TALK FACTORY: THE USE OF GRAPHICAL REPRESENTATIONS TO SUPPORT ARGUMENTATION AROUND AN INTERACTIVE WHITEBOARD IN PRIMARY SCHOOL SCIENCE

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ABSTRACT
In the classroom, children are often asked to work in groups and to discuss learning activities together. However, they can find this challenging as they do not always have the necessary discussion and argumentation skills and may fail to understand what they should aim to achieve. Discussion is important in the science classroom as it is an opportunity for children to express their views and listen to those of their peers so a clearer understanding can emerge. However, it is often the case that teachers adopt a role that focuses on imparting information, thus giving students little opportunity to discuss their own views. We report on a study that involved primary school children aged 9-10 years, together with their teachers, in the learner-centred participatory design and evaluation of software – the Talk Factory – aimed at supporting exploratory talk in science. The Talk Factory enables the teacher to represent, in real time on an interactive whiteboard, evolving graphical representations of specific features of classroom dialogue that constitute exploratory talk. We report on the participatory design process and how the teachers and students used the software during science lessons on evaporation. Analysis of video footage of lessons suggest that the Talk Factory was effective in supporting the teachers' awareness and facilitation of exploratory talk, as well as the students' engagement in rich discussions. We discuss how the teachers and students used the software to support the development of exploratory talk in the classroom. We argue that if children are to be enabled to participate fully in science learning, it is important that they are given the opportunity to discuss their ideas as a means of developing their own understanding of scientific concepts. Our study demonstrates that the Talk Factory can go some way to supporting this.

KEYWORDS
Graphical representations, exploratory talk, argumentation, primary science, interactive whiteboard

INTRODUCTION

Children often find it difficult to engage in effective group discussions in the classroom (e.g. Galton and Williamson, 1992) because they can find it difficult to understand how to talk together and what they should aim to achieve (Mercer, Dawes, Wegerif and Sams 2004). Similarly, argumentation skills do not come naturally to children and are acquired through practice and teaching (Kuhn, 1991). Argumentation is an important feature of the science classroom (Osborne, Erduran and Simon, 2004; Sampson and Clark, 2008) as it provides students with the opportunity to justify their views and challenge others' ideas so a clearer conceptual understanding emerges (Howe and Tolmie, 2003). These findings imply that the promotion of argumentation in the classroom would require a shift in the nature of pedagogy and classroom discourse. Scott and Amettler (2007) found that there tends to be far more authoritative presentation than dialogic consideration of ideas and Mortimer and Scott, (2003) argue that discourse in the science classroom needs to be more dialogic/interactive. We present a study that engaged primary students aged 9-10 years old, and their teachers, in participating in the design and evaluation of some software – The Talk Factory (TF) – which aimed to a) support teachers in their modelling and encouragement of argumentation in the classroom, and b) increase the students' understanding and use of some of the features of effective discussion. The TF is designed for use on an interactive whiteboard, which can be used by teachers to display resources to a whole class and to resource classroom discussions (Gillen, Staarman, Littleton, Mercer and Twiner, 2007). However, research suggests that this is relatively rare (e.g. Glover and Miller, 2001).

The design of the TF is influenced by the approach to meaning making in science by Mortimer and Scott (2003) and the work undertaken by the Thinking Together project (Mercer et al., 2004). The latter has demonstrated that encouraging children to generate and apply 'rules for talking' can be effective in facilitating 'exploratory talk' (Mercer, Wegerif and Dawes, 1999). Exploratory talk can be defined as when individuals engage critically and constructively with others' ideas so that ideas can be put forward and challenged and counter-challenged. Exploratory talk is identifiable by the presence of particular dialogic features such as 'I think X because Y', 'I agree because…' or 'I disagree because…'. Mercer et al (1999) claim that use of these words indicates that students are engaged in argumentation. The Thinking Together project focused on children generating rules for talking that facilitated exploratory talk (e.g. 'I must give reasons for my answers') throughout a series of lessons (Dawes, Mercer and Wegerif, 2004) and then applying them in future classroom dialogue. The TF builds upon this approach by representing rules for talking in the software, and enabling the teacher to quantify students' use of the rules, in real time, in dynamically evolving bar charts, emoticons and a timeline, as they engage in ongoing classroom dialogue. As a result, the teacher and students can both use the graphical representations to evaluate how their discussion is progressing.

In this paper we present findings from a study carried out with four classes in a UK primary school during their science lessons on sound and evaporation. We discuss the learner-centred participatory design approach we adopted to assure that the software met the needs of both the learners and teachers, and report on how the classes used the graphical representations in TF to resource their discussions.

Our research question was:

1. How can teachers and students use the graphical representations in Talk Factory to support students' engagement in exploratory talk in the primary science classroom?

METHODOLOGY AND DATA ANALYSIS

Four year-5 classes (aged 9-10 years) and their four teachers participated. One class (A) was involved only in the participatory design of TF, two classes (B and C) were taught about 'evaporation' using TF and one class (D) was the control class which did not use the software during their lessons on evaporation. The study was carried out as follows:

1. Meetings were held with teachers to discus how TF might compliment their existing teaching and to discuss some revisions to existing lesson plans and resources. These meetings took place throughout the whole software design process.
2. Lessons on 'sound' were video recorded so as to provide baseline data on teaching practices and classroom discourse in the intervention classes prior to any research intervention.
3. Class A took part in learner-centred participatory design and evaluation of the software. Following this, the design specification was given to a programmer and class A played no further role in the research because their participation in this stage would have confounded future participation in the study.
4. Classes B, C and D completed written pre-tests of argumentation ability before they were introduced to TF so as to avoid confounding their responses.
5. Teachers of classes B and C took part in a workshop where they discussed examples of exploratory talk from (Mercer and Littleton, 2007; Thinking Together website) and its utility in the science classroom. Teacher A did not take part as we wanted her teaching to be naturalistic and uninfluenced by any research aims.
6. Classes B, C and D received two 'talk lessons' (Dawes et al, 2004) which focused on introducing students to the notion of class talk rules, and then students generated the talk rules that they thought

were most important (that were represented in TF). All three classes received these lessons so that we could rule them out as a possible variable in future TF lessons.

7. Teachers of classes B and C evaluated early versions of the software and iterations were made as appropriate. Class D did not see any versions of the software as they were the control class.
8. Classes B and C were taught about evaporation using TF and associated lesson plans and worksheets that were developed by the research team in collaboration with the teachers, and class D was taught about evaporation using identical lesson plans and worksheets but without use of TF. These lessons were video recorded.
9. Following this, all classes completed post-tests of argumentation ability and teachers and some students were interviewed about their experiences of TF.

Following the intervention period, the intervention class teachers and some of the students were interviewed. The teachers' interviews focused on eliciting feedback regarding their opinions of TF, how they used it and whether or not they thought it was effective. The students' interviews focused on gathering their feedback on their experiences and opinions of TF.

The video recordings of the lessons were transcribed and qualitatively analysed. We adopted a deductive approach in analysing classroom talk. We focused on analysing the extent of the students' engagement in exploratory talk. The definition of exploratory talk was used as the theoretical framework for coding classroom talk into themes. For example, we created codes for 'giving a reason' and 'explaining disagreement'. We used these themes to compare:

- whole class discussion in the control class and intervention classes in evaporation lessons, and
- dialogue in the pre-software and software lessons in the intervention classes about sound and evaporation

Also, we used qualitative methods of data analysis to identify ways in which the teachers were using the software features to encourage use of exploratory talk. In this case, we worked inductively noticing interesting things in the data and assigning 'codes' to them to identify ways that the software was used to promote use of exploratory talk. The themes that emerged from our analysis were: using Talk Factory features to resource discussion about the talk rules; using graphical representations to evaluate the quality of discussion. We elaborate further on these below.

LEARNER-CENTRED PARTICIPATORY DESIGN OF THE TALK FACTORY

Iterative, learner-centred design is a valid and widely used approach in software design and has been proven to provide innovative solutions to educational problems (e.g. Druin, 2002). Our approach can be aligned broadly with the CARSS (Context, Activities, Roles, Stakeholders, Skills) framework proposed by Good and Robertson (2006). This focuses on participants' involvement in the design process (rather than only testing the end-product) of software for use in classrooms. The approach recognises the importance of considering:

1. Context (the constraints of: curriculum, timetabling, the environment, commerce and legal and ethical issues).
2. Activities (requirements gathering, design, evaluation of prototypes).
3. Roles (of: design partners, project manager, technology specialists, researchers, subject matter experts, child development experts, learning scientists and collaboration facilitator).
4. Stakeholders (such as: children, teachers, parents, industrial partners and academic funders).
5. Skills (of the child and adult team members).

Our approach ensured that the teachers and students were involved with each stage of the development of the software and were given an opportunity to feed back their opinions. It was also cost effective as it used low-tech paper and card mock-ups to test the utility of the software design before a specification was written and given to the programmer.

Following our observation of pre-intervention science lessons, and a consideration of our readings of the literature (e.g. Mercer et al, 1999; 2004) and following discussions with teachers, we decided upon three features of exploratory talk to represent (explaining reasons; explaining disagreements; asking others); and negative behaviours to discourage (not giving reasons; not listening to others; interrupting).

Based on the mathematics area of the Primary Framework (2009) we developed several potential graphical representations for quantifying the occurrence of constituent features of exploratory talk, so as to make the data available, in the software, to the students and the teacher in real time. Potential representations included pictograms (uniform or scale), tally charts, block graphs, bar graphs and pie charts. Pictograms, tally charts and block graphs were considered inappropriate for our purpose because both teachers and the literature (e.g. Ryan and Williams, 2007) suggested that students at this age have difficulty in interpreting their scale. Pie charts were rejected because they do not easily reveal exact values. Students' understanding of bar graphs was assessed before deciding to use these to visually represent some of the constituent features of exploratory talk. A total of twenty students were interviewed. Students were chosen by the teachers to represent all ability levels in mathematics. A selection of questions, based on examples from previous national tests, were developed to assess students' ability to represent and interpret discrete data using bar graphs. In addition, students were asked about their preferences about how to display the bar graphs on the software screen: they preferred a dynamically evolving sum of the number of incidences of talk rules occurring as represented by each bar, as well as a sum of the total positive and negative talk rules. Also, they evaluated our choice and use of colours in the software.

Following this, we used a Wizard-of-Oz approach (Dow, MacIntyre, Lee, Oezbeck, Bolter and Candy, 2005) where students in the participatory design class evaluated paper prototypes of TF in terms of their usability. Three groups of students were involved in an activity that was adopted from a lesson in the 'Thinking Together' book (Dawes et al., 2004) where students were asked to evaluate and select a family suitable for adopting a dog. Before discussing as a group they were presented with a series of talk rules that they needed to use during their discussion. It was also explained that a bar graph was going to be used to represent the occurrence of each rule as they talk. A researcher manually created the bar chart and updated the evolving sums as the children's discussion progressed. At the end of the task students were asked to comment on issues such as how well their group talked together, how easy it was to agree on what to do, and whether and how the rules and graph helped them to engage in discussions to match the families and dogs successfully. In addition, students were invited to make comments and suggestions for changing the representations used in the software prototypes.

THE TALK FACTORY SOFTWARE

Figure 1 illustrates the main features of the final TF software:

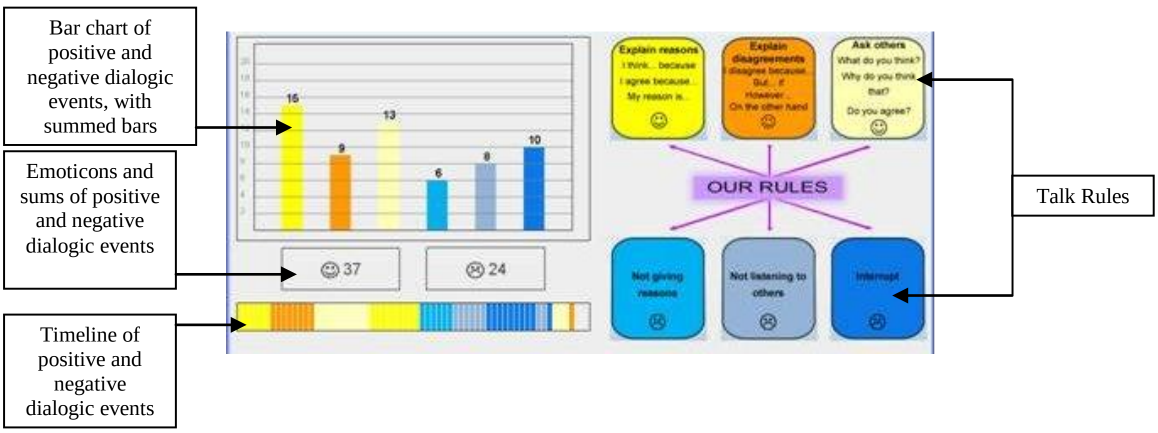

Figure 1. The main features of Talk Factory

TF was designed to support the hypothesis testing approach to science teaching (Howe and Tolmie, 2003): in addition to the generic ‘classic’ screen depicted in Figure 1, we designed three further screens that support specific phases in the inquiry process. Figure 2 provides an overview of the final TF resources.

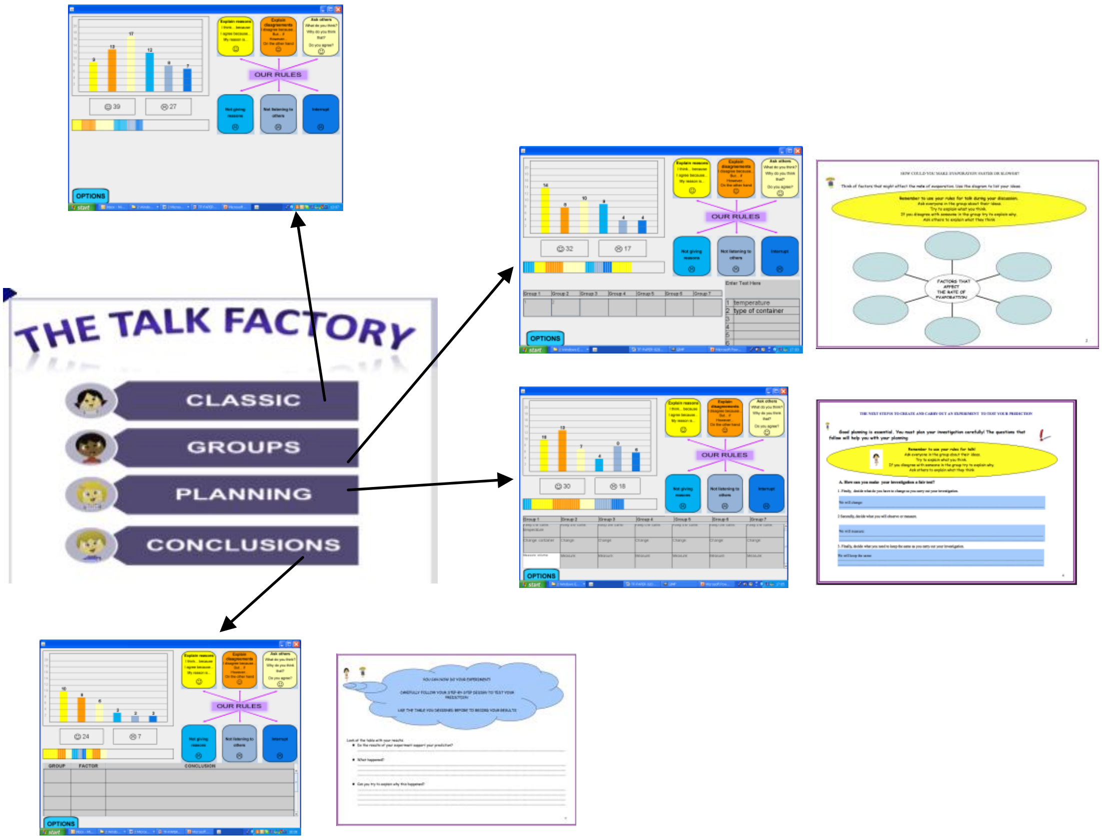

Figure 2. Talk Factory screens and their associated worksheets

The TF splash screen (see the screen shot centre-left of Figure 2) enables the teacher to navigate to four different screens:

1. A ‘Classic’ screen that can be used in any context to support any argument (as seen also in Figure 2).
2. A ‘Groups’ screen that contains all the elements of the Classic screen plus a table where the teacher can type in all the factors that the children think affect (in this case) evaporation and allocate one factor to each group to investigate.
3. A ‘Planning’ screen that contains all the elements of the Classic screen plus a table where the teacher can type in each group's decisions regarding the planning of a fair scientific investigation.
4. A ‘Conclusions’ screen that contains all the elements of the Classic screen plus a table where the teacher can type in each group’s conclusion.

Each screen can be used by the teacher to support discussion about the creation, and content, of the tables. Once the software had been tested by the teachers, it was used alongside the associated lesson plans and worksheets during the intervention lessons on evaporation (Figure 3).

Figure 3. A teacher using Talk Factory

TEACHERS' AND STUDENTS' USE OF THE TALK FACTORY BAR CHARTS AND EMOTICONS TO EVALUATE ENGAGEMENT IN EXPLORATORY TALK

Both teachers of the intervention classes used the bar charts and emoticons to resource class discussions about the extent to which their ongoing dialogue had been utilising the dialogic features represented in the talk rules. Below is a representative excerpt from classroom talk where the teacher refers to the emoticons:

Mrs Griffins: So at the moment, you have justified all your arguments really well because you've got lots and lots of smilies.

(later in the same lesson)

Mrs Griffins: Do you think it helped you to discuss the two situations that we were looking at today?

Bren: It gives us more, actually it stop us from chatting because with that we can see how good we are in lessons.

Mrs Griffins: And how do you get to see how good you are in lessons from looking at the board?

Bren: Because it's got the smiley faces and the unhappy faces.

Mrs Griffins: Yeah. So, I can't remember how many we got last time, but we didn't get anywhere near as many smilies did we? We got a few more blues the last time we used it. Ok has anybody else got any ideas? Do you think it's useful? James?

James: Yeah because it's like having a report on how good you are in using the rules and talk.

Here, the teacher used the emoticons (and associated numerical values) to resource a discussion where the students reflected on a) their current performance compared with a previous lesson, b) the utility of the emoticons in focusing their attention, and dialogue, on the task in hand, and c) the way in which the emoticons could be used to evaluate how well they were using the talk rules. In their interviews, both of the teachers said that use of the TF helped to focus the students' dialogue on the task in hand and one teacher said the emoticons motivated the students to engage in "higher level discussions where they justified their ideas…they cared about the score". One teacher said that her lower achieving students enjoyed using TF in lessons as it was "visual… they could express their ideas… they felt part of the [class] team". Both teachers thought that use of the TF allowed less confident students to take a turn at speaking and one said it created an environment in which disagreement was viewed positively: "nobody took offence when somebody disagreed with them".

The following excerpt is a representative example of a teacher using the bar chart:

Mr Roberts: Look at our chart. No disagree.

Sally: No because.

Mr Roberts: Well, there is one. How many did we have last week? About ten? Twelve on one of them. Sixteen at one stage I think.

Sally: I disagree with Sara because…

Here, the students were being encouraged to look at the bar chart and reflect upon the extent to which they have used the word 'because' and 'I disagree because' in the current lesson, compared to a previous lesson. The students can see clearly that they have not engaged fully with the talk rules during the current lesson and Sally seeks to amend this by offering a counterclaim against a claim made earlier in the lesson. It appears as though the facility to see a dynamically-evolving representation of the discussion, in real time, was useful for evaluating progress and taking immediate action to rectify identified shortfalls. One teacher said that "they could physically look at the [IWB]…and if they did not formulate their answers in the right way, it's very quick for them to grasp that they've got to change".

TEACHERS' USE OF THE TALK FACTORY TALK RULES TO ENCOURAGE STUDENTS' ENGAGEMENT IN EXPLORATORY TALK

As described above, six talk rules were graphically represented in the TF and available to the whole class throughout the lessons. Here, we report on how the display of the talk rules, together with the teachers' and students' interactions with them, remediated the nature of the classroom discourse across pre-intervention and intervention lessons.

The following excerpts represent the talk that took place in an pre-intervention class and the control class. The pre-intervention class were discussing the findings from an experiment which tested which material was most effective at muffling sound, to the rest of the class:
Andy: What was the highest?
Emma: Foam blocked the sound the best.
Mr Roberts: Right, ok, cool, ask them some questions then. Because this is very different to what other groups found out, they found out, polystyrene, cotton, cotton wool is quite good isn't it?
Emma: About the same.
Mr Roberts: It's about the same, not much difference between cotton wool and polystyrene.
Bob: How did you make it a fair test?
Mr Roberts: Excellent question Bob.
Emma: We err, I don't know actually.
Rebecca: It's not fair.

Here, the students did not give reasons for their answers and Rebecca did not explain why she thought the experiment had not been a fair test. Also, the teacher did not ask for justifications. In the following example, the control class had set up a small experiment in which various liquids have been left for a few days to evaporate in cups in the classroom and they were discussing which liquid they think will evaporate most quickly:
Mrs Daniels: What do you think might happen?
Jason: They might evaporate.
Mrs Daniel: Ooooh, do you think? Which ones do you think might, hands up?
Sarah: Definitely the water.
Mrs Daniels: Mmm, huh. Anything else?
Michael: More like the runny fluids?
Mrs Daniels: Hands up. Which one do you think? What do we predict to be?
David: The water.
Mrs Daniels: You think the water. Anybody think any different?
Stephan: The oil
Similar to excerpt one, here the students' replies are brief responses to the teacher's questions about predicting which liquid will evaporate most quickly (water, runny fluids, and oil). The students do not back up their claims with reasons and the teacher does not appear to encourage them to offer justifications.
In contrast, during the intervention lesson using TF, this was less likely to be the case. In the next excerpt (from a long discussion that was transcribed over 10 pages), a group of four students are presenting the results of an experiment set up to investigate whether the material of various cups affected the rate at which water evaporated. The cups were made of thin plastic, thick plastic, metal, polystyrene and glass. The students had previously displayed a graph of their findings and the teacher has invited classmates to ask them questions:
Sophia: It's not a fair test because Oliver said that the plastic cup was bigger than the rest (TAP 1[1]).

[1] TAP 1 indicates when the teacher tapped on the talk rule 'explain reasons'. TAP 2 refers to when the teacher tapped on the 'explain disagreements' talk rule.

Mr Roberts: She's saying the size of the containers are not the same, it's not a fair test. So you're changing two things. What do you say?
(a little later…)
Julie: We couldn't help that though, because we couldn't get all the same size cups. The top of the glass was wider or smaller.
[Mr Roberts gets the cups and displays them to the class]
T: So there's their containers OK. Thin plastic, metal, polystyrene, thick plastic, and glass. Sophia is not happy. What does everybody else think? Come on lets have some discussion. Do you agree, disagree?
Greg: I don't really think it's a big problem because (TAP 2) you, you can't, you can't get all the same size and they are nearer all the same sizes, maybe the polystyrene is a bit too small but I don't really see, well they are actually changing the thing but I don't really see
Sam: I think it is a big problem because (TAP 1) the amount of space its got could actually be critical.
(a little later…)
Olivia: Urm, I disagree with Tina, because (TAP 2) it doesn't matter what size it is because all of them had the same amount of water didn't they, so that's all that really matters.
Sally: I agree with Olivia, because maybe it could have evaporated because of the space they had (TAP 1), cos they might have not evaporated because of the material, they could have evaporated because of the space.
Tim: I agree with Tina because if, if they're bigger then urm, its going to take longer for the water to get out, (TAP 1) if they're short it won't take as long than it will as the long ones to get out.
(a little later…)
Daniel: I agree with Oliver (TAP 1) because like when they're doing the experiment, the wider the space the more that it can evaporate. Because if it's like that cup (points to polystyrene cup), it doesn't have enough space to like evaporate.
Greg: Urm, I've changed my mind because (TAP 1) you can see the glass cup and the polystyrene cup are different two sizes, so the polystyrene one will evaporate the slowest because it like has less space for it, but the glass has got more space.

This excerpt contains many features of Exploratory Talk. When compared with the pre-intervention excerpt above (from the same class), it can be seen that the students were more likely to use reasoning words (I agree\ disagree because) to provide a series of arguments and counter arguments building and elaborating on what has been said. Towards the end of the discussion Greg seems to reconsider his initial argument. There were several examples in our data where students appear to refine their thinking after their ideas were negotiated in the class. According to Driver, Asoko, Leach, Mortimer and Scott (1994), helping students to discuss the different views held and supporting them in justifying one position over another and then select views that are more viable leads to a deeper understanding. In this example, the graphical representation of talk rules on the IWB, and the teacher's skill in identifying when they occurred, and tapping on IWB as appropriate, seems to have enhanced the students' opportunities to express their views and discuss them with others.

THE EFFECTIVENESS OF THE GRAPHICAL REPRESENTATIONS OF TALK RULES

In both classes, the teachers used the graphical representation of the talk rules to initiate a discussion about their importance in science learning. The display of the talk rules, and their associated exemplar sentence openers, on the IWB, made them visible to the whole class, which meant that TF was a shared resource that mediated the common language of the classroom. In the following excerpt, a class is using the representation of the rules to resource a discussion about why the rules are important and how they could be implemented:
Mr Roberts: How do you explain something clearly to somebody?
Cheryl: You say, 'I think cos'. You give your reason.

Mr Roberts: (points to 'explain reasons' rule on TF screen) ‘I think because’, ‘I agree with you because’, so you’re giving a reason. You’re not just saying, I agree with you. You’re giving a reason. I think that one, but you’re giving a because, you’re giving a reason. The orange one please.
Rob: Er, the orange one is for explaining your disagreements. So if someone, so if Peter came up with a point and I didn’t agree, I would go, ‘well what if this, or however, or on the other hand’.
Mr Roberts: Well, as long as you say if I disagree with somebody I’ve gotta say...
Students: Why.
Mr Roberts: You’ve gotta explain why. So it’s all about explaining your reasons why.

Here, the students and teacher were looking at the talk rules on the IWB and discussing their importance. In their interview, the students demonstrated their understanding of this when they said that “we didn’t really explain our answers before” and “we don’t normally ask what you mean”. They went on to say that “if they explain what they mean you can understand why they disagree and you might agree with them” and “you need to explain your answer really good cos some people might not understand what you mean”.

One teacher said that his use of the TF had improved his own and his students’ listening skills. He thought that there was a lack of opportunity for students to express themselves in classrooms generally and that TF gave them an opportunity to do this and to listen to each others’ opinions. He said his own listening skills had developed during his use of TF and that he had “picked up on things that you would let go and not notice before”. He said that using TF “focused me on not asking closed questions, but asking open questions that would encourage a student to explain their answer rather than giving a one word answer”. As a result, he said that he found himself leading and directing the class less, and facilitating the students’ discussion more.

CONCLUSIONS

We have reported on the learner-centred participatory design and evaluation of the Talk Factory software which aimed to support the production of exploratory talk in the primary science classroom. Our participatory design approach ensured that students, teachers and researchers worked as a team to inform the design of software that met the needs of the institutional context, the teachers and students, and the researchers. The successful implementation of the software into lessons about evaporation demonstrates the virtues of this design methodology. Our evaluation of how the Talk Factory was used in the classroom suggests that the graphical representations were used by the teachers to promote classroom discussion that contained the features of exploratory talk and that engagement with the software promoted the teachers’ and students’ listening and explanatory skills. Moreover, the teachers said that their use of the software created a classroom environment that encouraged the expression of ideas even if they were contradictory.

These findings support those reported by the Thinking Together project which suggest that it is possible to teach children how to talk together and help them to understand what can be achieved by justifying their ideas and listening to others. We argue that if children are to be enabled to participate fully in science learning, it is important that they are given the opportunity to discuss their ideas as a means of developing their own understanding of scientific concepts. To engender this, teachers need to be supported in recognising and facilitating rich discussions that contain features of exploratory talk. The findings we have reported here go some way to suggesting how this might be achieved by the incorporation of the Talk Factory in classrooms. Both of the teachers in this study said that they had used TF in other subject areas such as history and said that it was useful to support discussions about controversial topics such as conflict resolution. We recognise the need for further research to identify the different ways that different teachers use the software in several subject areas.

REFERENCES

Dawes, L., Mercer, N. and Wegerif, R. (2004). Thinking together: a programme of activities for developing speaking, listening and thinking skills, Imaginative Minds, Birmingham, UK.

Dow, S., MacIntyre, B., Lee, J., Oezbeck, C., Bolter, J. and Gandy, M. (2005).Wizard of Oz support throughout an iterative design process. IEEE Pervasive Computing, 4(4), 18-26.

Driver, R., Asoko, H., Leach, J., Mortimer, E. and Scott, P. (1994). Constructing scientific knowledge in the classroom. Educational Researcher, 23 (7), 5-12.

Druin, A. (2002). The role of children in the design of new technology. Behaviour and Information Technology, 21(1), 1-25.

Galton, M. and Williamson, J. (1992).Group Work in the Primary Classroom, Routledge, London, UK.

Gillen, J., Kleine Staarman, J., Littleton, K., Mercer, N. and Twiner, A. (2007). A "learning revolution"? Investigating pedagogic practice around interactive whiteboards in British primary classrooms. Learning Media and Technology, 32 (3), 243-256.

Good, J. and Robertson, J. (2006). CARSS: A framework for learner-centred design with children. International Journal of Artificial Intelligence in Education, 16, 381-413.

Glover, D., and Miller, D.J. (2001). Running with technology: the pedagogic impact of the large-scale introduction of interactive whiteboards in one secondary school. Journal of Information Technology for Teacher Education, 10(3), 257-276.

Howe, C.J. and Tolmie, A. (2003). Group work in primary school science: discussion, consensus and guidance from experts.International Journal of Educational Research, 39, 51-72.

Kuhn, D. (1991). The skills of argument, Cambridge University Press, Cambridge, UK.
Mercer, N. and Littleton, K. (2007). Dialogue and the Development of Children's Thinking: a sociocultural approach, Routledge, London, UK.

Mercer, N., Dawes, R., Wegerif, R. and Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. British Educational Research Journal, 30 (3), 367-385.

Mercer, N., Wegerif, R. and Dawes, L. (1999). Children’s talk and the development of reasoning in the classroom. British Educational Research Journal, 25 (1), 95-112.

Mortimer, E.F. and Scott, P.H. (2003). Meaning Making in Secondary Science Classrooms, Open University Press, Buckingham, UK.

Osborne, J., Erduran, S. and Simon, S. (2004). Enhancing the quality of argumentation in school science. Journal of Research in Science Teaching, 41(10), 994-1020.

Primary Framework (2009), retrieved January 2009 from (http://nationalstrategies.standards.dcsf.gov.uk/primary/primaryframework/mathematics/)

Ryan, J. and Williams, J.S. (2007). Children's mathematics 4-15: learning from errors and misconceptions. Open University Press, Buckingham, UK.

Sampson, V. and Clark, D.B. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. Science Education, 92(3), 447-472.

Scott, P. and Ametller, J. (2007). Teaching science in a meaningful way: striking a balance between 'opening up' and 'closing down' classroom talk.School Science Review, 88(324), 77-83.

Thinking Together Project website: http://thinkingtogether.educ.cam.ac.uk/

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