In this paper I develop a microworld which might be construed as an example of my Sunrise pedagogy.

A script runs throughout the text presenting my minimalist exposition of a task which is designed to promote some desired activity. I annotate the script with a commentary in which I account for what I anticipate doing with students (see Mason, 1991).

For me, programming is just another form of expression and the computer is an extension of the expressive medium in which our culture develops and represents knowledge and skills. In this paper, I use programming in Logo as an end in itself as well as to gain access to mathematical ideas.

In order to explain microworld I develop an example of a particular microworld in the text. The specific example is not intended to provide a definition of microworlds in general but rather to act as a particular and paradigmatic case (Lakoff, 1987) for the purposes of the writing which describes it. Sunrise is a term which I leave more or less undefined in this paper. It is a label (Love & Mason, 1992) for a vast array of ideas and activities undertaken by a group of people in Australia within the last five years. Not all the people involved with Sunrise have acted in the same ways or in agreement one with another. What is presented here as Sunrise is a particular version of one aspect of it.

USING A SCRIPT

The script is intended to convey what I consider to be involved in the preparation of a lesson. It is worked upon extensively before the lesson, it contains what is considered necessary and sufficient to enable students to start useful work, and it is subjected to several imaginary trials prospectively, before it is used. These three principles (preparation of the environment, economy and minimalism, and the anticipation and preparation for activities and opportunities which might arise) are some of those which form the basis of my Sunrise pedagogy.

The script does not describe behaviour being sought and it does not specify tasks to be performed by the students. It aims to create a context in which students can work, a context as construed by the student.

The determination to leave unspecified the behaviour sought, depends upon an assumed role for the teacher when the student is working: then, the teacher will be expected to manifest the behaviour which is relevant to the discipline involved, in order to provide the student with opportunities to notice and work on behaving in appropriate ways.

The absence of set tasks is also the result of a deliberate choice. Teachers often set tasks to provide students with suitable activities for learning within a given context, and assume that activity is indication of learning. I provide tasks as a range of activity starters because I do not accept that there is a simple cause-and-effect connection between tasks and activities. (More generally, I consider the relationship of cause and effect lacks validity in classrooms, and in preference to it, I adopt a model of opportunities and preparation for those opportunities, as suggested here.)

The indirectness of the script is also deliberate: I aim to provide necessary and sufficient precision for my purposes.

SETTING THE SUBJECT DOMAIN

With the first section of the script I set the subject domain and with second, the task domain.

'Imagine a square which moves about on a plane. Now place some other squares beside it and then some squares beside them, until the plane begins to be covered by squares. Choose one side of the squares to work with. Imagine that in all the squares the side closest to you is distorted a little by being pulled away from you. The other squares will probably reshape themselves to accommodate these distortions. Is the plane still covered? It needs to be. Now choose a side adjacent to the one that was first altered. Distort that side a little in all the squares and let the necessary changes be made so that all the squares still cover the plane.'

This part of the script aims to create for the subject domain, a context rich enough to open up opportunities for useful work. The subject domain is broad enough to accommodate different interests, levels of skill and understanding. I have chosen to not provide complete specifications since I consider the process of interpreting the image into functional language is an important part of coming to work within the domain. Assuming the images are available, the next section of the script is offered for use with them.

SETTING THE TASK DOMAIN

'Suppose we want to teach a Logo turtle to draw squares. How would we start? How would a turtle draw the most basic square? What language would be appropriate for talking about what is happening to the squares? On what should we focus our attention? What kinds of tools will we want? What kinds of problems will we want to be able to solve? What kinds of patterns will we want to be able to make? What is important about this task? What can we afford not to worry about?'

In some classrooms, these questions might be construed as requiring answers, but I think of them as orienting thinking. The script is working towards making one activity for all which does not mean all students should be doing the same thing, but that they can all be active in the same task domain, using the same discourse even though they have individual, even unique, immediate goals. The discourse includes reference to and use of computer based tools which the students will use in common, no matter what specific project they choose to work on. This extended discourse is the microworld.
I consider the development of an appropriate discourse a critical aspect of the teaching process. In the language of Miller (1992), it is the difference between 'seeing as' and 'seeing that' which marks the move from one level of understanding to another, and very often being able to make the change depends upon access to an appropriate form of representation. Mason (1989) describes the process as a 'shift of attention'. Either way, it is the use of language and images which provide the frame through which the learner gains the necessary new view.

The microworld provides an activity centre in which to work on making connections and gaining insights, with the new way of seeing the problems within the subject domain: our perspective can influence how we construe a situation and the process of construal provides the learning opportunities.

'In order to have the Logo turtle draw a square, we need to define a square giving the turtle sufficient information for it to determine how to draw the sides and the angles between them (but not all this needs be given explicitly). There are several ways in which this can be done. For instance,

```
TO SQUARE : SIZE
  REPEAT 4 [FD : SIZE RT 90]
END

TO POLY : SIDES : SIZE
  REPEAT : SIDES [FD : SIZE RT 360 / : SIDES]
END
```

'This particular case, there are a number of constraints which arise because of the nature of the subject domain: problems related to the tessellating properties of the basic square. A possible solution is to find a way of dealing with the sides of the squares so that they can be transformed in a way which retains their tessellating property but which gives maximum scope for creativity in this process. A useful way to think of the basic square in this context happens to be in terms of the following procedure:

```
TO SQ
  RUN : SIDE1 RT 90
  RUN : SIDE2 RT 90
  RUN : SIDE3 RT 90
  RUN : SIDE4 RT 90
END
```

Adopting this approach, we soon discover that the relationship between the opposite sides of the squares, from the turtle's perspective, is the critical one.

As the turtle works its way around the sides, opposite ones need to be drawn by the same commands but with the directions reflected and the order reversed. This can be achieved if the sides of the 'square' are objects which can be reversed and reflected simply. For instance, suppose we could write run rev ref side1.

```
TO SQ
  RUN : SIDE1 RT 90
  RUN : SIDE2 RT 90
  RUN : SIDE3 RT 90
  RUN : SIDE4 RT 90
END

TO REV : LIST
  IF EMPTY? : LIST [OP [III]
    OP (SE LAST BL . LIST LAST . LIST
    REV BL . LIST)]
END

TO SQ
  RUN : SIDE1 RT 90
  RUN : SIDE2 RT 90
  RUN : SIDE3 RT 90
  RUN : SIDE4 RT 90
END
```

MICROWORLD ACTIVITIES

Now I am ready to invite my students to choose specific goals to pursue. If the discourse is suitable, students with different immediate goals will be able to discuss their problems and provide collegial support for each other. This will happen both because the students can usually find others who have had the same or similar difficulties and therefore will have a shared sense of what happens in the microworld, and because when they do encounter problems, they have a shared language with which to work on the problems.

The microworld's potential to provide one activity for all in part depends upon this resonance of difficulties. The microworld is powerful if students tend to interact with the powerful ideas of the topic, no matter what they are doing. In the case of turtle geometry, the discourse has unavoidable 'primitive' commands for

```
TO SQ
  RUN : SIDE1 RT 90
  RUN : SIDE2 RT 90
  RUN : SIDE3 RT 90
  RUN : SIDE4 RT 90
END
```

```
TO SQ
  RUN : SIDE1 RT 90
  RUN : SIDE2 RT 90
  RUN : SIDE3 RT 90
  RUN : SIDE4 RT 90
END
```

```
TO POLY : SIDES : SIZE
  REPEAT : SIDES [FD : SIZE RT 360 / : SIDES]
END
```

```
TO POLY : SIDES : SIZE
  REPEAT : SIDES [FD : SIZE RT 360 / : SIDES]
END
```

```
TOOLS WHICH PERFORM THESE FUNCTIONS WILL BE HANDY

A set of procedures for this purpose are contained in the figure 1. These procedures provide new structures for the discourse. They add words (bring into focus old, familiar words but with new, imperative meanings). Now the discourse is explicitly stated. It is narrow in some respects, but it allows the full use of Logo (on the computer) and (spoken) natural language and it constantly calls upon language and knowledge about tessellations, inverses, directions, Logo, and so on. (See Figure 1)

```
Figure 1 Useful procedures
```

```
TO STARTUP
  MAKE "SIDE1 [FD 50]
  MAKE "SIDE2 [FD 50]
  MAKE "SIDE3 [FD 50]
  MAKE "SIDE4 [FD 50]
END

TO SQUARE : SIZE
  REPEAT 4 [FD : SIZE RT 90]
END
```

```
TO POLY : SIDES : SIZE
  REPEAT : SIDES [FD : SIZE RT 360 / : SIDES]
END
```

```
TO POLY : SIDES : SIZE
  REPEAT : SIDES [FD : SIZE RT 360 / : SIDES]
END
```

```
TO POLY : SIDES : SIZE
  REPEAT : SIDES [FD : SIZE RT 360 / : SIDES]
END
```

```
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```
Figure 1 Useful procedures
```
directing the turtle in terms of distance (forward or back) and angle of turn (right or left). It is very difficult to do anything with the Logo turtle without having to deal with at least these basic but powerful ideas of geometry. In the case of the tessellation microworld, I aim to have students encountering and working on the powerful ideas of tessellation, no matter what goals they are actually pursuing.

THE TEACHER IN THE MOMENT OF TEACHING

In my experience, both the students and I are significantly more mentally exhausted after a session with a good microworld than after another type of lesson. It is very satisfying to work very hard but sustained ‘hard’ mental activity is tiring.

As teacher, I have already done a lot of hard work in order to prepare for the moment of teaching; in the moment of teaching I aim to be a model for my students, manifesting the behaviour of the subject domain, asking questions of the type which support investigation in the domain, in this case working on mathematics and tessellations.

It is important that I can notice and am ready to seize opportunities for instruction as they arise and this requires that I am awake and ready with appropriate actions and able to choose in the moment to use them. This last aspect of acting in the moment depends upon what has been done in preparation: merely recognising in hindsight that an opportunity has passed will not be acting in the moment, nor will I necessarily be able to act in the next moment when a similar opportunity presents itself. The teacher’s effectiveness in the moment (while the students are active) depends to a great extent then, on preparation for the opportunities which might arise. The being awake and being ready to notice, and being ready to act all depend on preparation. Disciplined work on this aspect of teaching within any domain is essential to the success of the teacher in the moment.

The role being described here for the teacher is one which has the teacher teaching for most of the class time, offering group instruction, individual instruction, and at times drawing the attention of a group or individuals to a particular aspect of the task domain or subject domain. Many of the more usual roles which teachers assume, such as adjudicator and entertainer, become less significant as the students take more ownership of the activities in which they are engaged. The investigations and goals which the students set for themselves are not for the teacher in the usual way. What soon becomes obvious about an activity of the type described is that all the participants are active: the students are not passive recipients of instruction but constructive of their own knowledge and their teacher is engaged in supporting that construction with instruction, as a constructionist. (Papert, 1991).

WHAT DOES THE CLASSROOM LOOK LIKE WHILE THIS IS HAPPENING?

One in which the [students] are engaged in the construction of something. They are engaged in a meaningful activity and they are learning a lot passionately. (Papert, 1991).

The usual ‘order’ is very likely to be replaced by buzzing activity. Students are designing new shapes and talking to each other about how to do this, what maths is involved. Many students, given the choice, like to work with other students, whether or not actually sharing a particular piece of work, or a computer on which to work. In order to establish a constructive climate, a conjecturing atmosphere, the teacher will at first have to work to develop an explicit acceptance, within the class, of the legitimacy of others’ ideas. It is important in such a classroom that the students’ standards are high and that they do not just adopt all that is said; the teacher will need to help them become a community of critics. While it is essential to develop a willingness to listen, there must be a balancing interest to critically evaluate and work upon what is being offered.

In such a classroom there is also a sense of play. But the play is ‘hard’. There are highs and lows involved, break-throughs and dead-ends. Imagine trying to make a fish from a square so that it can be used to tessellate the plane. So many ideas prove to be ineffective, unexpected results lead to new avenues for exploration, theoretical and practical problems interact to produce confusing feedback. Other people discover or invent ways of working which would be useful to me if only I could add their solutions to my mess. If this does this, then that ought to...

This is a classroom in which students are conjecturing, specialising, generalising (Mason, Burton & Stacey, 1984), and working on lots of other disciplinary skills as well as finding answers. Much more is happening than could be anticipated by any teacher, much more is learned than could be if all the students were dependent on interaction with the teacher only. The students are doing what they are doing for themselves in a supportive environment. They are working on the mathematics with their teacher, their peers and their computers. They are constructing mathematics.

REFERENCES


