Enhancing Learning Through Collaborative Inquiry and Action

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Abstract

A social constructivist view of learning places particular emphasis on collaboration, interpersonal skills and social aspects of learning. The emphasis of this research study is on children's learning and learning enhancement through cognitive conflict, social construction and metacognition during collaborative design and technology problem solving. The work evolved from the author's involvement with a Comenius 2.1 European project entitled DIAL:Connect (using dialogue to connect learning minds). Pupils worked in groups to develop a solution to a design and technology challenge that originated from within a story context. The children were encouraged to use dialogue as a tool for thinking in their collaboration: questioning, clarifying, challenging, reviewing and reflecting. The nature of the teacher intervention during the collaboration and reflective inquiry became a main focus of this research. The same teacher was involved with each of the three groups in the research study, but to a greater or lesser extent.

The hypothesis that quality of learning and learning outcome are dependent on the quality of communication; the reasoning and creativity embedded within the collaborative dialogues, was tested. Three composite groups, two girls and two boys, engaged with the same technology challenge, but at different times. Whilst the pupils were from the same year group of 11 yr olds, they were more used to working independently than interdependently. Having agreed the ground rules beforehand they were encouraged to work collaboratively and be reflective in action. Video and audio recordings of each group facilitated analysis of the verbal interaction and group dynamics.

A qualitative content analysis of the transcripts showed interpersonal relationships and the language of thinking, action and productive activity to be better managed by the third group. This group appeared to be better coordinated, more cohesive, and more productively engaged than the other two. There was greater goal conformity, tolerance of different viewpoints and the teacher adopted a key role in the orchestration and mediation of learning. All of this seemed to impact significantly on the quality of learning and learning outcomes.

Key words

collaborative, teacher intervention, metacognition, interpersonal skills, creativity, dialogical reasoning, thinking

Introduction

Engineering solutions in the past tended to depend for their success on the unique capabilities of a particular individual, namely the designer/engineer. The Clifton Suspension Bridge, for example, stands as a monument to the ingenuity, foresight and inventiveness of Isambard Brunel. Engineering achievements today stand in marked contrast to that kind of individualist, monumental attainment. Success today depends on the collective thinking and creative ingenuity of teams of designers and technologists, working together in collaborative and situated practice.

Success is not now the prerogative of the individual. Success belongs to the team or teams of teams that have accepted responsibility for the many facets of the project, and who spectacularly have been able to communicate and work with one another in creative and coordinated ways to achieve success. The joint outcome will stand as a tribute to *creativity, collective thinking, collaborative endeavour, interdependency, communicative competence, co-ordinated effort and unity of purpose.*

The message for schools and pupil learning is clear. To prepare pupils adequately for the demands of living and working in the 21st century, pupils need to experience this form of situated collaborative action in schools (Lave and Wenger, 1991; Watkins, 2001). They need to engage in activities and interactions that foster such qualities as interdependency, open-mindedness and self-regulation in learning. Design and Technology has the potential to equip pupils with the skills and capabilities to meet this challenge

RESEARCH

through engagement in authentic and creative problem solving experiences. Motivated by challenge and action-oriented inquiry, pupils are learning about learning, learning how to learn, and learning how to think and act independently and interdependently. They are being equipped for the real world – a world of complexity, challenge and change and one in which survival and success are dependent on the cultivation of creative and imaginative minds (Burgogne, 1998; Claxton, 1999; Pink, 2005).

A theoretical framework for action learning

Sociocultural perspectives on learning place an important emphasis on the use of language in the construction of meaning (Bakhtin, 1981; Vygotsky, 1934/1987). Talk is central to learning, and understandings are developed through socially shared thinking within a collaborative context. A situated view of learning suggests that meaning does not come ready-made but has to be constructed through dialogue, interaction, and collaborative activity (Brown, Collins & Duguid, 1989; Greeno, 1998; Lave and Wenger, 1991). Since learning is viewed as a reciprocal process embedded in the interaction between cognitive and social experience, the kinds of interactions that occur through action-oriented learning are personalized, goal-directed, and mutually supporting. Design and Technology, with its emphasis on problem solving and goal oriented activity, has real potential for harnessing the creative energy and critical thinking skills of students through collaborative and contextualized activity.

In this paper collaborative activity is seen as taking place within a negotiated and shared conceptual space that is constructed and maintained through language, action and productive activity (Roschelle & Teasley, 1993). Research theorists would contend that it is through internalization of these social processes that individual meaning and capability is constructed (Damon & Phelps, 1989; Tudge & Rogoff, 1989; Kumpulainen & Kaartinen, 2003). Through purposeful, coordinated and regulated activity participants collectively process and solve problems towards an agreed outcome. The teacher acts as a facilitator and resource within the dynamics of the interactional process. As an active and responsive participant, the teacher can become a significant catalyst for effective learning. In this research study, video recordings of

the three groups in action showed how effective pupils were in initiating, coordinating, and monitoring the language of thinking, action and productive activity that was considered key to a successful project outcome.

Creating contexts for collaborative activity and learning

Three groups of 11yr. old pupils, each comprising two girls and two boys, undertook separately the same design and technology challenge. The challenge had arisen from within a story context. Pupils speculated that Sam, a main character in the story, could design and make a drawbridge capable of opening to 30°. The challenge for each of the three groups was to design a better drawbridge and one that had the potential for reaching 90° when fully open. This was quite a challenge the pupils had set themselves, within a time limit of three hours.

The pupils in each group were encouraged to explore, share, and seek agreement before taking a decision or acting. They were asked to make their ideas explicit; challenge and negotiate alternatives; give clear reasons if they didn't agree; work and think together (Mercer et al., 1999; Wegerif et al., 1999). These social ground rules were considered important for supporting an exploratory orientation and shared inquiry, within a relationship of trust and co-operation. Wegerif & Mercer (2000) support the claim that exploratory orientations along with ground rules of exploratory talk contribute significantly to the development of dialogical reasoning and understanding. This research study explores the role of the teacher in modelling this form of reasoning and support structure needed to bring it about.

In each of the three groups the role and input of the teacher was significantly different. With the first group the teacher was not an active participant, tending to operate more as a technical consultant and acting only if needed. In the second group the teacher was more active, intervening at appropriate times to question, probe and encourage individual and group effort. With the third group, however, the teacher became an active participant right from the outset. He aimed to facilitate, support and scaffold pupils in their learning. Pupils were encouraged to visualize the bridge system in their minds eye, speculate on how it

Enhancing Learning Through Collaborative Inquiry and Action

might operate, explore possible ways of undertaking the task and then proceed to negotiate, implement and adapt an agreed course of action.

The video recordings of the third group showed there were times when the teacher appeared to remain silent and other times when he would probe and seek clarification and justification for the proposed action. There were several times when he prompted a change of track, but more significantly, he encouraged the group to listen and appreciate the special significance of the different ideas being suggested. With this group, the teacher appeared keen to promote a sense of tolerance and respect for alternative viewpoints, and for pupils to remain open-minded and resilient in their collaborative inquiry. Absence of this significant input, especially with the first group, was evident in that group's communicative discourse. This tended to be more of a disputational kind that was reflected in the rather poor quality of their final product. By comparison, there was greater evidence of the teacher scaffolding an approach to learning with the third group that was significantly more productive in terms of their creative thinking, exploration and productive activity.

Research context and methodology
This work arose from the author's involvement in a Comenius 2.1 European project, DIAL:Connect. The philosophy of DIAL:Connect encourages the use of dialogue to connect learning minds, construct understanding and initiate creative activity based on analogy and metaphor. Audio and video recording of pupil-pupil and pupil-teacher interaction facilitated analysis of the verbal interaction and group dynamics. Field notes, diaries and examples of pupils' work were all part of the data collection process.

The DIAL:Connect project is still at an embryonic stage but its philosophical underpinning has helped challenge teachers' views and conceptions of learning and teaching. In particular it has caused teachers and student teachers to rethink and critically reflect on classroom practices. Through the use of EPIC (Table 1), a conceptual framework designed to encourage the development of qualities such as open-mindedness, playfulness, and resilience in teaching and learning, teachers were being encouraged to shift from a teacher centred/content oriented classroom to a more pupil centred/learning oriented classroom (Kember, 1997).

The project is currently operating in ten European countries: Northern Ireland, UK, Italy, Romania, Sweden, Denmark, Portugal, Republic of Ireland, Slovenia, Cyprus. There is universal agreement amongst partners concerning its positive impact on pupil learning and sense of achievement. This view is transnational and not confined to one particular set of classroom circumstances. It encourages an approach to learning and teaching that emphasises purpose in learning, connectedness, a supportive classroom environment and acceptance of diversity. This is reflected in the following evaluative comment:

Dialogue, imagination, creativity, expression of individual and collective ideas and thoughts are all strongly stimulated during the teaching-learning process adopted.

Georgeta, Romania.

Engaging contexts: engaging minds
The extent to which the three groups in the study collaborated and used the language of thinking, action and productive activity in a coordinated way during problem solving was different. Critical reflection on the practice of the three groups points to a greater unity of purpose with the third group; better social cohesion, more evidence of exploratory and imaginative activity, tolerance and a willingness to negotiate and build on each other's contributions. Why this was so became a main focus of this study.

Transcripts of the verbal interaction during group problem solving helped make the language of thinking and productive activity visible and available for analysis and critical reflection. Findings from these tended to suggest that there were particular times during the collaborative process when the nature of the interaction and language used to progress a solution seemed more productive than others. This was evident, for example, during explorative activity and those times when pupils engaged in constructive, playful and creative activity. Analysis of the video and audio recordings for the third group in particular identified six such 'interactional contexts' during which pupils remained focused, on task, collaborative and productive. Ideas seemed to be better connected during these creative and productive phases and this was evident in the way language was used, modified and adapted during the interactional processes. The

Enhancing Learning Through Collaborative Inquiry and Action

nature of the interaction and language use of the third group was analysed in terms of the **initiation** and **response** components of that groups' communicative discourse. The communicative functions of the discourse during 'productive' activity tended to focus on: clarifying, explaining, thinking aloud, hypothetical, speculative, reflective, organizing, reasoning and negotiating behaviours (Halliday & Hasan, 1989). As suggested, the creative and productive activity of the third group seemed to take place within clearly recognizable interactional contexts that exhibited particular ways of thinking and acting. The six contexts

identified were co-construction, organizing, affirming, evaluative, exploratory, and off-task playful. A **co-construction** context is one where participants make positive attempts to reach a joint outcome, one that could not be reached unaided. Analysis of language use in such a context highlighted the following range of communicative functions: suggesting, clarifying, elaborating, explaining, justifying, contributing to and extending thinking. An **organizing context** tends to be one where an action plan is worked out and procedures are agreed individually and collectively. The **affirming context** is one that necessitates mutual

Table 1: Using EPIC to empower learner

Expressive		L1	L2	L3	L4	L5
Confidence:	communicating an idea with clarity, accuracy, precision and assurance					
Curiosity:	noticing, interested, inquisitive, inquiring questions, problem posing					
Open-mindedness:	speculating and predicting, hypothetical, joint construction					
Responsiveness:	interactive and participative, interpersonal, motivation and engagement					

Productive		L1	L2	L3	L4	L5
Exploratory:	open and exploratory orientation, considering alternatives, tentative					
Planning:	deciding and prioritizing, setting goals, deciding action plan					
Applying:	using what is known and willing to extend this, reaching understanding					
Monitoring:	self-regulating, checking progress, reflective, accepting ownership					

Innovative		L1	L2	L3	L4	L5
Adventurous:	trying out new ways of doing things, some risk taking, showing initiative					
Flexibility:	considering alternatives, different options and possibilities					
Creating:	insightful, resourceful, reflective, imaginative, making connections					
Evaluating:	self-efficacy and effectiveness, modifying, improving, reconstructing					

Collaborative		L1	L2	L3	L4	L5
Interdependence:	collectivity, intersubjectivity, accepting responsibility, mutuality					
Resilience:	persevering to make sense and make connections, reach conclusions					
Sensitivity:	empathy, tolerance, responsive understanding, suspending judgement					
Coaching:	assisting and guiding, supporting and encouraging, enabling					

L1   Reluctant to engage naturally, no exploratory / creative activity, practices avoidance tactics.
L2   Engagement is haphazard, exploratory activity not focused, easily distracted, high teacher dependency.
L3   Engagement is hesitant, explorations routine, requires probing, prompting and supporting.
L4   Engagement is more continuous, exploration more imaginative, interactive, accepting responsibility.
L5   Engagement is continuous, open-ended and reasoned, autonomous, independent and creative.

support. Pupils like to have their thinking confirmed, views listened to and ideas valued. An **evaluative context** provides pupils with opportunities to monitor and review their thinking, displaying such behaviours as thinking aloud, thinking and following through ideas, weighing up pros and cons, recognizing similarities and differences. The **exploratory context** was dependent on pupils being open-minded, flexible and adaptable. Other language and social functions included being hypothetical, curious, tentative, able to handle uncertainty, adventurous in thinking, willing to engage in some risk taking. The **off-task playful context** was as important as each of the other identified contexts. The video showed pupils seizing an opportunity or moment of freedom for being playful and in the process inventing a new name for the drawbridge. In such a context, pupils tend to see things in a new or different way, think out of the box, make new connections, change track or go in a direction not envisaged.

The following extracts, showing the dynamic nature of the interaction within **four** of these thinking and action-oriented contexts. Three of these interactional contexts are on-task (co-construction, exploratory, evaluative) and one is off-task but equally supportive of creative and productive activity.

1 Co-construction context

1. Stephen: Now we have the hinge working (demonstrates to Suzy and Chloe how the corriflute has been cut on the underside to make it act as a hinge for the drawbridge).
Initiates: demonstrates understanding.

2. Chloe: That's really good.
Responds: supports, encourages, affirms.

3. Jordan: *aside and playing with the syringes… comes across, places one of the syringes underneath the drawbridge and uses the other as a plunger to demonstrate how the bridge could be raised.*
Initiates: non-verbal.

4. Chloe: …not very high (observing the performance of the drawbridge).
Responds: evaluates.

5. Stephen: Needs to move in a bit *(points and encourages Jordan to move syringe*

closer to the hinge).
Initiates: reasons.

6. Jordan: *(Begins to experiment with the position of the syringe with Stephen taking control of the plunger).*
Responds: evaluates, mainly non-verbal

7. Chloe: put it (piston) right at the hinge…try it at an angle…see if that works…that's better…we want it to go higher… Sam's aiming for 30 degrees…we have to beat that *(referring to the story and the claim that Sam could raise the drawbridge to 30 degrees).*
Responds: evaluates, goal oriented.

8. Suzy: *Looks to the teacher and suggests…* how about using an electric band?
Initiates: hypothetical.

9. Stephen: *(Ignores Suzy's suggestion and along with Jordan continues experimenting with the positioning of the syringe/piston. Chloe looks puzzled).*
Responds: experimental, non-verbal.

10. Teacher: What have you in mind for the elastic band Suzy…can you share that idea? *(Suzy looks like she has been silently musing over an idea or something in her mind).*
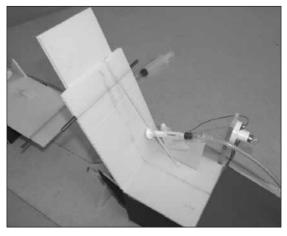**Intervenes: questions, seeks clarification.**

11. Suzy: *Without prompting, Suzy picks up an elastic band and stretches it over the corriflute. She then flicks the end of the corriflute and the drawbridge shoots up to over 90 degrees…absolutely amazing!*
Initiates: inventive, reflective, resourceful.

12. Chloe: That's brilliant…. Never thought of that…. We have beaten Sam…how do we get it *(pointing to drawbridge)* down again?
Responds: affirms, challenging.

Critical reflection

In this extract the group is engaged in situated, action learning. All minds are focused on the task and the

RESEARCH

challenge is to beat Sam's estimate of 30°. Jordan and Stephen are actively experimenting with the position of the piston and Chloe is offering constructive feedback. Suzy meanwhile has been standing back quietly observing this exploratory activity and appearing thoughtful. Suddenly she takes the initiative, becoming hypothetical (line 8). Her contribution may have gone unnoticed because of the others' preoccupation with a pneumatic system. The teacher, however, was keen for her voice to be heard and her thinking explored. In demonstrating a clever use of the elastic band, Suzy successfully switches roles from silent observer to lead partner (line 11). It also shows she had been quietly musing over the idea, perhaps engaging in a form of mental imaging, before deciding to act (Photo 1).

Photo 1: Clever use of elastic band.

The teacher's intervention appears timely and appropriate. It invites some really insightful thinking from Suzy concerning a clever use of the elastic band. Suzy follows up her idea with some very imaginative and largely unanticipated action. This has the effect of stopping the other participants in their tracks, causing them now to look in a completely different direction. Chloe is quick to acknowledge the brilliance of the idea and the group is keen to implement it after some slight modification. The verbal interaction and thinking of the group is ongoing, constructive and goal oriented. In this instance the teacher plays an active role encouraging open-mindedness, flexibility and initiative.

The action, production and communication evident in the interaction contributed to creating a shared thinking space that facilitated exploration, testing and evaluation of all ideas expressed. Peer collaboration was successful in exploiting this creative potential. It managed to challenge subjective understandings and helped process a joint outcome that surprised and delighted the whole group.

2. Exploratory context

1. Teacher	*(Points to the open drawbridge system).* How about another challenge now that the drawbridge is open? Is it possible somehow to switch on a bulb when the drawbridge opens to 90 degrees? Sam (referring to the story) thought he would be doing well getting the drawbridge to reach 30 degrees. Let's celebrate with a bulb switching on at 90 degrees. **Initiates: challenges.**
2. Group	*(Chorus answering and visible excitement at the idea. Chloe wants to know how you would go about doing it).* **Initiates: accepts challenge.**
3. Teacher	*(teacher and pupils interact to construct a circuit design that clearly annotates the components needed).* Teacher asks for possible suggestions and ideas for using this circuit arrangement. **Initiates: constructs understanding.**
4. Chloe	If we use a switch…no…if the bridge hits the wires on the way up they could touch…that would light the bulb. **Initiates: hypothetical.**
5. Suzy	*(pointing to the open drawbridge)* We don't want the bulb to light on the way up…better if the bulb stayed lit when bridge is open. What if it hit against something when it comes right up? **Initiates: counterchallenge, hypothetical.**
6. Jordan	*(points to drawbridge)* some sort of a crossbar…like a goalpost…have the wires there and they touch when the bridge comes up… **Initiates: hypothetical.**

7. Teacher Good idea Jordan…that could work… *(suddenly Stephen who has been standing quietly on the sideline leans forward and interjects with another suggestion…).*
Responds: affirms

8. Stephen *(Points to the triangular support he suggested using earlier as a stop for the drawbridge)….* We could put the wires through these *(points to the flutes of the corriflute)….* When the drawbridge comes up it could hit them and light the bulb…
Initiates: hypothetical.

9. Suzy That's really good…. That would work… let's try that.
Responds: mutually supportive.

10. Chloe That's cool… no way Sam could do this on his own….
Responds: encouraging, judgemental.

Critical reflection

In this extract the teacher introduces a further challenge: lighting a bulb when the bridge reaches 90-degrees. The reference to Sam and the 30-degree bridge opening appears sufficient motivation for the group to get involved. Chloe initiates the exploratory activity but the teacher intervenes to focus this, in the first instance, to a consideration of the circuit design. Once that is understood and agreed the challenge for the group is to find an appropriate way of using the circuit (line 3). Several possibilities are suggested but it is Jordan who comes up with the idea of a goalpost type switch (line 6). At that point, Stephen seems to intuitively move forward to show how the corriflute stop could be used to house a switch (line 8). He has made a clever connection with this particular bridge design feature; the group recognizes this and become intrinsically motivated to incorporate his idea. Interesting also to see the high incidence of initiatives shown during interaction within this exploratory context.

There is real delight when the bridge is tested and the open drawbridge comes to rest against the two switch wires and lights the bulb. Teacher and pupils work in close partnership to meet this challenge, continually monitoring, negotiating and agreeing a way forward.

The teacher participates and contributes to the thinking process but the pupils retain ownership of the challenge: the clever ideas for lighting the bulb belong to them. They have been adventurous in their thinking and resilient in their efforts to provide the solution they judge to work best. The pupils successfully negotiate different roles during their exploratory activity and interact with each other and aspects of the bridge with commendable skill. They explore different possibilities but remain open-minded and resilient in their search for the optimum solution.

3. Evaluative context

1. Stephen How about using this *(produces a small, right angled, triangular piece of corriflute from the resources box)* to stop it (pointing to the drawbridge) at 90 degrees?
Initiates: hypothetical

2. Chloe How'd you do that?…
Responds: seeks clarification.

3. Stephen Could use it like this *(positions the triangular shape on the top deck so that when the drawbridge opens, it comes to rest against its vertical edge – 90 degrees).*
Initiates: hypothetical, non-verbal.

4. Jordan That's good…put a pencil mark there and I'll get the glue gun *(Stephen marks the position of the triangular shape and Jordan is quick to use the glue gun).*
Responds: evaluates.

5. Suzy Let's try it and see what happens.
Initiates: hypothetical.

6. Stephen *(Operates the plunger and immediately the drawbridge springs up and stops at 90 degrees against the triangular support).* Perfect. *(Stephen then lowers the drawbridge by hand).*
Responds: evaluates.

7. Chloe *(Reaches forward and wiggles the triangular support)* We could glue another triangle against the side of that one to make it even stronger.
Initiates: evaluates.

RESEARCH

8. Stephen   We could do that…that's a better idea… *(Stephen and Chloe spring into action to implement it).*
Responds: judgemental

9. Teacher   This is going really well…it gives me an idea now…. *(points to the drawbridge and gesticulates with hands in a way that helps explain his thinking).* If we had two drawbridges, a bit like the London bridge, then as this drawbridge springs open it opens the other one as well …not sure how well it would work but it's worth a go…
Initiates: hypothetical, evaluates

10. Jordan   Let's make the other drawbridge first, then we can try it… this is going to be better than Sam's bridge *(the group quickly set about making another drawbridge similar to the first one).*
Initiates: hypothetical, evaluates

11. Teacher   *(Gesticulating with his hands)* This is now like the London Bridge with two drawbridges able to open. This one *(points to the first drawbridge)* opens really well… What do we need to do to cause it to open this one? *(points to the second drawbridge)*
Initiates: invites speculation, evaluates

Teacher opens the first drawbridge and because the two drawbridges are rubbing along the contact edge the second bridge rises slightly as the first one springs open.
Responds: non-verbal

12. Suzy   Did you see that? …the other one moved as well… it opened a bit….
Responds: hypothetical, evaluates

13. Stephen   Maybe we could make them touch each other more…. Have that one *(points to the second drawbridge)* …sitting over a bit on that one *(resting on the first drawbridge).*
Initiates: evaluates, suggests

14. Teacher   good idea… you mean *(using both hands to help explain)* one is resting slightly on top of the other…. When the bottom one goes up it pushes the other one up first… great idea.
Responds: evaluates, extends thinking.

15. Suzy   but then the road *(points to the drawbridge surfaces)* would not be level… *(standing back quietly musing over the situation)*… we could glue a piece underneath the first one and sticking out a bit so that the other one rests on it… that could work…
Initiates: evaluates, hypothetical.

Critical reflection

This episode illustrates the quality of pupil and teacher engagement in monitoring and negotiating a common understanding and a productive outcome. At the outset, Stephen sees a way of improving the performance of the drawbridge (lines 1-3), which is quickly followed up by Jordan (line 4). Evaluation of the bridge in action leads Chloe to suggest a further modification (line 7), which Stephen welcomes as an improvement (line 8). At this point the teacher makes a significant and sensitive intervention. Having watched the smart operation of the single drawbridge he makes a connection with the London Bridge design and its system of operation.

When the second drawbridge is in place the teacher participates by using the control plunger to operate the bridge system (line 11). The attentiveness of Suzy and others to the mating of the two drawbridges causes Suzy to call out…"did you see that!" The first drawbridge on opening had caused the second drawbridge to rise slightly but not enough to flick open to 90-degrees. A modification or improvement became the next important goal to be successfully negotiated by the group. This resulted in a bridge design, which went beyond anything that was envisaged either individually or collectively, at the outset.

There were several significant aspects to this episode. Stephen had seen the need for a means of stopping the drawbridge going beyond 90-degrees when fully open. Chloe evaluated Stephen's idea in action and suggested a further improvement (line 7). When the teacher evaluated the smooth functioning of the single drawbridge he decided to introduce a further challenge, one that was not in the original task

specification. The pupils were not left to handle the London Bridge concept on their own. Working together and in active partnership the responsibility for turning an idea into a working solution was shared. The motivation for doing so was self-evident. Increasingly the action, production and communication within this learning community was becoming self-directed, self-assessed and self-evaluated through a process of mutual support and collaboration.

4. Off-task Playful context

1. Jordan *(Produces a small polystyrene block as a notional car and moves it along the top deck, just short of the hinge mechanism… movement is accompanied with appropriate car engine sounds).*
Initiates: simulation.

2. Stephen *(Stephen joins in and decides to activate the drawbridge).* Up goes the drawbridge… lets the boat through…
Responds: Role-play.

3. Chloe Say we don't like this car… we could just throw it off the bridge *(Stephen smiles and decides to lower the drawbridge again).*
Initiates: inventive idea.

4. Jordan *(repositions the polystyrene block on top deck and moves it on to the drawbridge… Chloe now activates the drawbridge and catapults the polystyrene block into the air to shrieks of laughter).*
Responds: simulation, non-verbal, fun

5. Stephen We just whack off cars we don't like…wicked
Responds: agrees

6. Jordan *(acting out the scene again and this time with all the sound effects in place)* when the whacky cars come along we decide which ones we don't like and then whack them off.
Responds: animated sequence

7. Chloe Whacky cars… whacky bridge… this is fun.
Responds: spontaneity, fun, humour

8. Stephen Let's give it a name?
Initiates: hypothetical.

9. Suzy We've designed a whacky bridge… the whacker…
Initiates: invents.

10. Stephen The wacky whacker…
Responds: creative word play.

11. Chloe Whacky… Whack… Oh (laughter)
Initiates: creative word play.

12. Jordan Whacko…
Responds: creative word play.

13. Chloe Whackso… WHAC SO… (with emphasis)
Responds: creative word play.

14. Suzy WACK-O…. WAC-SO …. The WAC-O bridge *(spells out the letters)…*
Initiates: new name.

Critical reflection

Here the spontaneity and creativity of the group is reflected in the nature of the interaction during some off-task, playful and imaginative activity. It is Chloe who sparks off the creative interplay by seeing the drawbridge as something other than a drawbridge: a kind of fun machine for catapulting unwanted objects into the air. Jordan seizes on the idea and can be seen activating the newly discovered catapult with spectacular results. It seems to be a lottery as to which objects get chosen for catapulting and which don't. This heightens the surprise factor and fun element even more. The group becomes gripped with this discovery and Stephen suggests giving the fun machine a name (line 8).

Creative word play moves on from being more than just a bit of fun to being really helpful in finding a name that best matches their new invention. The talk is oriented to finding the best possible solution to the challenge they have now set themselves. They are in control of the situation; it is their invention, their challenge and they are enjoying it. The extract shows them feeding off each other's contributions and linking their creative word play to the task in hand. They keep fine-tuning their individual interpretations and ideas until a name that satisfies their own creative and idiosyncratic imaginations is reached. They are behaving in a way similar to real designers

RESEARCH

and marketing executives using word play and creative reasoning to invent a name for a new product. This toy creation has now become a wicked fun machine with a WACK-O name.

The communication tends to open up a 'thinking space' in the minds of participants in such a way that creativity occurs intuitively and with surprise effects. This then becomes channeled towards a shared purpose and the development of a new product. When one of the teachers call with the group to see their progress the pupils are keen to talk about the

bridge but more keen to demonstrate their wacky invention for disposing of not so wacky cars!

A visual display of the talk-in-interaction of the third group is shown below. This representation in terms of initiatives and responses from participants highlights the contingency of responses and democratic functioning of the group.
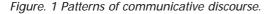
When considering the use of language, action and productive activity during problem solving, it was felt helpful to map patterns of communicative discourse
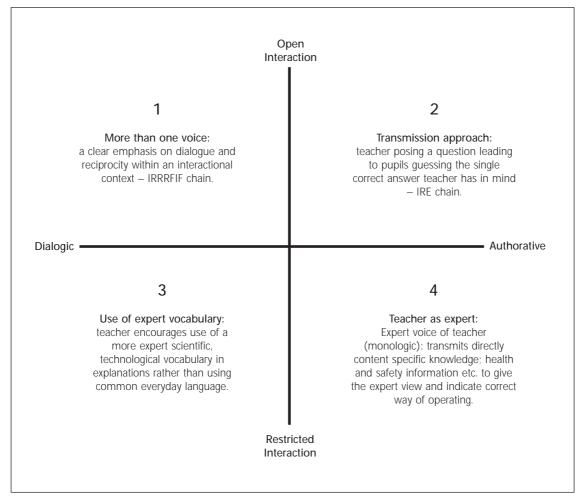
Table 2

1. Constructive context — ■ Initiates   ■ Responds

	1	2	3	4	5	6	7	8	9	10	11	12
Stephen	Initiates				Initiates				Responds			
Chloe		Responds		Responds				Responds				Responds
Jordan			Initiates				Responds					
Suzy								Initiates			Initiates	
Teacher										Initiates		
Line	1	2	3	4	5	6	7	8	9	10	11	12

2. Exploratory context

	1	2	3	4	5	6	7	8	9	10
Stephen								Initiates		
Chloe				Initiates						Responds
Jordan						Initiates				
Suzy					Initiates					
Teacher	Initiates		Initiates				Responds		Responds	
Group		Initiates								
Line	1	2	3	4	5	6	7	8	9	10

3. Evaluative context

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stephen	Initiates		Initiates			Responds		Responds					Initiates		
Chloe		Responds					Initiates								
Jordan				Responds						Initiates					
Suzy					Initiates							Responds			Initiates
Teacher									Initiates		Initiates			Responds	
Group															
Line	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

4. Off-task playful context

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stephen		Responds			Responds			Initiates		Responds				
Chloe			Initiates				Responds				Initiates		Responds	
Jordan	Initiates			Responds		Responds						Responds		
Suzy									Initiates					Initiates
Teacher														
Line	1	2	3	4	5	6	7	8	9	10	11	12	13	14

Enhancing Learning Through Collaborative Inquiry and Action

along the two dimensions of dialogue and interaction. This is shown in Figure. 1. The horizontal axis represents the dialogic-authoritative dimension and the vertical axis, the open interaction-restricted interaction dimension (Mortimer & Scott 2003).

The communicative approach characterizing the talk between teacher and students in each of the six *interactional contexts* identified in this study could be classified as **dialogic-open interaction** (residing in the first quadrant above). This is in stark contrast to traditional patterns of classroom discourse where teacher tends to be the main voice in the classroom.

In each of the interactional contexts defined, more than one voice was heard and there was a clear emphasis on open-mindedness, trust, and reciprocity. There was a significant use of 'could be' language and 'where to from here' type questioning and reasoning. When the teacher, however, encouraged the pupils to use a more technical vocabulary to explain the operation of the pneumatic control system, the pattern of communicative discourse revealed interaction of a more restricted type. In this instance, the teacher became the authority on technical content and vocabulary and pupils were being required to model their thinking on teacher explanations. Whilst

Figure. 1 Patterns of communicative discourse.

Open Interaction

1

More than one voice:
a clear emphasis on dialogue and reciprocity within an interactional context – IRRRFIF chain.

2

Transmission approach:
teacher posing a question leading to pupils guessing the single correct answer teacher has in mind – IRE chain.

Dialogic — Authorative

3

Use of expert vocabulary:
teacher encourages use of a more expert scientific, technological vocabulary in explanations rather than using common everyday language.

4

Teacher as expert:
Expert voice of teacher (monologic): transmits directly content specific knowledge; health and safety information etc. to give the expert view and indicate correct way of operating.

Restricted Interaction

RESEARCH

the pupils were still engaged in dialogue, it tended to be dialogue of a more restricted kind: *dialogic-restricted interaction* (second quadrant).

The third quadrant *open interaction-authoritarian* is more reminiscent of traditional modes of teaching where the class teacher is not satisfied until given the single correct answer he is looking for. This characterization is reflected in the number of 'no, not the right answer' or 'not the answer I'm looking for' teacher replies contained in the relevant transcript. The teacher as expert characterizes the fourth quadrant, *restricted interaction-authoritarian*. The expert voice in this case is the teacher's and the pupils respect that. When a teacher demonstrates safe practices in the workshop, he is the authoritative figure and communication tends to be characterized in clearly definable procedures.

Analysis of the problem solving characterizing this study showed identifiable patterns of communication, action and productive activity. Significantly, it was the third group that had a preponderance of activity in the first quadrant of Figure 1. Whilst the work of that group majored in the dialogic–interactive quadrant, analysis showed that the nature of the learning demanded recourse to all four quadrants, depending on need.

Conclusion

The extent to which the three groups collaborated and coordinated the language, action and productive activity in each of the three situated learning contexts was different. There seemed to be greater unity of purpose, better social cohesion and greater evidence of exploratory and imaginative activity during the meaning making and knowledge building processes of the third group, than with the other two. The teacher played a key role in the third group, modelling an approach to learning that valued 'student voice' and an 'effort based view of learning' (Costa 2002; Dweck, 2000).

In the process of negotiating and solving problems the pupils could be seen exploring, sharing, listening and working together. This act of collaboration and purposeful inquiry seemed to have real potential in opening up a 'mental space' between participants encouraging them to think for themselves, negotiate

meaning, construct and reconstruct understanding. In addition to stimulating creative thinking, the bridge challenge seemed to provide a landscape for the development of positive dispositions and attitudes to learning. When a class teacher visited the group at the end of the activity, Kathryn was very quick to call out:

'If we did more of this Mr. McWilliams, we would be really smart'.

Kathryn, 11 yrs old.

The story provided an *authentic context* for this design challenge. Authenticity of context, learning experience and means of assessment seemed to induce in the pupils the kind of creative problem solving behaviour needed to complete this successfully. With the third group the teacher adopted a role that helped mediate critical thinking and metacognition about strategies (Sternberg, 1998). The teacher seemed to provide what Newman et al (1989) refer to as 'challenge-plus-support' by helping make the thinking processes visible and available for development.

This research study helped highlight a number of factors that seemed to contribute, in a significant way, to the motivation and creative disposition of the learning group. The following four points are not listed in a particular order or as a checklist for guaranteeing success. When viewed holistically they do, however, represent a particular approach to learning and teaching that emphasizes the importance of authenticity, collaboration, and language, in the process of knowledge construction and understanding.

1. Authenticity: the context was authentic and the pupils were involved in a process that was self directed, self managed and self assessed. Ownership was key to engagement.
2. Collaboration: the language of thinking and action was made visible by the teacher modelling an approach to learning that valued student voice, respect for alternative viewpoints and the ability to listen. Thinking and working together in a coordinated way fuelled the motivation to succeed.
3. Language: in working collaboratively the pupils were learning to learn and learning how to reason and think creatively. The transcripts showed the

important use of 'could be', how about' and 'what if' language. The pupils were learning to give reasons in support of their thinking and in the process they were learning the language of learning. Language was working as a tool for thinking and reflection.

4. Quality of learning and teaching: Teacher helped mediate and orchestrate the learning by intervening sensitively and at times indirectly in the learning process: asking a question, seeking clarification, challenging an idea, encouraging student voice and a disposition to be curious, resourceful and resilient.

Kite (2001) claimed that "in general, little guidance is given to teachers as to how they can translate the teaching of thinking into their classroom practice…". The approach to learning advocated by this research study encourages more divergent and holistic forms of assessment in the classroom as a means of initiating change in classroom practice. To this end EPIC was designed as a conceptual framework for encouraging teachers to adopt a more 'futures oriented' view of the curriculum (Table 1). EPIC places an important emphasis on the strengthening of learning dispositions by encouraging more open forms of learning engagement, social interaction, and creativity in thought and action. Schools need to 'turn out people who, in addition to being proficient in basic skills, will be prepared to learn new things, collaborate in the solution of novel problems, and produce innovations in areas that presently may not even exist' (Bereiter, 2003).

The pupils who really succeeded in this research study immersed themselves in a challenging situation. They designed a clever way out of the situation by being inquisitive, interdependent, and initiating action based on reasoned argument.

'Children are the future… this project was good because we got to use our brains'.

Suzy,11yrs old

The following evaluative comments are from the teachers involved in the DIAL:Connect project at the end of the first year.

'The story provided a good context for thinking and learning. Contextualised learning provides a mental framework that enables pupils to make connections, build and reflect on what they already know, understand and can do. This is important in making their own learning more secure and in enabling them to engage in further creative activities, for example: writing a poem, designing a poster, constructing a letter, successfully undertaking a design and technology challenge. All of these activities the pupils experienced through engaging imaginatively with the story'.

Peter, Belfast.

'There was a great happiness and sense of invention in those groups that collaborated well together – and so was the longing for the next lesson! We learnt a lot.'

Karl-Uno and Rolf, Sweden.

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Enhancing Learning Through Collaborative Inquiry and Action

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