Using technology to enhance children's spatial sense

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Abstract

This paper examines the way in which two young children engage in a computer-based problem solving activity that required a degree of visual-spatial reasoning. The case study traces the children's spatial-visual understandings and looks at the way in which these understandings were activated and developed through the particular activity.

Literature Review

Computers make it possible to represent visual and spatial mathematics with an amount of flexibility not offered by other media. Graphic programs, for example, allow the user to represent images accurately as either two- or three-dimensional representations. These images can then be transformed or rotated with precision. With appropriate software the computer can become a powerful tool that enables children to manipulate spatial arrangements and construct visual images which would usually be limited by their own drawing capabilities. As Clements and Battista (1992) commented "the potential of such drawing tools lies in the possibility that children will internalize such functions, thus constructing new mental tools ... Interaction with certain computer environments may help students build less restricted concept images" (p. 452). Moreover, an increased familiarity with relevant software allows the user to investigate and construct mathematical understandings at increasingly sophisticated levels of development. Such claims are particularly relevant to the development of visual and spatial understandings. As Noss, Healy and Hoyles (1997) commented:

> the computer can incorporate the visual into every stage of the activity. It can externalise visual images and at the same time render them manipulable...Computer screen representations of visual objects and even visualised relationships can be acted upon directly and we can observe the ensuing changes in the represented relationships. (p. 209-210)

Importantly, these representational changes provide immediate feedback for the user and foster valuable learning environments. Provided the computer environment is flexible, children are able to explore, predict, become more adventurous, and be more responsible for their own learning. It may be the case that visual images are evoked when a user engages in the use of, and interacts with, particular computer software. Nemirovosky and Noble (1997) argued that visual representations "in the mind" take place when using a tool requires the user to analyse external images (on paper or on a computer screen etc).

Interactive programs allow the user to explore and develop 2D and 3D environments that closely simulate "real-life" experiences. We are able to take a *Magic schoolbus* ride through a human's body by navigating a path through various body systems. The more advanced technology becomes, the greater the visual impact it will have on the user. It could be argued that such technology is under utilised in educational settings (Lowrie & Hill, 1996a) and that even when it is used, it is not developed to its full capacity.

Visual imagery can be a powerful source of reasoning in problem solving (Antonietti, 1991; Lowrie, 1998; Lowrie & Hill, 1996b; Kaufmann, 1990) and such reasoning is linked to the development of spatial concepts. Imagery is often viewed as particularly important in the initial stages of the problem solving process (Kaufmann, 1990; Lowrie, 1996; Pirie & Kieren, 1992). Computers simulation programs, despite their obvious advances, do not always make these representations easy to understand. Children often find it difficult to transform their understanding of real life experiences to the representations created on the screen.

For children, and particularly young children, some form of direct instruction or external interaction may help to support learning experiences that emerge from using simulation based software. Moreover, if guidance and appropriate questioning take place mathematical understandings that are not necessarily made explicit in the program can be developed. The interactive relationship between the user, the teacher and the technology may develop a sound model for processing information. Osborne and Wittrock (1983) suggested that problem-solving performances are likely to be fostered in situations where procedures for focusing children's attention—such as providing motivating experiences, questioning, assisting students to clarify ideas, and providing alternative experiences of a particular concept—are adapted. Moreover, initial discovery stimuli should provoke personal feelings and understandings so that children are able to relate new ideas to previous concepts. If these experiences evoke a range of verbal cues, in an interactive manner between student and teacher, important understandings can be clarified to help represent the problem more clearly.

Lived experiences are visually represented on a computer screen, with the user able to manipulate these representations with freedom and flexibility. New insights about these experiences are generated through the interactiveness of the technology . The teacher also plays a vital role in this process. As Brown & Wheatley (1997) commented, the concrete representations offered by the technology may evoke, in the user, visual representations that are crucial in doing mathematics . In this paper, it will be argued that children's spatial sense can be further enhanced through directed questioning from the teacher.

Methodology

A case study methodology (Yin, 1994) was used to investigate the way two young children, Dylan and Rhiannon, used visual-spatial understandings to solve a computer-based simulation activity. Data were collected from audio-taped interviews, annotated transcripts, children's work samples and their responses to open-ended questions. In some instances the researcher was positioned behind the student in the role as a participant observer, whereas on other occasions the researcher interacted with each student as they solved the task. The study had two main purposes:

1. to determine the nature of the visual-spatial understandings used by the children completing the task; and
2. to examine the extent to which the interactions between the student, the researcher and the computer-based activity created an effective learning environment.

The participants

Both case study participants were competent computer users for their age. Dylan, aged 7, used computers once a week at school and almost everyday at home to play a variety of 'educational' and 'entertainment' games. Rhiannon, aged 8, did not use the computer as much as Dylan but tended to use it for a variety of writing and information purposes. Both children were used to reflecting upon the thinking processes they used to solve problems.

The computer software program

The computer program used for the investigation was Electronic Arts (1996) *Madeline thinking games.* The interactive program, which is based around a popular children's cartoon character, has twelve problem solving activities. The *Let's decorate* activity was selected for study. The challenge is to create and decorate a bedroom. There are a selection of wallpaper and floor designs, furniture, flower bouquets and toys that can be selected from icon boxes positioned at the bottom of the screen. Three walls of a bedroom are used as the template to introduce perspective. Many pieces of furniture, pictures and windows are tilted in a certain direction so that they can fit against the walls of the bedroom. The main objective is to select an appropriate item to be positioned on walls in the room.

It was postulated that a range of visual-spatial reasoning skills or understandings were required to solving this problem. Specifically, ideas associated with position, dimension, perspective, and angle seemed likely to be encountered. At no point did the investigation attempt to evaluate the "educational value" or relevance of the program. Computer programs of this genre are becoming more popular in schools and are often catalogued in book club advertisements. This program was selected because it was (a) already being used in the school, (b) suitable for young children, and (c) perceived to encouraged a degree of visual-spatial reasoning.

Initially, the children were exposed to a template of the bedroom. A voice, of Madeline, then invited the user to select a bedroom scene. The first time the children played the game the researcher did not interact with the students, but took notes of the individual's reactions and comments. In subsequent sessions, the researcher encouraged the children to describe what they were thinking about, posed questions in relation to the movement of objects, and attempted to establish the type of images the children constructed "in their mind." In these sessions the researcher aimed to determine the nature and type of visual-spatial understandings used by the children, and to consider the strategies they used in applying this knowledge. Dylan's representation of the problem is presented in Figure 1 with Rhiannon's in Figure 2.

Results and Discussion

Spatial-visual Processes and Understandings

The template of the bedroom provided the children with an opportunity to use their knowledge of spatial relations to conceptualise the representation. Although the problem was actually represented for them, they were still challenged to interpret the three-dimensional representation. Dylan knew that the template was a representation of a bedroom and could actually imagine what you would see when you walked into the room.

INT: What is this [the image on the screen] a picture of?
Dylan A bedroom
INT: What is in the bedroom?
Dylan Carpet and walls with wall paper on top.
INT: Where would the door be?
Dylan Back here somewhere [indicating that the door is in front of the screen]
INT: But it is not on the screen?
Dylan Because we are facing out that way [gesturing that we are looking in to the room with his hands] and as soon as you walk into the room you would see this [the image of the screen].

He thought carefully about where the door might be and attempted to locate it in front of the screen. In other words, the space "outside" the screen was related to the space "inside" the screen. Dylan, however, found it difficult to fully understand the relationship between the screen image and that of a bedroom. The compression of space—from a life sized bedroom to a representation of it on a computer screen —was not easily interpreted. When asked to identify were a point in the middle of the front wall would be he was able to say "just above the top of the drawers." When asked to do the same on the right hand wall he replied "near the plant" (see Figure 1). This response was obviously not correct. He commented that:

> you can see five squares that go across the wall (see Figure 1). Halfway would be in the middle of the third square (Dylan).

His argument may seem logical but he has not yet come to terms with the way space is represented on the screen. Mathematical understandings associated with perspective, diminishing line, and the representation of 3D space in a 2D environment have not been considered in his response.

Rhiannon was more intent on explaining why the representation actually looked like a bedroom. She uses terminology including "straight" and "diagonal" to describe understandings related to proportion and perspective. Although she did not describe the side walls in terms of a set of parallel lines, she used her hands to replicate the top and bottom lines of the side walls.

> Because it is 3D it makes it more real that way...The lines on the front are straight and the lines that way [points to the screen] are diagonal. When the lines are diagonal it actually looks like we are standing there... The diagonal make this part of the room further away than this part. Up here [points to the front] it is smaller because it is further away than those walls. Because we are closer to here it appears to be a lot bigger. (Rhiannon)

At her level of spatial development, Rhiannon was beginning to consider perspective and 3D to 2D representation. In her explanation she used phrases like "actually looks like we are standing there" and "it appears to be a lot bigger" to describe the simulated world. Interestingly, she commented that she could imagine herself walking around in the room.

> I could see myself walking through the door, walking up to the front wall, turning around and walking back out again. (Rhiannon)

Her vivid use of imagery was in contrast with her analytic description of why the 3D representation appeared to be real. Moreover, it appeared that she could move between real and imaginary environments.

Rhiannon's use of both visual and analytic reasoning is also evident in her justification for putting furniture or other objects on specific walls.

Rhian.: If I were to put it over here [on an inappropriate wall] it looks like the window is floating in the air.
INT: Why does it look good on that side?
Rhian.: Because that's were the angle goes.
INT: Is there any other reason?
Rhian.: Because this side of the wall is bigger than the side with the corner and the picture goes the same way.

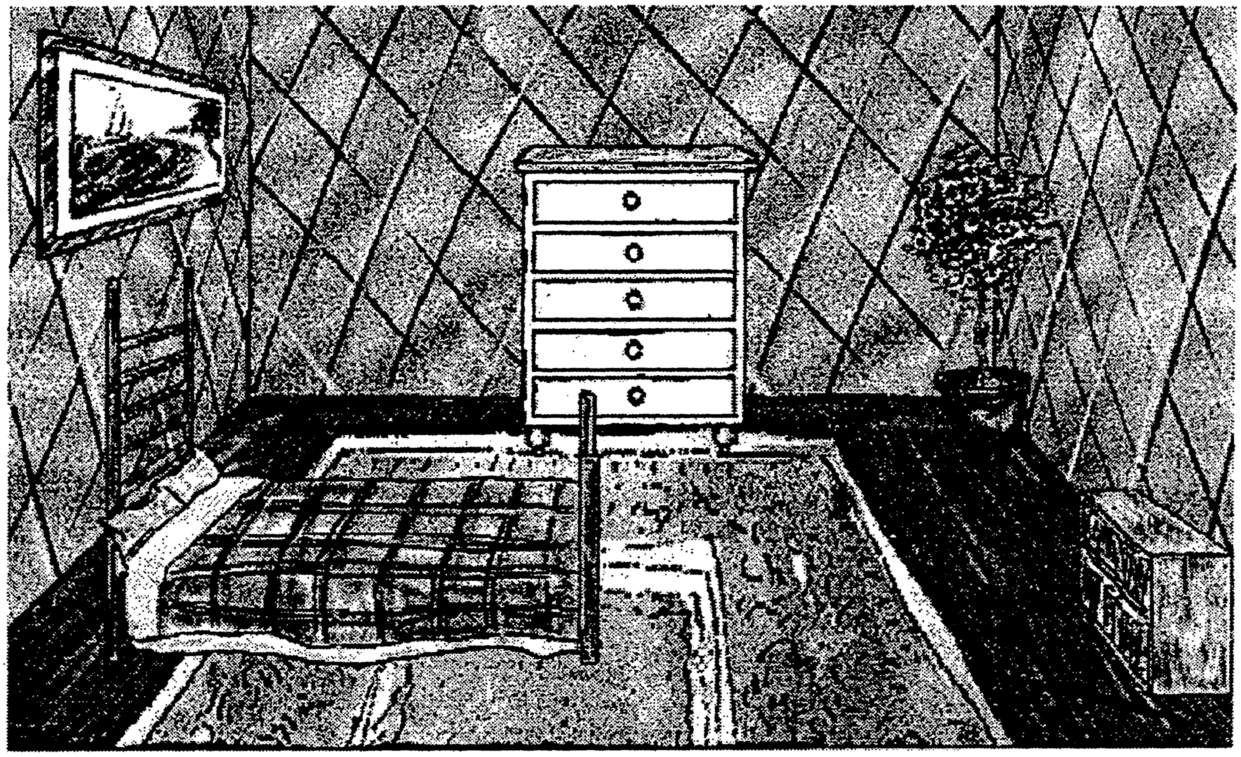

Figure 1: Dylan's Representation of the Problem.

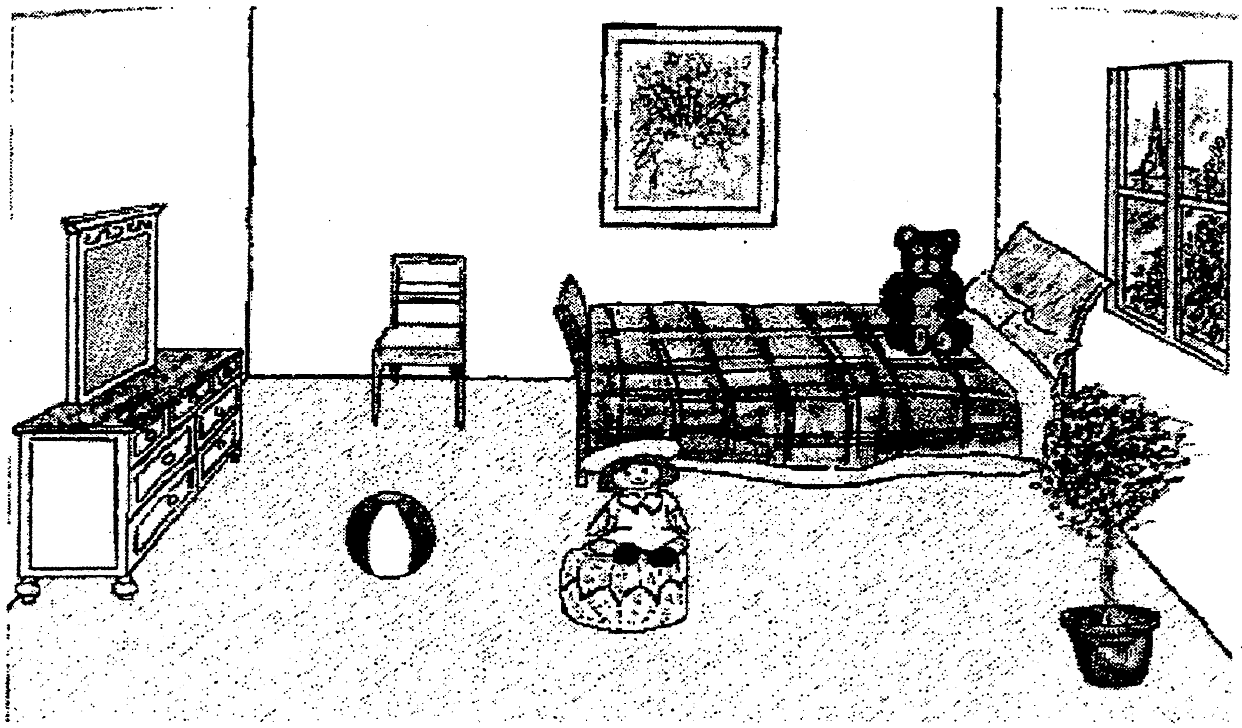

Figure 2: Rhiannon's Representation of the Problem.

The Interaction Between the User, the Teacher and the Technology

It could be argued that simulation games such as the one presented in this paper do not really develop visual reasoning skills. This would be based on the premise that children have the opportunity to use trial-and-error strategies, in a somewhat random manner, until the objects are placed in appropriate positions. The user would not make reflective judgements about their decisions, or critically evaluate their solutions (the completed picture of the bedroom). On the contrary, the two children in this study carefully selected the furniture to be positioned around the room and would often change selections when additional furniture was placed in the room. This may have happened because someone was watching them. Rhiannon commented that "the picture needs to be further forward now that the mirror is on the same wall." Although this may have been for aesthetic value, the decision was probably influenced by ideas of converging parallels and vanishing points. Nevertheless, the program did seem to challenge the children's mathematical understandings more frequently when they were encouraged to reflect upon decisions they had made.

The three way interaction provided the children with opportunities to verbalise their thought processes in what Vygotsky (1962) claimed were opportunities for complex thinking. Dylan, for example, formulated his decisions by analysing what he could see on the screen. This changed when he was challenged to think about his responses.

INT: Show me where halfway along this wall would be [interviewer points to the side wall]?
Dylan: About here.
INT: How did you know that?
Dylan: You can see five squares that go across the wall [and] halfway would be in the middle of the third square .
INT: Is this wall shorter than the front wall?
Dylan: No, but we can't see it all.
INT: Why not?
Dylan: Because it can't fit on the computer screen. The wall would go out to about here [demonstrated space outside the screen with his hand].
INT: So, where would halfway be?
Dylan: Oh, it would be about here —above the bookcase [see Figure 1]. I forgot that you have to think about the parts you can't see.

Ideas associated with perspective and representation were now considered. At the end of the interview Dylan was asked what he had learnt from the experience. He was able to make statements about the direction of the lines that were based on mathematical understandings.

INT: What have you learnt today?
Dylan: The way the lines run. On one side of the wall the lines run up and on the other side they run down.
INT: Show me what is up.
Dylan: [He positions his hand close to the left side of the screen and tilts his fingers down]. It goes the other way on the other side.

His "analytic" observations were supported by effective visual reasoning processes. Zazkis, Dubinsky and Dautermann (1996) described situations were problem solvers move back and forth between visual and analytic strategies and that this is sometimes more effective than using one type of representation in isolation.

Directed questions were also used to monitor the thinking processes used by Rhiannon and to encourage her to reflect upon particular mathematical understandings as they arose. In one instance a comment she made ("it doesn't matter where you pout the plants") was challenged and she seemed to become confused with the ongoing questioning. She was then instructed to select a similar object to use as a baseline measure to compare its shape with other pieces of furniture. She made the connection almost immediately.

Rhian.: It doesn't really matter where you put the plants.
INT: Why is that?
Rhian.: Because it could go here or over there because it doesn't have an angle.
INT: What is the difference between the plant and other shapes in the room?
Rhian.: I don't know what you mean.
INT: All right, select another plant and place it on the screen for me. Now talk about this shape in comparison to the window or the bed.
Rhian.: [the plant] doesn't have an angle. The angle doesn't matter.
Well it's like the seat [She selects a seat and puts it on the screen].
I can put it anywhere too because they haven't got any angles.
INT: What other words could you use to describe the differences?
Rhian.: Well it's rounder.
INT: What about the corners do you know what they are?
Rhian.: A corner is when two edges come to a point and they come to an end. Yes, most of the pictures [the objects] have sharp corners but the round shapes do not. That is why they can go anywhere.

The flexibility offered by the computer program allowed the interviewer to help the user construct ideas and understandings as the problem was being solved Additional examples could be selected to reinforce patterns and relationships among the objects. The computer was particularly useful in these situations. Both children developed understandings of representation and perspective by using the program. I would suggest, however, that the ongoing interactions between the user, the teacher and the program stimulated the children's thinking and provided them with opportunities to develop complex spatial understandings associated with perspective and representation.

Conclusion

This paper described the way in which two young children constructed spatial understandings associated with perspective and representation when using computer software that aimed to develop problem-solving skills. The metacognitive interactions that took place during the activity provided opportunities for the children to not only represent the problem—but to also assess possible success (Garofalo & Lester, 1985) as they responded to specific questions. Importantly, negotiation of meaning between the teacher and the student took place on a regular basis (Bauersfeld, 1991) with the student free to abandon, correct or change developing ideas. As Gagné and White (1978) suggested, quality questioning techniques can assist students to process information more effectively. The flexibility of the computer environment enhanced these interactions.

In the present study, the young children found it difficult to move between and link 'life-like' three-dimensional space with images presented in the simulation program. Although the screen images appeared to be representative of the walls of a bedroom, these images were not always immediately apparent to the children. On several occasions, however, the students were able to modify their spatial understandings as they verbalised their thought processes. Being able to think carefully about the problem representation helped the children to develop mathematical understandings associated with perspective, proportion and angle. Moreover, they were able to transfer their understandings of real situations to a representation of reality on the screen. The interactive environment helped the students engage in a range of visual and spatial understandings in a stimulating problem-solving environment.

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