the slow ball rolling off a table in Task 4.

Anne: Wouldn't it (the ball's trajectory) arch more half way down?...I guess it would arch more...It leaves the table. Rolly, polly...

(Anne continues to draw the pathway.)

Jane: Or would it dip or would it just go straight down? I don't know what do you think? Like umm...

Anne: Yeh

Jane: It'll just like roll a bit

(Jane performs a mini experiment here by rolling a pencil slowly off the table and observing the outcome.)

Anne: Sort of like out a bit

Jane: OK not as much as that but...OK well um....So the ball initially arches slightly away from the table then just drops? (Looking for support)

Anne: Yeh, the ball's motion is still going this way but due to gravity it's dropping. It doesn't land straight down because it's got (forward) motion.

Jane: Yeh, as the ball's motion is still moving away from the table but gravity is pulling it towards the ground.

(Jane rolls the pencil off the table again.)

As one student articulated a response, her partner immediately built on this statement in their next comment. Both students began this dialogue in a tentative manner but increasingly gave each other confidence to formulate a detailed reason. This had the overall effect of the two students 'co-constructing' a mutual reason for their prediction.

Negotiating shared meanings during the Explanation phase of the POE strategy

The explanation stage of the POE strategy allowed students to reconsider their views, particularly after viewing the outcome of a video demonstration which was inconsistent with their prediction. Cath and Michelle tried to negotiate an explanation for their 'incorrect' prediction after viewing the video of the slow ball rolling off a table in Task 4. After a careful comparison between the drawing of their predicted pathway and their video observations, they made a collaborative attempt to explain the observed path of the ball. (They actually attempted this verbal explanation straight after viewing the video clip.)

Michelle: Play it fast first and then I can do it slowly.

Cath: Do you think our (prediction) was a bit more steep than that?.

Michelle: Yeh.

Cath: Or not. I think ours was a bit too steep.

(Pause)

Michelle: Do you think it was more like that? (drawing picture)

Cath: Do you think?

Michelle: Because it wasn't nowhere near that steep.

Cath: Yeh, ok. Do you want to check (with the video) one more time just to make sure?

Michelle: Yeh - it (the ball's pathway) was steeper. That's right.

Cath: That's the bit that's different (pointing to drawing) How can we say it different to what we predicted? (Starts writing the response) It seems to fall steeper at the bottom than it does at the top.

Michelle: It falls in a curve; it curves; it's projected off the table and goes forward and the gravity force slowly pulls the ball down to the ground.
Cath: (slowly and thoughtfully) It pretty much falls though really.
Michelle: Yeh, but I mean it still comes over here (going forward) and falls towards the ground.
Cath: Do you think? It's almost a line. Although it does curve from the top. Maybe it curves before it falls, I don't know.
Michelle: So it gains velocity and falls faster (whilst typing response).
Cath: Yeh.

Like their student colleagues, these students have never formally studied two-dimensional motion and hence these ideas represent a very nice attempt by Cath and Michelle to negotiate some meaning of horizontal and vertical components of a projectile's motion. Cath's comment that the projectile "pretty much falls" (as well as Michelle's following comment) is particularly perceptive as it quite accurately describes the vertical motion of a projectile!

SUMMARY AND CONCLUSIONS

The POE computer tasks encouraged students to engage in rich discussions with their partners about their preconceptions. These discussions occurred mainly at the prediction and reasoning stage and also after surprising outcomes in the observation stage of the POE strategy. Not surprisingly, more detailed discussions were generally observed during the more challenging tasks. (Although the use of a drawing format for student responses seemed to enhance discussions in more 'simple' tasks.) Both students and teachers perceived these discussions to be valuable learning experiences.

Most students freely articulated their ideas to their partner. Students often disputed their partner's views and this gave them many opportunities to defend and justify their own views; often elaborating on a previously articulated idea. However, a limited vocabulary base sometimes impeded the articulation process. This was particularly the case when students attempted to describe or explain the two dimensional nature of projectile motion.

Most students listened carefully to their partner's ideas and there were many instances where students showed strong reflection on the viability of their own and their partner's ideas. Again this mainly occurred during discussions over a disputed prediction and reason or after a surprising outcome. Some students reviewed their experiences from previous tasks and made quite complex and mature comparisons between tasks. One of the features of this student reflection was the high incidence of groups conducting their own 'mini experiments' and 'gestures' as they thought about their responses. The dialogue which accompanied these student initiatives indicated a high level of engagement and reflection on force and motion concepts.

Incidents of genuine co-construction and negotiation of new or reformulated ideas between group members were less frequent. This could be attributed to various influences ranging from the time constraints placed upon the students as they worked through the POE tasks to the students' limited vocabulary and consequent lack of confidence to engage in such 'meaning making'. However, some groups certainly engaged in this process and their co-construction of new ideas was highly successful.

In summary, the use of the POE computer tasks in collaborative pairs served as a learning experience for all students. Students participated in rich and meaningful discussions leading to articulation and reflection on force and motion concepts. In some cases, students reformulated and co-constructed new shared meanings of these concepts. Although not the subject of this paper, the computer program was also used by the teachers in this study as an effective 'probe' to identify and record students' force and motion preconceptions at the beginning of their Mechanics unit.

There has been strong criticism of passive multimedia use in science classrooms (Madian, 1995; Yeo, Loss, Zadnik, Harrison & Treagust, 1998). There has also been criticism of the limited influence and impact of constructivist research findings on the practice of science education in the classroom (Ben-Zvi & Hofstein, 1996). This study attempts to respond to these criticisms by providing an example of an effective use of multimedia to enhance constructivist teaching strategies in the science classroom.

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