Running head: COLLABORATIVE SCIENCE LEARNING ENVIRONMENT

Creating a Collaborative Science Learning Environment for Science Inquiry at the Primary Level

Abstract

Over the years, there has been much discussion of the use of groups to promote pupils' academic and affective outcomes through increasing the quality of interactions in the groups. Despite the emergence of numerous group work strategies, there is concern over the integration of group work and subject teaching. In this study, a collaborative science learning environment (CSLE) is designed to help teachers incorporate small-group learning with science inquiry. The CSLE engages pupils collaboratively in an active thinking and talking process in a scaffolding inquiry cycle. The changes in pupils' competence in science inquiry, feelings of relatedness, and the challenges faced in the CSLE were discussed.

Creating a Collaborative Science Learning Environment for Science Inquiry at the Primary Level

In today's economy, merely memorizing facts and procedures is not enough for success (Sawyer, 2006); understanding *why* and *how* instead of *what* has become increasingly important for learners. Hence, the inquiry approach is encouraged to help pupils develop their skills in making observations, collecting, analysing and synthesising information, and drawing conclusions to answer questions (Curriculum Development Council, 2002). For easy management and sharing of resources, groups are commonly used in science lessons, particularly for science inquiry activities. And how group work can facilitate collaboration among learners is always an area of investigation in science education research.

Literature Review

Science Inquiry in Science Learning

Inquiry, what science is fundamentally about, is the process of posing questions about the world in which we live and then investigating and evaluating possible answers to the questions (Patrick & Yoon, 2004). Duschl (2008) suggested that the new perspective of science education should focus on what pupils need *to do* to learn science and inquiry is a way through which pupils *do* to learn science. Over the years, research on inquiry approaches to science instruction has shown promising effects on pupils' learning (e.g. Schroeder, Scott, Tolson, Huang, & Lee, 2007).

In respect of science inquiry, practical work alone is insufficient to bridge the gap between what pupils observe from hands-on activities and the ideas of science; minds-on activities are needed for pupils to talk about the ideas, and to think about the meanings (Wellington & Osborne, 2001). Moreover, pupils should be engage in "oral and written discourse" (National Research Council, 1996, p. 36), providing explanations for the problem-solving strategies used, because doing so promotes self-reflection which is an essential component of metacognition, understanding and self-regulation (Baird & White, 1996; Davis, 2003). Researchers have repeatedly demonstrated that conceptual understanding in science is supported by having pupils discuss ideas among themselves (Howe & Tolmie, 2003). Pupils who experience discussion, consensus and guidance make more conceptual and procedural progress than those who do not (Howe, Tolmie, Duchak-Tanner, & Rattray, 2000).

Traditionally, science inquiry is viewed as an individualistic process during which a scientist works alone in a remote laboratory. Indeed, science inquiry is both an individual and a social process (Duschl, 2008).

Science Learning in Groups

Group work has long been used in science classrooms due to practical and pedagogical considerations. The practical consideration refers to the nearly impossible supply of science apparatus on a one-to-one basis, while the pedagogical consideration to the support of conceptual understanding in science by discussing, debating, and defending ideas among pupils. However, little genuine and good quality group work has been found in authentic classrooms (Baines, Blatchford, & Kutnick, 2003; Galton, Hargreaves, Comber, Wall, & Pell, 1999).

Cohen (1994) found that asking individuals to work in groups would not necessarily benefit individual learning. Much of the time, teachers assign pupils into groups and ask them to complete a task by themselves without much concern for how the task is completed. Gillies (2006) suggested that structured groups be established so pupils understand how they are to work together, contribute, accept responsibility for completing their part of the task, and help others to learn in a supportive environment in order to maximize the benefits of cooperation, and ultimately to promote learning (Johnson & Johnson, 1990; Johnson & Johnson, 2006; Slavin, 1995). Research studies on group work indicated that cooperative learning has positive effects on pupils' academic and social outcomes (O'Donnell & King, 1999; Slavin, Hurley, & Chamberlain, 2003; Webb & Palincsar, 1996) as well as on pupils' science learning (Lin, 2006; Lynn, 1992).

Collaborative Learning Environment

Learning environments supports pupils' deeper understanding by requiring them to be more motivated, and getting them cognitively engaged (Bransford, Brown, & Cocking, 2000). Blumenfeld, Kempler, and Krajcik (2006) discussed how the intertwined features of learning-sciences-based environments – authenticity, inquiry, collaboration, and technology – influenced the four determinants of the motivation and cognitive engagement of learners, namely value, competence, relatedness, and autonomy.

Authenticity helps to motivate pupils by increasing interest, providing a reason for understanding, creating value for learning through drawing connections to the real world, pupils' daily lives, and practice in the discipline, and requiring knowledge transformation (Newmann, Marks, & Gamoran, 1996).

Inquiry includes components that motivate pupils by influencing value and perceived autonomy. During inquiry, feelings of value and commitment are enhanced when pupils take an active role in exploring real-world topics and sharing results and conclusions with others; it is also when pupils need to be cognitively engaged to synthesize, plan, make decisions, and transform information and data into a variety of forms (Blumenfeld, Kempler, & Krajcik, 2006).

Collaboration enhances motivation as it meets pupils' needs for relatedness by providing opportunities for them to work with peers and adults, and promotes pupils' feelings of competence through shared effort (Hickey, 1997). It also benefits cognitive engagement when pupils explain, clarify, debate, and critique their ideas (Yackel, Cobb, & Wood, 1991).

Successful incorporation of these features helps create effective learning environments that scaffold pupils' active construction of knowledge (Sawyer, 2006). As Pea (1993) asserted, "knowledge is socially constructed through collaborative efforts" (p. 48); therefore, it seems reasonable and meaningful to create a collaborative learning environment for pupils to engage in the social process of constructing science knowledge and understanding during science inquiry.

Methodology

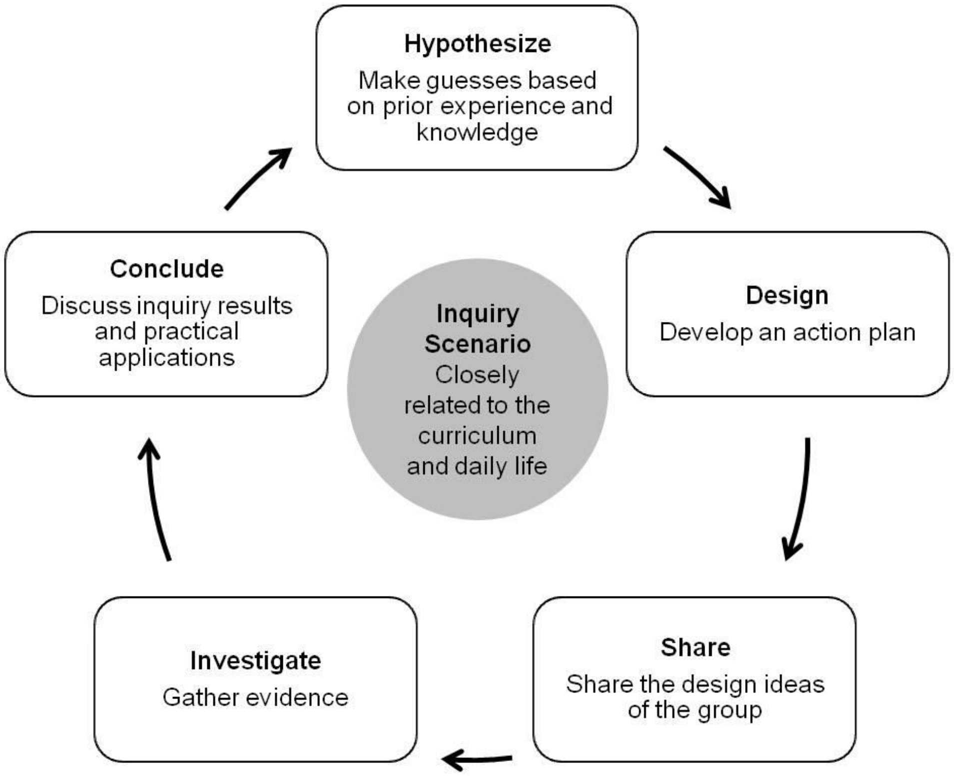
Design of a Collaborative Science Learning Environment

In this study, a collaborative science learning environment (CSLE) with three of the features of the effective learning environments – authenticity, inquiry, and collaboration – was designed to support pupils' development of competence in science inquiry and enhance pupils' feelings of relatedness during group work.

Authenticity. Teachers selected grade-appropriate science inquiry topics closely related to pupils' everyday life to help them connect their prior experience and knowledge to real-world problems. By situating content in questions, problems, designs, or anchoring events that encompass important subject matter, pupils can learn the ideas, processes, and skills when they get involved in working (Blumenfeld, Kempler, & Krajcik, 2006).

Inquiry. Anderson (2002) summarizes the key components of inquiry-based learning as teachers facilitating pupil thinking through scaffolded instruction and explicit reflective thinking. In this study, a five-step science inquiry cycle focusing on developing pupils' science inquiry skills was designed with reference to several discussions on inquiry/ investigation cycles (Bowers & Zinnen, n.d.; Bybee; 1997; Trowbridge, Bybee, & Powell, 2004; White & Frederiksen, 1998). Scaffolding for science inquiry is provided to pupils develop the ability to hypothesize based on inquiry questions posed by the teachers (make guesses based on prior experience and knowledge), design (develop an action plan), share (share the design ideas of the group), investigate (gather evidence), and conclude (discuss inquiry results and practical applications) (Figure 1).

Figure 1. Science inquiry cycle for upper primary pupils



Collaboration. This study took the sociocultural perspective of learning, and emphasized on encouraging teachers to use collaboration-oriented and dialogically-organized instruction (Pappas, Kiefer, & Levstik, 2006) to foster pupil-pupil interactions and to flexibly adapt different types of co-learning to benefit pupils' science learning, regardless of whether they are "cooperative learning", "collaborative learning" or "helping and tutoring" strategies (Baines, Blatchford, & Chowne, 2007). Since the teachers were inexperienced in integrating science inquiry and group work, various cooperative learning structures (Table 1) and group roles (Table 2) suggested by Kagan (2007) were recommended so the variety of ways of interactions would match the tasks of each step of the science inquiry cycle. The teachers could flexibly modify the structures suggested or make informed decisions about the use of other group work strategies to address the needs of their pupils.

Table 1
Suggested Cooperative Learning Structures for the Science Inquiry Cycle

Step of science inquiry	Purpose	Suggested cooperative learning structures
Hypothesize	Promotes science talk and discussion by	Pairs Check

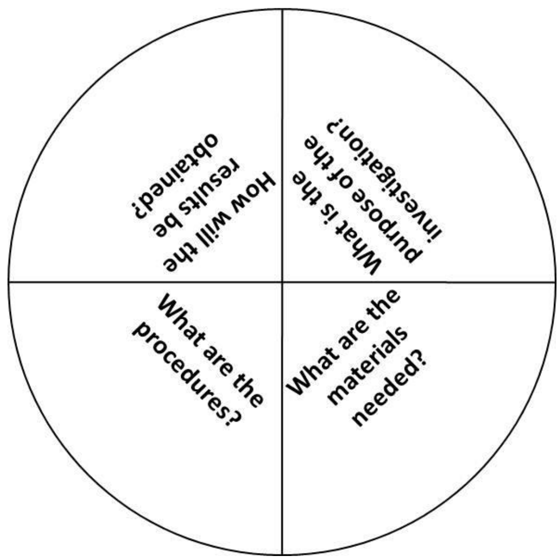
	activating pupils' prior knowledge to make hypotheses with evidence	
Design	Develops an investigation plan with the collective effort of the group	Team Word-webbing
Share	Allows the exchange of ideas and critiquing among groups through sharing and asking questions	Team Presentations
Investigate	Practices science investigation skills and completes an investigation through collaborating with group members	Pairs Check
Conclude	Enhances science thinking and discussion through data analysis and interpretation data to make conclusions	Pairs Check

Table 2
Suggested Group Roles

Group role	Responsibilities
Reporter	• Reports the results of group discussions or investigation results
Summarizer	• Synthesizes group members' opinions • Records investigation results and presentation time
Gatekeeper	• Ensures all group members express their ideas and complete their tasks on time • Answers the questions from other groups after the Reporter finishes the presentation
Challenger	• Studies and checks the investigation data • Puts forward challenges against the ideas of group members • Raises questions against the other groups after their presentations

Table 3
Suggested Cooperative Learning Structures

Cooperative learning structures	Description
Pairs Check	The 4-member group is further divided into two sub-groups. One pupil in each sub-group answers the first question, the other pupil checks and praises. The two pupils then exchange roles. After

	finishing every two questions, the two sub-groups compare and discuss the answers together. Finally, the whole group celebrates or resolves differences. Repeat the steps until all questions are answered.
Team Word-webbing	Questions are arranged around a circle on a worksheet. The whole group starts with discussion, followed by each member in the group writing simultaneously on a piece of chart paper with a pen of different colour. The worksheet is then turned clockwise for 90 degrees each time so each member can add ideas to each question. 
Team Presentations	The reporter of each group shares the group ideas with the rest of the class and asks the class a question concerning their design while the challengers from other groups raise questions concerning the design suggested by the presenting group.

Design of Study

Phase I Professional Development Stage. The teachers were introduced to the use of communication strategies that challenge children's cognitive and metacognitive thinking during group work (Gillies & Khan, 2009) in workshops illustrating how cooperative learning structures could be integrated into science inquiry to create a CSLE. After the workshops, they worked out the plans of CSLE for science inquiry topics related to the local curriculum. The plans, including the teaching designs and pupil worksheets, were reviewed and commented on by the researchers in terms of the design of the science inquiry and the use of cooperative learning structures for the teachers to make further refinements.

Phase II Classroom Implementation Stage. The teachers implemented the CSLEs in their classrooms. Pupils' perception of competence in science inquiry and their feelings of relatedness were studied. Perceived competence refers to pupils' feeling of competence or efficacy regarding their ability to succeed in a particular task whereas feelings of relatedness are pupils' feelings of belonging in interacting with peers and teachers.

Participants

Teachers. A total of 47 teachers from 22 local primary schools were involved. They all attended the workshops in Phase I and implemented the CSLEs in their classrooms with different science inquiry topics in Phase II. None had previous experience of implementing science inquiry with group work.

Pupils. In all, 647 upper primary pupils, aged 10-12, from the 22 schools were involved. All the pupils had experience in small-group activities but had not participated in any science inquiry activity with group work. Teachers were encouraged to help pupils form heterogeneous groups for the inquiry lesson.

Methods of Data Collection and Analysis

Qualitative and quantitative data were collected to answer the following research questions:

1. What was the pupils' perceived competence to succeed in a science inquiry task in the CSLE?
2. What were the pupils' feelings of relatedness of themselves and members' in the CSLE?

From the perspective of pupils. All pupils involved in this study completed a 4-point Likert scale questionnaire consisting of exactly the same questions before and after the inquiry lesson. The questionnaire were designed with reference to three major sources, including (1) evaluations of cooperative and observed interactive behaviours (McManus, 1996), (2) a cooperative survey for a cooperative environment (Neo, 2004), and (3) the quality of the group interactions and social/ interpersonal skills (Developmental Studies Center, 2005).The first part of the questionnaire consisted of 9 items focusing on the pupils' perceived competence in the science inquiry and the second part consisted of 10 items related to the pupils' feelings of relatedness of self and members in the group. The coefficient alpha of internal consistency for this pupil questionnaire is .89. This indicates a high degree of internal consistency among the items, signifying the reliability of the pre- and post-questionnaires.

From the perspective of teachers. For the triangulation of the data collected regarding the challenges experienced by the pupils in the CSLE, in-depth face-to-face group interviews with the teachers were conducted. Each interview session lasted for approximately an hour. In total, 47 out of the 56 teachers who participated in Phase II (at least one teacher from each school) were interviewed. The following areas concerning pupil learning in the CSLE were discussed during the interviews: Pupils' competence in carrying out science inquiry; pupils' collaboration in the groups; and challenges facing pupils.

Results

Pupils' Perceived Competence in Science Inquiry

Paired sample *t*-test analyses were performed to compare the mean differences between the pre- and post-questionnaire scores of each item. As for the pupils' perceived competence in science inquiry, the results indicated significant gains after they worked in the CSLE.

By comparing the mean scores of the pre- and post-questionnaires using the paired sample *t*-test, significant difference, $p < .001$ (two-tailed), was found for every item concerning pupils' perceived competence in science inquiry (Table 3) including "Making hypotheses based on prior experience" (t = 11.52***); "Designing testing methods" (t = 11.39***); "Assigning variables (changing factors)" (t = 12.85***); "Selecting appropriate materials for the test" (t = 11.38***); "Making observations and recording data" (t = 8.08***); "Drawing conclusions based on observations" (t = 9.02***); "Coming up with alternative testing methods" (t = 7.19***); "Raising more questions related to the inquiry topic" (t = 7.56***); and "Connecting the inquiry results to daily life" (t = 11.52***).

Table 3

Mean Score Differences for Items Concerning Pupils' Competence in Science Inquiry from the Pupils' Pre- and Post-Questionnaires

Items	pre-questionnaire Mean (*SD*)	post-questionnaire Mean (*SD*)	*t*-value and significance
Making hypotheses based on prior experience.	2.72 (.85)	3.18 (.76)	11.53 ***
Designing testing methods.	2.71 (.87)	3.18 (.75)	11.39 ***
Assigning variables (changing factors).	2.47 (.92)	3.02 (.83)	12.85 ***
Selecting appropriate materials for the test.	2.97 (.87)	3.43 (.72)	11.28 ***
Observing and recording.	3.03 (.85)	3.37 (.75)	8.08 ***
Making conclusions based on observations.	2.84 (.86)	3.23 (.77)	9.02 ***

Coming up with alternative testing methods.	2.71 (.90)	3.03 (.85)	7.19 ***
Raising more questions related to the inquiry topic.	2.70 (.88)	3.01 (.81)	7.56 ***
Linking inquiry results to daily life.	2.77 (.91)	3.13 (.85)	8.27 ***

*** $p < .001$

During the teacher interviews, the teachers explained how science inquiry in the CSLE is different from science inquiry activities that the pupils usually participated. In the past, pupils mostly carried out science inquiry by merely following the procedures provided by their teachers to complete the investigations and find out the results; they were rarely asked to design the experiments by themselves. The CSLE instead actively involves pupils in every step of the science inquiry cycle. Pupils not only have to conduct investigations, but they also have to engage in science thinking and discussions, supporting them to construct a better understanding of science inquiry. The quotes below exemplify some common science inquiry practices in local classrooms:

> Pupils have very little experience of or opportunity to carry out experiments. They are rarely required to make hypotheses, design an experiment or compare the results collected with the hypotheses. (T-Sch05)

> Pupils are usually not required to think much about the test. They only have to follow the steps given by the teachers. They do not have to design an experiment by themselves. (T-Sch10)

> Pupils have the opportunity to participate in science inquiry once or twice a year, but it usually focuses on finding out results instead of carrying out a systematic and in-depth investigation like this time. (T-Sch19)

> Pupils may make hypotheses when undertaking science inquiry, but they really lack training in designing experiments. (T-Sch20)

Moreover, the teachers showed recognition of the importance of thinking in science inquiry. Though challenging, the teachers believed that thinking would raise the pupils' interest in science inquiry (e.g. T-Sch08), develop their critical thinking and problem-solving skills (e.g. T-Sch03), allow them to have a clearer idea of the purpose of the inquiry (e.g. T-Sch11), and promote their understanding of the inquiry topic (e.g. T-Sch16). During the interviews, the teachers described the merits of thinking in science inquiry. For example:

> Though thinking may be challenging to the pupils, it increases their interest in inquiring into the topic. (T-Sch08)

> Through expressing their own ideas and discussing with one another, the pupils' critical thinking and problem-solving abilities are promoted. I believe thinking is kind of the essence of science inquiry. (T-Sch03)
>
> The pupils need more training in thinking … thinking is important because the pupils should start with some questions in mind that they would like to answer by carrying out an inquiry. They need to learn how to think and then search for knowledge. If we [teachers] provide all the information for the pupils, there's no need for them to search, then there would not be any inquiry. (T-Sch11)
>
> Pupils must be required to think before carrying out the inquiry so that they have a much deeper impression of what they have learned, and they would be able to learn more about the inquiry topic. (T-Sch16)

Pupils' Feelings of Relatedness in the CSLE

As shown in Table 4, the means for all items were above the mid-point (Mean > 2.00) in the pre-questionnaire, implying that the pupils' feelings of relatedness were not low even before the implementation of the CSLE. Still, it is worth noting the improvement to different extents for individual items concerning their feelings of relatedness (self and members) reflected by the results of the paired sample *t*-test (Table 4).

With regard to the pupils' feelings of self-relatedness, despite having the highest mean score in the pre-questionnaire, ,the score for "I participate in the group" was significantly higher (t = 5.64***) after implementing the CSLE. It was also found that the pupils became more willing to listen to others (t = 3.11**) albeit the relatively higher score in the pre-questionnaire. Yet, there was no significant change in other items.

Table 4

Mean Score Differences for Items Concerning Pupils' Feelings of Relatedness from the Pupils' Pre- and Post-Questionnaires

Items	pre-questionnaire Mean (*SD*)	post-questionnaire Mean (*SD*)	*t*-value and significance	
Self-relatedness				
I participate in the group.	3.45 (.70)	3.65 (.64)	5.64	***
I'm not willing to listen to others' ideas in the group. (reverse item)	3.22 (.95)	3.36 (.95)	3.11	**

I encourage/remind others to participate in the group.	3.07 (.79)	3.08 (.82)	0.21	
When I do not understand something, I will not ask others in the group. (reverse item)	2.95 (1.04)	2.88 (1.13)	-1.38	
When I disagree with others' ideas, I will express my own ideas.	2.23 (.77)	2.22 (.81)	-0.30	
Members' relatedness				
Group members do not pay attention to what others say. (reverse item)	2.78 (1.01)	2.87 (1.07)	1.80	
Everyone has the opportunity to participate or express ideas.	3.29 (.81)	3.32 (.84)	0.76	
There is conflict amongst group members. (reverse item)	2.59 (.98)	2.74 (1.04)	3.07	**
When group members do not understand something, they will ask others in the group.	3.05 (.83)	3.12 (.89)	1.68	
Decisions are made after agreement by everyone in the group.	3.27 (.82)	3.29 (.83)	0.34	

*** $p < .001$
** $p < .01$

Data from the interviews revealed that most teachers (20 out of the 22 schools) adopted the group roles suggested, in that 38 % assigned roles for the pupils, 43% allowed them to choose their own roles, and 19% had the roles rotated from step to step in the science inquiry cycle. Only the teachers from one school did not make use of group roles and simply assigned a leader for each group. The teachers commented that the pupils, each with a specific role in the group, knew better what to do when collaborating with others in the group. Giving each pupil a unique group role also acknowledged the value of each individual in the group, and therefore motivated participation. Two teachers explained how the use of roles got the pupils involved in collaboration tasks:

> I could see that the participation of each pupil was increased. Usually some pupils would dominate the discussion and some others would be very quiet, but now everyone had a role to play. (T-Sch18)

> If pupils are simply divided into groups, some may do more and some may do less. The good thing about this [the CSLE] is that each pupil is assigned a role in the group, so they must do what they have to do. This can really "force" those who are lazy or reluctant to make an effort to participate because the pupils are

> interdependent on each other. (T-Sch22)

Another teacher found that the pupils had greater confidence when they had a role to play:

> The reporter not only presented to the whole class the group ideas, but he/she also had to ask other groups a question to see whether they were really listening. The audience also had to pay attention to what the reporter said because they had to think of a question to "challenge" him/her. Therefore, the reporter had a greater sense of success because they used to worry a lot about not being listened to by other pupils. (T-Sch16)

Whereas for the pupils' feelings of members' relatedness in the CSLE, though pupils' feeling of "there is conflict amongst group members" (reverse item) was relatively low before, implying little conflict within the group, the data analyses indicated a significant improvement ($t = 3.07^{**}$) (Table 4). The following quotes describe what the teachers observed during the implementation of the CSLE:

> The pupils communicated with each other quite well in the group. Even when they had different opinions, they would try to explain to others patiently and give reasons. They wouldn't just shout and make a commotion. (T-Sch04)

> Group members divided the work among themselves according to their roles, each being responsible for a specific task. (T-Sch01)

> Group members were willing make an effort and did what their roles required them to do; no one shirked their responsibilities. They virtually couldn't "escape". (T-Sch22)

Discussion

Challenges Facing Pupils during Science Inquiry

As found from pupils' questionnaires, there were significant gains in their perceived competence in science inquiry, indicating that the pupils felt more competent about succeeding in science inquiry tasks. Nonetheless, some challenges facing pupils during inquiry were revealed from the teacher interviews.

First, the pupils had difficulty providing evidence for their claims. This problem was prominent during the Hypothesis Stage. Explanations given by the pupils were often superficial (e.g. T-Sch01) or were based on common sense or subjective experiences (e.g. T-Sch21 and T-Sch22). The pupils seemed unable to give a scientific and logical account of their hypotheses. The following quotes below illustrate the difficulties that the pupils experienced:

> The pupils mostly made hypotheses based on their daily experiences, or they simply made a guess. (T-Sch01)

> The pupils spent a great deal of time discussing "why". However, their guesses were based only on daily experiences. (T-Sch21)

> The pupils hypothesized based on their daily experiences, but because they all have different experiences it was hard for them to reach a consensus and make a single hypothesis for the group. (T-Sch22)

Second, the pupils failed to express their ideas well in written form, especially when more complex and abstract concepts were involved. Particularly during the Hypothesis Stage, some teachers found that the pupils could express their ideas orally but not in writing. The quotes from two teachers capture the difficulty that the pupils had in writing:

> Since the pupils are better in oral expression than written expression, it would be better if they are allowed to present their ideas in oral form. (T-Sch01)

> It's quite difficult for them [the pupils] to provide reasons or give explanations. They may be able to say the reasons, but it's hard for them to write them down. (T-Sch04)

This finding echoes the concern raised by several studies (see Reznitskaya, Anderson, & Kuo, 2007; van Amelsvoot, Andriessen, & Kanselaar, 2008) that while pupils may be able to demonstrate the use of different discourses during small group discussions, transferring these skills to independent and novel "text-like" tasks is more difficult and may require a period of practice and consolidation.

During the Design Stage, the teachers noticed that the pupils could easily state the purpose of the investigation and list the materials needed but not planning the steps of the test seemed to be an obstacle to them. For example, one teacher commented:

> It's hard for the pupils to write down the steps; they just couldn't list the steps one by one. (T-Sch15)

Third, the teachers found that the pupils experienced difficulty in raising meaningful challenging questions with regard to the test design presented by the other groups in the Share Stage. The questions that the pupils raised might be unreasonable or unrelated to the test design. For example:

> Two-thirds of the groups failed to raise meaningful questions to challenge the presenting group. Some groups even raised questions that were unrelated to the test design. (T-Sch04)

> The pupils tried to design questions to challenge other groups, but the questions were not related to the test. This part was difficult for the pupils. (T-Sch11)

Fourth, it was revealed from the teacher interviews that some pupils had no idea of making sense of the data collected from the investigations to draw conclusions. For example:

> The pupils couldn't draw conclusions because they didn't know how to integrate the data collected. (T-Sch13)

Challenges Facing Pupils during Collaboration

Since pupils' ratings for their feelings of relatedness before implementing the CSLE were above mid-point (Mean > 2.00), the implementation of CSLE in this study did not seem to have significantly enhanced pupils' collaboration as only a few items from the pupils' pre- and post-questionnaire showed significant improvement. During the interviews, the teachers mostly talked about the challenges pupils working with the cooperative learning structures. For example:

> At first they [pupils] tried to do the discussion using Pairs Check but then they failed and four of them just discussed together because the two sub-groups were just sitting too close to one another. (T-Sch05)

> Pupils were not familiar with the steps of Pairs Check. Some pupils simply answered the questions together while some missed some of the questions. (T-Sch21)

A few teachers talked about the unfavourable interactions that occurred during pupil collaborations. The following two quotes some examples:

> The pupils still considered themselves as individuals. If they were not required to do so, they just wouldn't care about others in the group. They would not modify their ideas because of what others said. (T-Sch11)

> Some pupils are quite self-centred and always wanted to be the first one to speak. (T-Sch01)

In line with what the teachers mentioned during the interviews, the division of work among group members was not a particular challenge to the pupils.

Conclusion

Pupil engagement through an authentic inquiry context of contemporary science-related issues closely relevant to the pupils' daily life is captured in the present study. Authenticity engages pupils in "hands-on" and "minds-on" activities that develop their practical science inquiry skills and science thinking skills. This helps pupils construct the meaning of the inquiry, therefore providing a reason to inquire and learn. To understand new ideas, pupils should be given authentic opportunities to talk about new ideas, use appropriate terminology, and think about their meaning (Wellington & Osborne, 2001). Moreover, to think, which means to reason, requires pupils to have the ability to use ideas and language and to construct arguments that connect evidence and empirical data to ideas and theories. Rivard and Straw (2000) believe that talking and writing complement each other to support the knowledge construction of pupils. Talking is about the social construction of knowledge, while writing can be used as a means for the personal construction of knowledge.

As for pupil collaboration in the CSLE, the use of group roles made division of work among group members more even and therefore reduced conflicts and at the same time allowed everyone to participate in the science inquiry task. Ensuring more equal opportunities for participation might result in better understanding and deeper learning. Besides, pupils' self-confidence and motivation for learning were enhanced when they could contribute to the group. Hence, effective grouping of pupils in a class and proper arrangement of work within the groups are critical to pupils' participation in the group and motivation to learn.

The challenges presented to pupils in this study were primarily concerned with working with cooperative learning structures. The pupils still tended to work as individuals rather than as groups, because some cooperative learning structures are quite complex and the pupils have not yet adopted them as a natural part of the school day. In facilitating pupils to familiarize themselves with these complex cooperative structures in a progressive and systematic manner, incorporating various cooperative learning strategies into the teaching of different subjects is a possible way to help them get used to collaboration.

To conclude, a CSLE which engages pupils collaboratively in an authentic and active process of thinking and talking about science in a scaffolding inquiry cycle requires purposeful planning for the interactions between pupils to promote the quality of pupil collaboration for the benefit of their social and academic advancement.

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