Goodchild, S. (Ed.) Proceedings of the British Society for Research into Learning Mathematics 22(1&2) February/May 2002

DESIGN INITIATIVES FOR LEARNING: ICT AND GEOMETRY IN THE PRIMARY SCHOOL

Rosamund Sutherland, Steve Godwin and Federica Olivero,

Graduate School of Education, University of Bristol,

Pat Peel, Easton CE VA Primary School, Bristol

Abstract

This paper draws on an ongoing project whose overall aim is to examine the ways in which new technologies can be used in educational settings to enhance learning. In particular it discusses the process of developing a design initiative for primary pupils to learn about the properties of polygons. The process draws explicitly on the role of the teacher within the context of exploiting the potential of a dynamic geometry environment. Design evolves in a contingent way related to pupils' developing conceptions and the purpose of the dynamic geometry environment is to help pupils pay attention to the invariant properties of particular quadrilaterals.

Introduction

This paper draws on an ongoing project whose overall aim is to examine the ways in which new technologies can be used in educational settings to enhance learning (Sutherland and Robertson, 2000). The project is concerned with learning across a range of subjects, although this paper focuses on the mathematics education strand of the project. The research is framed by a socio cultural theory of learning which suggests that mental functioning of an individual has its origins in social life. This position stresses the crucial role which communication through language and other semiotic systems play in learning and points to the importance of creating classroom environments which support the communication and exchange of ideas (Crook, 1994, Mercer et. al. 1999). Another implication of socio-cultural theory is the claim that human action is mediated by 'technical' and 'cognitive tools'. The notion of 'tools' includes a wide range of artefacts and semiotic systems and where "cultural artefacts are both material and symbolic; they regulate interactions with one's environment and oneself. In this respect they are 'tools' broadly conceived, and the master tool is language" (Cole and Engestrom, 1993, p. 9). Perkins (1993) talks about the importance of considering the person plus the immediate physical and social resources outside the person (p 90), whereas Salomon (1993) argues that it is important to consider both the effects-with and the effects-of technology. In all, this suggests that both interaction and its contexts are central to understanding the conditions for human learning.

The project is based upon working in partnership with teachers and researchers to design learning environments which are supported by research on teaching and learning. The project is predicated on two assumptions. The first is that teachers are central to learning in schools and that much of previous research on the use of ICT for learning has underemphasised this crucial role (Sutherland and Balacheff, 1999). The second is that ICT should be incorporated into a designed learning situation as appropriate, with attention being paid to the whole classroom context to include classroom talk, work on paper and all the technologies that are normally available to a teacher.

This paper focuses on the work of one primary school teacher Pat Peel (also a co-author) and the development of a mathematics design initiative concerned with learning about 2-D shapes and their properties. Pat works in an inner city multicultural primary school in Bristol, which is also part of an Education Action Zone (EAZ).

Partnership and Design

The mathematics design team consists of 14 teachers (from the primary, secondary and post-16 sectors), and three researchers (Godwin, Olivero and Sutherland). The team have met together at the University four times since June 2001 (two whole days and two half day meetings) and will continue to work together until July 2003 (fifteen days of teacher supply cover are allocated for each teacher partner). Working within the mathematics design team each teacher is responsible for designing a learning initiative for one class of students, which focuses on a key area within their subject which: a) pupils normally find difficult and b) could be enhanced by the incorporation of an appropriate ICT environment into the learning situation. Choosing this area is a process of negotiation between the teacher and the research team. Pat chose to work on the development of a design initiative concerned with learning about 2-D shapes and their properties.

The design process involves working within the constraints of the situation in a creative and systematic way and thinking as far as possible out-of-the-box. For example the aim is that all pupils in Pat's Year 6 class (age 10-11) learn about quadrilaterals but within this constraint we have thought creatively about: how to design a Cabri microworld which makes it likely that all pupils (whatever their confidence with language) will engage with both the properties of polygons and the names of these properties; how Pat will work with the class in the computer suite and use the interactive whiteboard and other technologies; what work pupils will do on paper and pencil in their normal classroom. . Throughout this process Pat has been learning about Cabri through hands-on work on her home computer.

The design process has also involved giving all the Year 6 pupils a diagnostic assessment and interviewing 6 of these pupils on their conceptions of quadrilaterals and other polygons. The design initiative is being evaluated in a systematic and rigorous way from the point of view of pupils' learning (approximately 10 hours of teaching time in both the computer suite and the normal classroom).

Research and Design

The theory which frames the project emphasises learners as active constructors of knowledge who come to a learning situation with a history of learning. It also foregrounds the social construction of knowledge and the role of language and other semiotic systems within this process. Within this context mathematics itself has also to be foregrounded. We also believe that pupils learn most effectively when they are supported to ask mathematical questions within a community of inquiry and when the teacher focuses their attention on the similarities and differences between mathematical objects (Brown and Coles, 2001). When working on a subject design we are loosely influenced by these theoretical ideas but we do not and could not 'apply' them in a positivist way.

The aim of the design initiative which is the focus of this paper is to support 10-11 year old pupils to: 1) recognise geometrical figures and know the names of these figures; 2) characterise geometrical shapes by their properties; and 3) to classify figures hierarchically. We chose to work with quadrilaterals as a starting point as we believe that these are the ones which are more common in everyday life and thus more likely to be familiar to the pupils. Aims 1), 2) and 3) above relate to van Hiele (1959/ 1985) levels and we do not know whether 3) is an attainable possibility with this group of pupils (Pat thinks that it will not be, although the researchers think that working within the Cabri environment may make it attainable for some pupils in the class).

The results of the diagnostic assessment and interviews with three pairs of pupils (chosen to include a spread of mathematical attainment) suggest that before starting the work the majority of pupils could recognise a square, a rectangle, a parallelogram, a rhombus and a kite, with only the minority being able to recognise a trapezium. The majority of the pupils were not able to articulate the properties of these geometrical figures although they were more likely to be able to say that a figure has 'opposite sides equal' than 'opposite sides parallel'. Some of the pupils interviewed said that parallel lines are like 'train tracks' which never cross (in response to a question about whether two lines which crossed were parallel one pupils said "no because if a train went along those tracks it would crash"). This image sometimes broke down with respect to the opposite sides of a rectangle. The longer pair of sides were said to be parallel but the shorter pair were said to be too far apart to be parallel. None of the pupils knew what perpendicular meant and the majority of pupils could not identify an equilateral triangle from images of six triangles. In summary it would appear that the majority of pupils in the class were recognising figures as visual gestalts, considered to be level 1 of van Hiele's levels "In identifying figures they often use visual prototypes. Students say that a given figure is a rectangle for instance, because 'it looks like a door'. They do not however, attend to geometric properties or to characteristic traits of the class of figures represented. That is, although figures are characterised by their properties, students at this level are not conscious of the properties" (Clements and Battista, 1992, page 427).

We customised the Cabri drop-down menus for the purpose of this study, although the menu items may vary from session to session. In the first session the menu items were restricted to: point, line, segment, circle, perpendicular line, parallel line, reflection, parallel and perpendicular (in the check property menu), distance and length, label, comments, colour, fill. This restriction of the menus is aimed at focusing pupils' attention. Initially we wanted to construct macros for each of the 'special' quadrilaterals (square, rectangle, parallelogram, rhombus, trapezium, kite). We wanted pupils to be able to click on the name of the quadrilateral in a menu item and then be able to construct the associated quadrilateral. However because of the particular properties of each of these quadrilaterals the 'primitive' objects differ for each of them, and we decided that working in this way would add an unnecessary level of difficulty. Instead the quadrilateral microworld which pupils worked with in the first session consisted of the six special quadrilaterals already constructed and a general quadrilateral. We anticipated that pupils would be motivated to manipulate these quadrilaterals and through this process would begin to notice their invariant properties.

Some Results

The first lesson of the design initiative started with the teacher (Pat) working in the computer suite, with all pupils sitting as a class in the middle of the room paying attention to the interactive whiteboard. On a flipchart at the front of the class were the words: Quadrilateral, Square, Rectangle, Parallelogram, Rhombus, Kite and Trapezium (these words were also on of paper by each computer). Pat showed pupils (on the interactive whiteboard) how to move the quadrilaterals, how to colour in a quadrilateral, how to label it with its name. She then asked the pupils to work in pairs at each computer and "find out how to move the shapes, how to make them bigger". Throughout the session two video cameras were used to record two pairs of pupils (one high attaining pair and one low attaining pair) and also the whole class work. A tape recording was also made of the discussion of one additional pair and the three researchers made notes of the session. The 'low attaining' pair spent considerable time moving each individual quadrilateral and also filling them with colour. Although they did not talk very much they used language such as :what was that…oh yes a square..it doesn't look like a square now (as they manipulated the square); how can we make it a square, that's a square…what was it..a rectangle..(as they manipulated the rectangle). They did not label any of the quadrilaterals until the teacher explicitly intervened and told them to do this, and they had only labelled three quadrilaterals before this activity was finished. The 'high attaining pair' first filled all the quadrilaterals with colour and then very systematically (and correctly) labelled each quadrilateral. After this process they then started to manipulate each quadrilateral saying things like: that looks like a kite now (as they moved the general quadrilateral); that looks like a parallelogram (as they moved the rhombus). This suggests that the pupils were beginning to discriminate in a holistic way between the different quadrilaterals, they were also actively saying and writing the appropriate names of the quadrilaterals.

After about 20 mins of work at the computer the pupils came together as a whole class and the teacher asked the pupils if they knew any of the special properties of each one of the quadrilaterals. All responses were accepted and the following responses were given: all sides the same length, it is a quadrilateral (for a square); not all the sides are equal, a four sided shape, its longer than a square (for a rectangle); they are diagonal..the sides are diagnonal, the sides are like train tracks, there's two parallel lines on there (for a parallelogram); like a square, if you squash a square you get a rhombus, they are parallelish (for a rhombus); like a triangle with its top cut off (for a trapezium). The session ended with pupils returning to the computers to make any picture they liked with quadrilaterals.

At the point of writing this paper we have not made final decisions about how we will construct the quadrilateral microworld for session 2 (January 18th). We will start the lesson with the whole class being asked to say everything they notice about the similarities and differences between a parallelogram and a rectangle as these objects are manipulated in Cabri projected onto an interactive whiteboard. These properties will be written on the screen as they are noticed by pupils. Pat will prepare language support by constructing phrases (possibly on card) such as: opposite sides are equal; opposite sides are parallel; adjacent sides are perpendicular. Pat will also draw their attention to the internal angles of the quadrilaterals (so far no pupils have said anything about angles of quadrilaterals). She will also show them how to construct the diagonals of a quadrilateral and ask them to say what they notice about these diagonals. After this whole-class work pupils will work in pairs and continue to investigate the properties of quadrilaterals, possibly each pair choosing a pair of quadrilaterals to work on. We are aware of the tension between focusing on mathematics and keeping pupils engaged in the activity. However in the first session the pupils appeared to be more engaged with the activity of investigating polygons than they were with the activity of drawing a picture with polygons. We are not sure when we will introduce the measuring tools and we also plan to introduce the parallel and perpendicular line constructions and the parallel and perpendicular check-properties. Some aspects of the design process are contingent on pupils' responses in each session and others relate more to the mathematical aspects of the activities which can be more readily planned in advance. At this stage we wonder if the fact that a Cabri rectangle can be transformed into a square will lead pupils to incorrectly conjecture that 'all rectangles are squares'. This type of analysis influences the design choices which we make.

Some Concluding Remarks

As the project and the particular design initiative reported in this paper evolve we shall more systematically research the teaching and learning processes which relate to particular learning outcomes. We shall focus on the dialogue between teacher and pupils and also on other mediators of learning, including the computer activity, whole class discussion and work on paper. We shall also investigate the effects - with (ie what students can achieve with technology) and the effects - of (ie the residue left after the experience of using technology) using digital technologies in the classroom. This paper shows how design evolves in a contingent way, related to pupils' developing conceptions. The purpose of the dynamic geometry environment is to allow pupils to 'see' the invariant properties of particular quadrilaterals and one of the roles of the teacher is to provoke pupils to become aware of what they are 'seeing' through spoken and written language. If pupils in this study do become able to classify geometrical figures hierarchically we will be able to analyse the processes and mediating factors which have supported this ability.

References

Brown, L. and Coles, A.: 2001, Natural Algebraic Activitiy in Proceedings of the 12th ICMI Study Conference *The Future of the Teaching and Learning of Algebra*, vol 1, 120-127pp, H. Chick, K. Stacey, Jill and John Vincent (eds).

Clements, D. and Battista, M.: 1992, Geometry and Spacial Reasoning, in D. A. Grouws (ed), *Handbook of Research on Mathematics Teaching and Learning*, NCTM, Macmillan Pub. Company.

Cole, M. and Engestrom, Y.: 1993, A Cultural-historical approach to distributed cognition, Salomon, G. (ed) *Distributed Cognition*, CUP, Cambridge.

Crook, C.: 1994 *Computers and the Collaborative Experience of Learning*, Routledge, London.

Mercer, N., Wegerif, N. and Dawes, L.: 1999, Children's talk and the development of reasoning in the classroom, *British Educational Research Journal*, Vol 25, No 1, 1999.

Perkins, D.: 1993, Person-plus: a distributed view of thinking and learning, in Salomon G. (ed) *Distributed Cognitions*, CUP, Cambridge.

Salomon, S.: 1993 *Distributed Cognitions, Psychological and Educational Considerations*, CUP.

Sutherland, R. and Balacheff, N.: 1999, Didactical Complexity of Computational Environments for the Learning of Mathematics, the *International Journal of Computers for Mathematical Learning*.

Sutherland, R.J. and Robertson, S.L.: 20021, Interactive Education: Teaching and Learning in the Information Age, project funded by the ESRC Teaching & Learning Programme (Award No. L139251060)

van Hiele, P.M.: 1959/1985, The child's thought and geometry. in D. Fuys, D. Geddes, and R. Tischler (eds). *English translation of selected writings of Dina van Hiele-geldorf and Pierre van Hiele* (pp 243-252), Brooklyn, NY, Brooklyn College School of Education

Acknowledgements

The project discussed in this paper is funded by the ESRC Teaching and Learning Programme (Award No. L139251060). It could not have taken place without the support of Ian Sheddon, Head of Easton CE VA Primary School, Andrew Biggs, ICT co-ordinator in the school and Sheila McGill, Primary ICT Advisor in Bristol EAZ. In addition we are grateful to Jean-Marie Laborde for providing the school with a Cabri Géomètre site licence.