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Classroom Use of Multimedia-Supported Predict–Observe–Explain Tasks in a Social Constructivist Learning Environment

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Abstract

This paper focuses on the use of multimedia-based predict–observe–explain (POE) tasks to facilitate small group learning conversations. Although the tasks were given to pairs of students as a diagnostic tool to elicit their pre-instructional physics conceptions, they also provided a peer learning opportunity for students. The study adopted a social constructivist perspective to analyse and interpret the student's conversations, focussing on students' articulation and justification of their own science conceptions, clarification of and critical reflection on their partners' views, and negotiation of new, shared meanings. Two senior science classes participated in this interpretive study. Data sources were mainly qualitative and included audio and video recordings of students' small group discussions at the computer, interviews with selected students and their teachers, classroom observations, and student surveys. Findings indicate that the computer-based POE tasks supported students' peer learning conversations, particularly during the prediction, reasoning and observation stages of the POE strategy. The increased level of student control of the POE tasks, combined with the multimedia nature of the program, initiated quality peer discussions. The findings have implications for authentic, technology-mediated learning in science.

Key Words: interactive multimedia, peer learning, physics learning

This paper emerged from a doctoral study (Kearney, 2002) that investigated the design and classroom use of computer-mediated predict–observe–explain (POE) tasks. These multimedia-based tasks were created by the author and used digital video-based demonstrations to encourage student discussion about their own ideas and to elicit their pre-instructional conceptions on force and motion. The video clips showed difficult, expensive, time consuming or dangerous demonstrations of real, observable events, primarily focussing on projectile motion, whilst the predict–observe–explain strategy was used to structure the students' engagement with the clips. These multimedia-supported POE tasks represent a new development in the use of the POE strategy in science education.

This paper focuses on the students' learning conversations during their engagement with the tasks and uses qualitative data sources under an interpretive methodology (Guba & Lincoln, 1989) to address the following research question: to what extent did the computer-mediated POE tasks promote meaningful discussion about students' science ideas? Other foci of the study are reported elsewhere, including details about the design and construction of the POE tasks (Kearney & Treagust, 2001) and the affordances and constraints of these multimedia tasks (Kearney, Treagust, Yeo, & Zadnik, 2001). Also, the actual physics alternative conceptions elicited through the students' use of the program are identified and analysed as another focus in Kearney (2002). The findings reported in this paper indicate that the collaborative use of multimedia-based POE tasks offers meaningful peer learning opportunities for science students.

Background

Social Constructivism as a Theoretical Perspective

Social constructivism is used in this study as a referent to analyse and interpret relevant data presented in this paper. The core view of constructivist learning suggests that learners construct (rather than acquire) their own knowledge, strongly influenced by what they already know (Driver & Easley, 1978). Consequently, students are considered to learn science through a process of constructing, interpreting and modifying their own representations of reality based on their own experiences. Social constructivism acknowledges the social dimension of learning whereby students make meaning of the world through both personal and social processes (Driver, Asoko, Leach, Mortimer, & Scott, 1994), co-constructing and negotiating ideas through meaningful peer and teacher discussions (Solomon, 1987). Students are given opportunities to test the viability of new knowledge claims with peers and link these new ideas with personal experience and existing knowledge (McRobbie & Tobin, 1997). Hence, from a social constructivist perspective, the development of understanding by writing and discussion of ideas with peers is an essential part of learning and involves articulation, clarification, elaboration, negotiation and consensus-making: "Accordingly, students should be encouraged to be involved in putting language to ideas, testing their understandings with peers and listening and making sense of the ideas of other students" (p. 197). Students can identify and articulate their own views, exchange ideas and reflect on other students' views (through attentive listening), reflect critically on their own views and when necessary, reorganise their own views and negotiate shared meanings (Prawat, 1993).

Social Constructivist Perspective on Eliciting Students' Ideas

Learners come to science classrooms with a range of strongly held personal science views and the elicitation of these ideas is central to pedagogy informed by constructivism (Driver & Scott, 1996). The process of eliciting students' pre-instructional ideas not only helps teachers to identify common alternative conceptions and inform subsequent teaching episodes but also offers students an opportunity for learning (Duit, Treagust, & Mansfield, 1996). Students are motivated to find the correct science view and meaningful discussion can take place (Taber, 1999). From a social constructivist position, when students engage in this process in small groups, they receive an opportunity to articulate and clarify their own views and reflect critically on their own and others' views. The eliciting of students' ideas at the start of a unit of work provides an ideal time to initiate these discussions: "... procedures which elicit students' prior ideas and make these the basis of conversations are needed to bring about helpful change" (Carr, 1991 p. 22). Indeed, Linn and Hsi (2000) emphasised this elicitation process in a social setting as a starting point in their knowledge integration process: "Knowledge integration includes the process of eliciting ideas, introducing new ideas and encouraging new connections..." (p. 93). This paper focuses on the collaborative use of a new technology-mediated probe (multimedia-supported POE tasks) and draws on social constructivist theory to analyse the students' discussions while using these probes to elicit their pre-instructional science views.

Social Constructivist Perspective on the Predict–Observe–Explain Strategy

A strategy promoted by White and Gunstone (1992) for efficiently eliciting student ideas and also promoting student discussion about these ideas 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. This strategy is known as a predict–observe–explain procedure and was a central feature of the computer-based tasks used in this study. The POE procedure is based on the classic model of research where a hypothesis is stated and reasons are given for why this may be true, relevant data are gathered and results are discussed (White, 1988). The procedure was developed at the University of Pittsburgh (Champagne, Klopfer, & Anderson, 1980) where it was initially labelled a DOE (Demonstration, Observation and Explanation). The procedure generally uses observable, real-time events as stimuli to provoke student thinking about concepts. From a social constructivist perspective, the collaborative use of the POE strategy offers students the opportunity to articulate, justify, debate and reflect on their own and peers' science views and negotiate new and shared meanings.

Significance

According to Salomon and Almog (1998), we live in an age of "constructivist, socially shared, situative, technology-intensive learning environments" (p. 233). Indeed, a review of the science education literature informed by constructivism indicates that good learning is a process of socially-based, active co-construction of contextualised knowledge. There has been a demand for appropriate investigations of these types of technology-mediated learning environments. For example, Kozma (2000) called for more research on the impact of technology environments on the cognitive processes and social practices of science learning. Indeed, Harper and Hedberg (1997) challenged researchers to "demonstrate for developers how to capture these opportunities and support the intrinsic motivation of learners to explore their own world and the variety of viewpoints within it" (p. 15) and identified a need to further investigate facilitative strategies that support learners in socio-cultural processes. The study described here attempts to add to the knowledge base of these types of authentic technology-mediated science learning environments by investigating the collaborative use of computer-mediated POE tasks for the purpose of promoting discussion and reflection on students' science views.

Many recent studies in this area have explored new and exciting developments that make use of on-line technologies. For example, web-based facilities can support and keep track of synchronous dialogue amongst students that then serve as a public archive of conversations: "... conversations can be stored, reflected on and reacted to, creating a common knowledge base that is open to review, comment and manipulation" (Blumenfeld, Marx, Soloway, & Krajcik, 1996, p. 39). From a social constructivist perspective, the success of these web-based communications depends on the opportunities afforded to students for critiquing the ideas of others as well as soliciting alternative ideas, sorting out conflicting information and responding to other learners (Linn, 1998). Nevertheless, this strong focus on on-line settings has resulted in computer mediated collaboration within classrooms being neglected as a research setting: "... studies in the naturalistic setting of the classroom, which is still the dominant place for formal science learning, appear to have been neglected" (Tao, 2000, p. 4). This study contributes to this neglected field of enquiry within classrooms.

Similar Studies

Studies focussing on the social aspects of computer-based science learning environments involving the use of the POE strategy have been limited. Tao and Gunstone (1999a, b) used computer-mediated POE tasks designed to provide students with experiences of co-construction of shared understanding or peer conflicts while using a physics microworld. In their study, Year 10 students worked collaboratively in pairs using a force and motion microworld. The program used animation (rather than digital video clips) and students used worksheets to record their work. In each task, students made a prediction about the consequences of certain changes being made to the simulation. Case studies of collaboration were reported for various student dyads and inferences were made as to whether or not these experiences lead to conceptual change. Social construction of knowledge took place through this peer collaboration and in many cases this led to students' conceptual change in the context of the tasks attended to. However, when probed at a later time, many students had regressed to alternative conceptions. Conceptual change occurred for people who were cognitively engaged in the tasks and prepared to reflect on and reconstruct their conceptions. Tao (2000) also reported on a similar use of computer-supported collaborative learning designed to help students develop an understanding of image formation by lenses. The aim of the project was to investigate how students constructed shared knowledge and understanding while working with a multimedia program. The rich qualitative data collected from peer interactions during the study showed that students experienced many instances of conflicts and co-construction that were conducive to the development of understanding. Finally, Russell, Lucas, and McRobbie (1999) looked at the use of constructivist microprocessor-based laboratory activities to facilitate student understanding of physics. In this study, the Grade 11 students worked in pairs on seven POE tasks relating to the subject of kinematics. In these tasks, the students had to predict the shape of relevant motion graphs before simulating the scenario using the MBL equipment (e.g., motion sensors) and making second-hand observations as they monitored the graphs produced by the MBL equipment. If there was any discrepancy between their predicted graphs and the computer generated graphs, they were required to explain these differences. Analysis of students' discourse and actions revealed many instances where students negotiated new understandings mediated by the computer activities.

Unlike the computer-based POE tasks used in the above studies, the tasks in this study use digital video-based demonstrations of real-life events and are used explicitly as a pre-instructional probe of understanding. Hence, this study adds to limited literature on the collaborative use of computer-based probes of understanding (or more specifically, the POE strategy) and their potential to initiate meaningful peer learning at the start of a new unit of study. In this way, this study explores new developments in the use of the POE strategy in science education.

Design and Methods

The study focussed on two senior high school science classes using sixteen computer facilitated POE tasks incorporating digital video clips of real life events. Students used the tasks in collaborative pairs at the beginning of their study of mechanics for the purpose of eliciting and promoting discussion of students' preconceptions of force and motion. The study did not attempt to address conceptual change issues (as in Tao and Gunstone's (1999a, b) study) but rather focused on the use of the POE tasks as a technology-mediated probe of understanding and its role in facilitating discussion and reflection on students' views. An interpretive methodology was used in the study (Guba & Lincoln, 1989) and social constructivism was used as a theoretical framework to analyse the students' learning conversations and address the main research question relevant to this paper: To what extent did the computer-mediated POE tasks promote meaningful discussion about students' science ideas? The following subsidiary questions are also addressed:

1. To what extent did the students articulate, justify and reflect on their own ideas?
2. To what extent did the students reflect on the viability of their partner's ideas?
3. To what extent did the students co-construct ideas and negotiate shared meanings?

The qualitative nature of this study is most appropriate in light of Weller's (1996) comments that too many studies investigating technology use in science education have continued to be media comparison studies adopting quantitative methods. According to Weller, a lack of insightful qualitative data in these studies has been noticeable: "In their endeavours to control all other variables, [they]... may have missed some of the richness of the interconnected network of variables involved in the human experience of learning and doing science" (p. 480).

Participants

The classes were from two different schools in Sydney, Australia. The first class was a Year 11 physics class following the New South Wales Higher School Certificate (HSC) physics course. The class consisted of 18 girls and their female teacher (Judy). The second class was a Year 10 advanced level science class from a different school and consisted of 26 boys and their male teacher (Wayne). Each class was familiar with cooperative group work and POE tasks in a normal, non-computer environment.

Computer-Based POE Tasks Used in This Study

The 16 POE tasks were created by the 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 researcher and the other half were obtained from commercial VHS tapes after copyright permission was granted. The demonstrations mostly presented real-world contexts to the students, although a few featured laboratory equipment that would be difficult or time consuming to set up. Such real-life scenarios 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 (Escalada & Zollman, 1997). Table 1 reports a description of sample tasks. Also, see Kearney and Treagust (2001) for detailed information about the design of these tasks.

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 student surveys. There were frequent informal interviews with the teachers and documents were collected during visits to the classes.

The students worked in pairs with the program for two lessons at the beginning of their unit of study on motion. During this time they completed the 16 POE computer tasks. The typed responses were automatically stored in a text file on the computer as a source of data for other sections of the study not relevant to this paper. Students'

Table 1
Description of Sample POE Tasks.

Task and motion type	Description (from introduction screen)	Prediction question and given options (from second screen)
1. Falling ball (Vertical and passive launch)	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.
2. Rising ball (Vertical and active launch)	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.
3. Ball throw (Half flight projectile and active launch)	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 arrow in the photo.	What is the shape of the pathway that the ball follows while it is in the air? Paper drawing required.
4. Slow ball jump (Half flight projectile and active launch)	A tennis ball is about to roll off the table as shown in the photo. The ball is travelling SLOWLY from left to right. *Note*: The projectile is launched in a different way from Task 3.	What is the shape of the pathway that the SLOW ball follows while it is in the air? Paper drawing required.
8. Ball and swing (Half-full flight projectile and passive launch)	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.

Table 1
(Continued.)

Task and motion type	Description (from introduction screen)	Prediction question and given options (from second screen)
9. The astronaut (Vertical and passive launch)	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.
12. Sailing boat (Half flight projectile and passive launch)	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).
14. Cart and ball I (Full flight projectile and active launch)	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.

paper-based drawings completed during the computer sessions were also used as a data source. Student discourse and teacher discussions with groups were recorded on audiotape and sample group interactions of students using the program were filmed using a video camera. The researcher also recorded field notes during these sessions in the role of participant observer. These notes were updated and completed after each session.

Immediately after completing the computer sessions, all students completed an extensive survey about their experiences during the computer-based lessons. The student survey, *My Experience Using the POE Computer Tasks*, comprised 60 Likerttype items (5 point) that were designed by the researcher to help probe student perceptions and beliefs relating to the research questions. Relevant items from this survey were grouped together and used as data for various sections of the study. Some students and their teachers were also formally interviewed after the sessions. Students were selected for these interviews by means of purposeful sampling (Bogdan & Biklen, 1998) based on their survey responses, observations of group dynamics and teacher recommendations. They were interviewed in pairs, using the same groups that worked together during the computer sessions.

Audio and Video Tape Analysis

A social constructivist perspective was used to analyse and interpret the student's conversations recorded on the audiotape. Tapes were viewed and analysed with the students' written and drawn responses in full view. Critical incidents that were relevant to the research questions were identified and transcribed immediately, providing "thick description" (Guba & Lincoln, 1981) of key events. These included incidents of students' articulation and justification of their own science conceptions, clarification of and critical reflection on their partners' views, and negotiation of new, shared meanings. If there was any relevant non-verbal behaviour to investigate, the video recording of the whole-class was viewed to facilitate further rich description of these incidents. Where possible, critical incidents also were checked with relevant data from field notes, interviews and surveys. Close-up video footage of sample groups from each class also was analysed thoroughly for critical incidents. The video cameras' microphones had recorded the conversations of each group and the video tapes were viewed in light of the students' written and drawn responses. Transcriptions of critical incidents contained sufficient narrative and commentary to describe relevant visual data such as off-computer activities, gestures, posture, gazing, etc. Where possible, critical incidents were checked with relevant data from field notes, interviews and surveys.

Findings

Generalisations and claims were formed from the data in two strategic ways. Firstly, they were formed through direct interpretation of individual instances. Secondly, they were formed by an aggregation of instances (across both cases) until general themes emerged (Stake, 1995). These interpretations and themes are stated as four general assertions that were grounded in the data and were reformulated and refined as the study proceeded (Merriam, 1988). These assertions provide a framework for discussion of findings and are supported mainly by quoted learning conversations representing critical incidents that occurred during the computer-based sessions. Claims also are supported by data from interviews, student survey responses and class observations. All names used in the following findings are pseudonyms.

ASSERTION 1. The computer-mediated POE tasks encouraged students to articulate and justify their own conceptions.

Most groups of students attempted to articulate their science views as they formulated and edited their written or drawn predictions and gave reasons for these predictions. Students often justified their views as they debated their responses. Data from student and teacher surveys and interviews supported these claims.

Discussion of critical incidents

The rich contexts encouraged the students to reflect on and articulate their ideas relevant to the problems posed. Disputes over responses gave students an opportunity to justify and defend their viewpoints and the high incidence of students editing their written and drawn predictions was testimony to these meaningful discussions.

Disputes often occurred during the prediction or observation stages of the POE strategy. For example, Cath and Michelle disagreed with each other in Task 8 (The Swing). In this task, a boy is moving forward on a swing and passively releases a ball. Students had to predict (using a drawing) the path of the ball after release. After disagreeing with her partner, Cath defended her view by explaining the reasons for her prediction:

Michelle: I think ... so he's travelling up, then just lets it go so I think it (the ball) will 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 that depicted the ball moving forwards before falling vertically downwards.) Maybe a bit sharper.
Cath: No, I don't think that's right. Because the swing is still moving so it's giving the ball a bit of (forward) velocity. (Defending her own views.)
Michelle: OK. (In agreement.)

Pat and Dave also had a small dispute over the drawing of their predicted pathway of a ball rolling slowly off a table in Task 4. Dave's disagreement with Pat's prediction eventually caused Pat to justify and defend his view. The students edited their drawing on numerous occasions during this process:

Pat: It's going to go down more than out.
Dave: No. My prediction is it's 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 showing the ball moving a considerable distance from the table.)
Pat: But the thing is it's going slowly – go back a bit – I reckon [believe] it's going a lot slower than that Dave.
Dave: Like that? (Dave now edits the drawing, effectively reducing the predicted horizontal range of the projectile.)
Pat: Yeh – I reckon it's more like that Dave.
Dave: Oh yeh – OK. (Not quite convinced.)
Pat: 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.)

Indeed, 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. For example, Joan and Leigh had a small disagreement during their Task 8 (The Swing) prediction. As they defended their views, their drawing became a focus of their discussion:

Joan:	What's he going to do, throw it or drop it?
Leigh:	He's going to release the ball. Let's look at the preview.
Joan:	Yeh – he's still travelling forward. Let's see that again (the preview) . . . I think it'll go up a bit then go down.
Leigh:	Well it's dropped so it'll go in a bit of a curve.
Joan:	Up? No . . . (Thoughtfully.)
(Pause)	
Leigh:	Sort of from there. (Pointing to the drawing.)
Joan:	What do you mean?
Leigh:	It won't go up. It'll sort of go . . . (drawing path) as it goes down.
Joan:	Do you think? (Obviously disagreeing.) I thought it would keep going up for a bit and then go down! (Tracing a path on the drawing with her finger.)
Leigh:	(Defending her view.) Because he drops it right?
Joan:	Oh yeh – he just drops it doesn't he! He doesn't throw it. OK then. (Sounding convinced.)

(They again edit their drawing.)

There were numerous incidents where groups changed their drawing up to three times in either the prediction or observation stages. This high incidence of students editing their drawings was testimony to these meaningful discussions and indeed, many of the critical incidents quoted in this paper feature the students' drawings as a backdrop to their conversations.

Teacher and student perceptions

Judy (teacher of the girls' class) reflected on the students' small group discussions during her interview: "There was heated discussion about the projectiles." Indeed, she believed that her observations of these conversations helped her to gain a good understanding of students' views during the computer sessions. In his interview, Wayne (teacher of the boys' class) also chose to reflect on the students' conversations at the computer. He referred to their discussions more generally but in a similar positive tone: "They [the students] liked being able to discuss and think and actually being able to confront the questions . . . " Later in his interview, he mentioned: "There was relatively unbroken long periods of time that they worked together on successive tasks and I think that just generated a lot more talk – it was on the subject and it didn't waver." Wayne believed the students themselves appreciated the opportunity to talk to each other about the tasks: "They wanted to talk between themselves about what was on the screen. It was as if the pair and what was happening there was the thing of significant importance [to the students]."

Students also perceived that meaningful discussions occurred during the computer sessions (Table 2) and agreed that the POE computer tasks encouraged them to talk

Table 2
Students' Responses to Items Relating to Articulation and Justification of Ideas from the Survey: My Experience Using the POE Computer Tasks ($N = 46$).

Item	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
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

about and debate their ideas (e.g., refer to responses to survey Items 1 and 2). The responses to Item 28 indicated that most students appreciated the opportunity to work with a partner in order to clarify their own views.

In summary, students articulated their own ideas relevant to the various scenarios, and debates about predictions and outcomes were common. Student drawings were important foci in some of these conversations and students often edited their pathway predictions during such discussions. In this sense, the drawings acted as 'conversational artifacts' (Pea, 1993). Teachers also perceived meaningful discussions occurring during the sessions and students appreciated the opportunity to clarify their own views with their partner.

ASSERTION 2. The POE computer tasks encouraged students to reflect on the viability of their partner's conceptions.

There were many incidents where students demonstrated mature and thoughtful listening skills as they evaluated their partner's ideas relating to the POE tasks. Silent pauses in the conversation and frequent questioning of students' views were a feature of these incidents. In particular, task video clips served as a focus for the reflections occurring during the observation phase of the POE tasks. Interview and survey data revealed that most students felt they had listened attentively to their partner during the sessions.

Discussion of critical incidents

The students' engagement with the POE tasks initiated some quality conversations leading to students reflecting on each other's ideas. Students were enthusiastic in listening to and evaluating their partner's views.

Jessica and Alison conducted an in-depth conversation about the outcome of Task 1 (Falling Ball). Although the task was probably the most simple of all 16 POE tasks, both students made meaningful reflections relating to this scenario of a ball being dropped (from rest) to the ground from a height of about 1.5 metres. In the process of trying to articulate a reason for their prediction, they changed their actual prediction three times. (As in the drawing tasks, 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 as it fell towards the ground:

Jessica: What are our reasons for this prediction? (They had predicted the ball would increase its speed.)
Alison: I know but I can't explain it. It's 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 of 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 and feet.)
Jessica: Oh, OK (reluctantly). Well. We need to give a reason, let's see.

Jessica was still not satisfied at this point. She wanted to go back to the prediction page and change their response to "constant speed." She eventually made this change, at which point Alison reflected 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 and choose constant speed instead. Alison is reluctant.)
Alison: Why would it fall at constant speed but?
Jessica: Because it's 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 changed their answer back to "speeding up." Jessica tried to articulate her thinking as she typed in her response:

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

As they proceeded to the movie, Jessica revealed a sense of anticipation in finding out the correct answer. Still unsure about their prediction, she stated: "Either way this could be a learning experience – we'll find out why!" This rich conversation from Alison and Jessica focussed on the 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, hypothesised about the nature of gravity on earth, asked each other many questions and interrogated one another's views.

Dave reflected on the views of Pat during the prediction and reasoning stage of Task 12 (The Sailing Boat). This classic 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.)	
Pat:	Yeh. But it (the ball) is going at the same speed (as the boat), Dave.
Dave:	Yeh. (Listening carefully.)
Pat:	If it's going at the same speed as the boat, as it falls, it should land at B.
Dave:	Yeh but as it falls like . . .
(Pause)	
Pat:	It won't fall backwards. (Sensing Dave's thoughts.)
Dave:	Does it lose any (horizontal) speed as it falls?
Pat:	No, it won't.
Dave:	As it goes forward? (Continuing thoughts from previous question.) I reckon [believe] A. (Option A is 'behind' the mast.)
Pat:	No way. We'll soon see.

The silent pauses were significant and indicated that both students were considering each other's viewpoints. Dave finally decided to disagree and stay with his intuitive ideas that the boat would continue to move forward and leave the ball behind. Although there was no negotiated meaning-making here, there was evidence of both students listening and reflecting on each other's views.

Similar reflective silence was evident in a conversation between Cath and Michelle in Task 3 (Ball Launch). Again the students' drawing became a focus of the discussion as they attempted to describe the pathway of the ball during their observation of the video clip. (In this task, a person throws a ball horizontally from approximately two metres off the ground.) Michelle initially disagreed with Cath's drawing. After evaluating each other's ideas, both students attempted to provide a detailed description of the ball's pathway. In particular, Michelle tried to justify her own idea that the pathway was steeper than the pathway that Cath had observed.

Cath: OK – play it (the video clip) again.
Michelle: When she throws it, it sort of comes up a bit and then comes down. Do you think or not?
Cath: Um ... (pause) Well she throws it underarm, she doesn't throw it straight out ... OK.
(Long pause as students watch another replay.)
Michelle: See it sort of goes up, then it comes down. (Drawing picture.)
Cath: It curls up just a tiny bit, maybe not up like that. (Pointing at Michelle's drawing.) When it starts to drop a bit, it comes down more gradually.
Michelle: Isn't it more than gradually; it's a bit more than gradual!
Cath: Ah ... (Pause as students again watch the video clip.)
Michelle: Don't forget she's a lot higher.
Cath: That's all right, we'll change it.

Another feature of this incident was the students' use of the video clip as a backdrop to the conversation. The students frequently used the replay and slow motion facilities to help them closely observe the pathway of the ball before formulating their arguments.

Student perceptions

Students' survey and interview responses showed that most students felt that they had learned something from listening to their partner's views. As shown in Table 3,

Table 3
Students' Responses to Items Relating to Reflection on Their Partners' Ideas from the Survey: My Experience Using the POE Computer Tasks ($N = 46$).

Item	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
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

responses to Item 17 indicated that most students believed they had listened attentively to their partner's ideas during the computer sessions. Although Item 34 attracted a range of results, the majority of students felt they had tried to persuade their partner to change their ideas – indicating they had at least considered their partner's viewpoints. Indeed, Anne chose to make the following optional comment in her survey: "It was a very interesting experience and I learned a lot by working one on one with my partner and the computer. It was helpful hearing her ideas and comparing them with my own." During her interview, Kirstie commented on the way she compared her ideas with her partner's ideas:

> I think her reasoning is very well behind things – like she won't say something just on the spot. She has to have the reasons behind it and say 'I think this because . . . ' and then you think 'oh yeh.' Then you consider her's against what you thought would happen. Like sometimes her's would be more logical, sometimes mine would be more logical. (Student interview with Kirstie.)

Similarly, Pat reflected on the advantages of working with his partner Dave during the sessions. In his interview, he mentioned: "There was a lot of benefit hearing about another person's insights – about what they thought – and sometimes you can change what you think – or they can convince you."

In summary, students listened attentively to their partner's views, initiating reflection on the viability of these conceptions. Significant reflective pauses in the conversations as well as engaging questions were a feature of these incidents and indeed, most students indicated that they had listened attentively to their partner during the sessions. The digital video clips served as a particularly effective 'backdrop' for these reflective discussions during the observation phase of the POE tasks. Learning conversations quoted in subsequent sections provide further examples of this reflection leading to students considering the viability of their own ideas (refer to Assertion 3) and in some cases, negotiated sense-making (refer to Assertion 4).

ASSERTION 3. The POE computer tasks encouraged students to reflect on and test the viability of their own conceptions.

A feature of the students' conversations was the frequent use of hand gestures and the performance of mini-experiments, particularly during the prediction and reasoning stages of the tasks. These physical actions were often collaborative and provided evidence of students reflecting on and testing their own ideas. Surprising outcomes also initiated meaningful discussion, sometimes leading to students reconsidering their own views. Survey data showed that most students believed they had changed some of their ideas as a result of their conversations at the computer.

Discussion of critical incidents

A notable and unexpected aspect of the students' engagement with the computer-based POE 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 and outcomes were closely observed and discussed. Melissa, Belinda and Joanna's discussion in Task 2 (Rising Ball) was typical of these dynamic and meaningful conversations. (In this task, a child throws a ball vertically into the air.) During the prediction phase of this task, Belinda performed a mini-experiment to help her group predict the motion of the ball:

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 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'! (The 'other' option was one of the multiple choice distractors.)
Belinda: Yeh.

Although this was a relatively simple linear motion task, this group devoted a lot of time and consideration to their prediction here. After some conjecture over the outcome, Belinda's repeated mini-experiment (with her pencil case) seemed to focus the group's thinking. (Indeed, most mini-experiments occurring within other groups were also repeated at least twice.) It also was interesting to note that although these students were considering this motion for the first time, Joanna was observant enough to see that the pencil case come to rest as it reached its maximum height. There were many other examples of students conducting off-computer mini-experiments to test the viability of their own views. Some of these are included in descriptions of critical incidents in other sections of this paper.

Just as noticeable was the use of hand gestures by students as they articulated and reflected on their thoughts. The following text was an entry into the researcher's field notes from the Year 10 class: "Many boys can be seen pointing to the video clips on screen to trace pathways of objects with their fingers or their pen. There are frequent gesticulations in each group." Analysis of the conversations occurring at these times indicated that students were using these gestures to enhance reflection on their ideas. This was particularly evident during tasks requiring a drawing response. For example, Jenny and Kirstie used hand gestures to help them predict what would happen when a ball rolled slowly off a table in Task 4:

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

Jenny: (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.)
Jenny: It'll go straight to the ground because it's got more force on it.

The video-based observation phase of the POE tasks often produced the stimuli for students to critically review their ideas, especially if their prediction was incorrect. Leigh and Joan were surprised when they saw the hammer and the feather reach the moon's surface at the same time in Task 9. (In this task, an astronaut simultaneously dropped a hammer and a feather from the same height on the moon.) 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. However, 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 (see Kearney, 2002). Similarly, Anne reviewed her thinking quite accurately after unexpectedly seeing the ball land back into the cart in Task 14. (This task depicted one of the few laboratory-based scenarios. It showed a cart travelling horizontally at a constant speed while launching a small ball vertically into the air.)

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!

However, surprising outcomes did not always initiate such conversations where students reflected on the viability of their own ideas. Some students simply conceded that they were wrong and made unsatisfactory attempts to explain an unexpected outcome. Indeed, this explanation phase is the most challenging stage of the POE strategy (White & Gunstone, 1992) and further comments regarding this phase are made in the *Discussion* section.

Student perceptions

Only one item from the students' survey was related to this section (Table 4). Most students felt that they had changed some of their ideas as a result of the learning conversations with their partner. Indeed, Jessica and Alison commented on this issue in their interview:

Table 4
Students' Responses to Items Relating to Reflection on Their Own Ideas from the Survey: My Experience Using the POE Computer Tasks ($N = 46$).

Item	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3. I changed some of my own ideas after talking with my partner.	1	3	5	33	4

Alison: We sort of learnt from each other.
Jessica: We were both inputting things.
Alison: We would have a conversation about it and then we realised who was right.
Jessica: The thing is that we had different views and we would talk about it and figure it out . . .

Later in the same interview, Alison stated:

I think because we were both working together, it made us think about the things a lot more because we had differing opinions, so we had to think about the problem a lot more. But if we were just by ourselves, we'd go: "oh yes – that's right because I'm me!" (From student interview with Alison and Jessica.)

These perceptive comments showed their appreciation for each other in the collaborative decision-making processes encountered during the computer sessions. These students obviously valued each other's ideas and used them to reflect on the viability of their own conceptions.

In summary, the frequent use of hand gestures and the performance of 'off-computer' mini-experiments were a feature of the students' engagement with the tasks and provided evidence of students reflecting on and testing the viability of their own views. In this sense the multimedia-supported POE tasks served as a "gestural resource" (Roth, Woszczyna, & Smith, 1996, p. 1001) to the students' interactions. Many groups experienced surprising outcomes from various tasks, initiating quality discussions about students' views. Survey and interview data from students supported the assertion made in this section.

ASSERTION 4. The POE computer tasks encouraged some 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. However, a few groups did provide strong evidence of student negotiation and reformulation of ideas.

Alison and Jessica conducted an in-depth discussion over their predicted outcome of Task 12 (Sailing Boat). 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 of the moving boat. 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 demonstrate her predicted path of the ball.)
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.

Jessica struggled to articulate her thoughts at this stage of the conversation. However, she soon overcame this lack of confidence to help negotiate a joint 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 (i.e., in a forward direction). Yeh – that makes sense!
(Pause)
Jessica: Yes, it does!

The paraphrasing evident in the discussion here showed active listening by both participants as they constructed their views. The students also frequently interrupted each other as they progressively built on each other's previous statements. Anne and Jane also 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 and considers her observations.)

As one student articulated a response, her partner immediately built on this statement in the next comment. Both students began this dialogue in a tentative manner but increasingly gave each other confidence to formulate a detailed reason. The final outcome was the students' negotiation of a mutual reason for their prediction.

In summary, there were incidents of genuine co-construction of knowledge in the peer groups. These discussions often showed characteristics of an "open discourse" (Taylor, Fraser, & White, 1994), as students actively listened to each other and generated ideas with a mutual respect for each other's point of view.

Summary of Findings

Most students participated freely in meaningful discussions about the contextualised science phenomena presented in each task. They freely articulated their own conceptions as they engaged in the activities and there were many disputes caused by conflicting views between students. Most students listened carefully to their partner's viewpoint and there were numerous occasions where students showed strong reflection on the viability of these and their own conceptions. For example, there were many reflective pauses during group discussions and students often asked each other thoughtful and relevant questions. Although there were some cases of genuine shared meaning-making and co-construction of ideas, such in-depth negotiations were less frequent.

Discussion

The findings reported in this paper need to be discussed in the light of three principal affordances of multimedia-based POE tasks as reported in (Kearney, Treagust, Yeo, & Zadnik, 2001). Firstly, the computer environment affords student control over the pacing of the POE tasks and also facilitates student control over the presentation of the video-based demonstrations. Secondly, the use of digital video-based demonstrations in the observation phase of the POE strategy offers students a refined tool to make detailed and clinical observations of physical phenomena and hence, enhances the quality of feedback on their earlier predictions. Thirdly, the real-life physical settings depicted in the video clips provide interesting and relevant contexts for the students. These three previously reported affordances were a major factor in helping students articulate their views with confidence and initiating some of the rich learning conversations quoted in this paper. For example, the extra autonomy involved in these computer-based POE tasks gave students the flexibility and time to thoroughly discuss their science views relating to task predictions, reasons and observations. The many critical incidents quoted in this paper involving students editing their drawn and written responses or performing off-computer mini-experiments are testimony to this claim. Also, the interesting contexts depicted in the video-based demonstrations became "conversational artifacts" (Pea, 1993) or backdrops to the students' discussions, providing them with a focus for voicing their opinions. These same video clips also acted as a "gestural resource" (Roth, Woszczyna, & Smith, 1996) for the students during these learning conversations. The many critical incidents occurring at this (video-based) observation stage of the POE tasks and the common sight of students gesturing around these video demonstrations are testimony to this claim.

However, students generally did not conduct rich conversations during the explanation stage of the POE tasks in this study. There are two possible reasons for this result, although these are somewhat speculative and would need further research to confirm. Firstly, there were some instances where students would not admit to incorrect predictions, instead making excuses to defend their strongly held alternative conceptions. Secondly, students from both classes were more familiar with teacher-led POE tasks where the teacher can provoke and initiate quality comments in this difficult reconciliation stage. Indeed, this raises questions for future research relating to the role of the teacher when using computer-mediated POE tasks – particularly during this challenging 'explanation' stage of the POE strategy. It may well be more appropriate that this difficult, final stage is facilitated by the teacher in whole class discussions rather than small, computer-based group discussions. Alternatively, further software development of these multimedia-based tasks (Kearney & Wright, 2002) has attempted to address this problem by providing a link to previous students' sample responses (predictions, reasons, observations and explanations) as an extra page in these computer-based tasks. These samples do not necessarily present correct science views but model the depth and scope of responses needed at this stage. Indeed, future investigations could explore possible ways for students to communicate between groups and reflect on other groups' beliefs to facilitate more meaningful engagement in this challenging explanation phase of the POE strategy. For example, if all groups posted their responses on a central database accessible through a network, they could establish a 'discourse community,' comparing and reflecting on the multiple perspectives of others (e.g., see Lin, Hmelo, Kinzer, & Secules, 1999).

Salomon, Perkins, and Globerson (1991) discussed two types of effects relating to technology-mediated learning. The effects with the technology refers to the effects attained during the 'partnership' with the tool and the effects of the technology refer to the more lasting effects (or 'cognitive residue') as a consequence of students' 'mindful engagement' with the tool. Clearly this study has focused on effects with the computer-mediated POE tasks. Future research could investigate the genuine transfer of learning from this environment to other tasks (i.e., effects of the technology). For example, does the students' use of these computer-based POE tasks affect their value of the POE strategy overall? Does it help them to engage more skilfully in non-computer based POE tasks or indeed in other collaborative learning tasks? Are certain peer learning skills (negotiation, conflict resolution, etc.) developed through their use of these computer-based tasks? Are their general observation skills developed and is their attitude to the process of observation improved? Indeed, do the tasks affect their attitude to the relevant subject matter?

Conclusion

The POE strategy is a well-known instrument used to elicit students' views and, like any probe of understanding, also provides students with an opportunity for learning. Although POE tasks have been used in a computer environment in similar studies (e.g., Tao & Gunstone, 1999a, b; Russell et al., 1999), the collaborative use of multimedia-supported POE tasks for these purposes has not been reported in the literature. Hence, this paper takes up Carr's (1991) challenge to investigate new procedures which elicit students' prior ideas and make them the basis of conversations. The findings indicate that the computer-based POE tasks supported students' peer learning conversations, particularly during the prediction, reasoning and (digital video-based) observation stages of the POE strategy. The extra learner control of the POE tasks and the capabilities of the digital video medium (Kearney & Treagust, 2001) gave students unique opportunities to articulate, debate, justify and reflect on the viability of their own and their partner's science conceptions associated with each scenario.

The rich conversations reported in this paper were testimony to the quality of peer learning that occurred during this process of eliciting students' ideas using the computer-based POE tasks. Hence, these conversations provided an example of learning with computers (Jonassen & Reeves, 1996) and collaboration at the computer (Crooks, 1999). Indeed, they make a contribution to the literature relating to the *Computer-supported Collaborative Learning* (CSCL) movement (Koschmann, 1994), marking a re-focus on recently neglected collaboration issues within the classroom (as distinct from collaboration outside the classroom through online technologies). These finding also are supportive of Kozma's (2000) observations that "these new symbolic systems ... may best be used within rich social contexts that prompt students to interact with each other and with the multiple symbol systems to create meaning" (p. 44). Finally, the findings address the perceived need raised by Roth et al. (1996) to explore how technologies can facilitate collaborative sense-making amongst science learners.

Understanding science involves developing and refining ideas about science phenomena into an integrated perspective. This process requires analysing, linking, testing and reflecting on scientific ideas (Linn, 1998). The research reported in this paper provides an illustration of how technology can mediate this learning process. As well as acting as an efficient and convenient teaching instrument to elicit students' pre-instructional conceptions (see Kearney, 2002), the multimedia-supported POE tasks facilitated reflective peer conversations and took advantage of new affordances offered by the multimedia nature of the tasks. In this way, the study has explored new developments in the use of the POE strategy in science education.

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