Shaping Practice: Worksheets as Social Artefacts

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Part of a broader research project on the development of mathematical understanding in primary classrooms, the research reported in this paper focused on how opportunities to learn about percentage in two classrooms were shaped by worksheets. The words in the text, the way that the teachers replicated these orally, a grid used to illustrate the concept of percentage, the genre of both mathematical and non-mathematical aspects of the worksheet's presentation, and the calculation methods presented were all potentially influential aspects. It is argued that the "knowledge" conveyed by the texts of the worksheets was distributed over a much wider field than the classrooms involved.

In this paper I draw on the theory of situated cognition, where the focus is on ways in which potential for knowledge development emerges from socio-cultural contexts. Situated cognition is a body of conjecture that grew out of the work of Vygotsky, who demonstrated how individual and social knowledge develops from intersubjective activity. Here, internalisation of knowledge is not a matter of absorption of experience and of organisation of perceptions into frameworks of cognition, as it is in constructivism, but is a process whereby the constitution of the internal plane is continually mediated by and distributed over activity in social contexts (Leont'ev, 1972/1981).

Theories of situated cognition have developed from Vygotsky's position by sharing the premise that "meaning, understanding, and learning are all defined relative to actional contexts, not to self-contained structures" (Hanks, 1991, p. 15). With situated cognition, the social process subsumes the learning of knowledgeable skills"; cognition becomes a way of being; and the interaction of instructors, learners, activities, and environments is mutually influential, co-constructed, and multi-level (Lave & Wenger, 1991). Hence learning outcomes, for both individuals and social groups, vary according to components of settings —including their interactions, activities, tools (including language tools), and artefacts. Social "artefacts", in this context, include not only curriculum documents and teaching aids, but also patterns of activity and expectation as well as knowledge that is common within particular social groups. While Vygotsky (1978) differentiated between physical and mental artefacts, Cole (1995) noted that even material artefacts are conceptual artefacts.

> [An artefact is] an aspect of the material world that has been modified over the history of its incorporation into goal directed human action. By virtue of the changes wrought in the process of their creation and use, artefacts are simultaneously *ideal* (conceptual) and *material*. (p. 17)

My focus in this paper is on how worksheets, as social artefacts, shape classroom interactions and hence have potential to impact on children's mathematical learning. It is important to identify such influences because (a) the use of worksheets is rife in primary mathematics classrooms; and (b) there seems to have been no research on links between intended curriculum, the use of worksheets, teaching processes, and knowledge development (or at least learning opportunity).
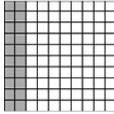
The Research Context and Methods

I am reporting here on a small component of an extensive project involving case studies of four experienced primary teachers in one public primary school. The aim of the research was to analyse how mathematical understanding develops in classrooms. Case study was considered appropriate for this inquiry because it allows us to analyse human behaviour related to the development of meaning in individual contexts.
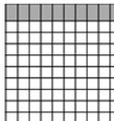
The data were collected over a period of four months. Mathematics lessons taught by each teacher were videotaped for about one month. The teachers were interviewed briefly before and after many of their lessons, and had one longer interview each. Parts of the video of the lessons were selected and transcribed to support a closer analysis of the teachers' interactions with the children using (a) advice about "teaching for understanding" that was gathered during an extensive literature review, and (b) the theory of situated cognition.

Two Grade 6 teachers and two Grade 2 teachers were involved. It is school-wide practice that year-level pairs of teachers plan their lessons together in order to support their professional development, to share preparation workload, and to ensure that the children progressing to the next level had similar knowledge and skills. This paper refers only to the Grade 6 teachers—"Russ" and Janet"—who planned most of their lessons together but taught them separately. Overviews of what was to be taught each week were constructed together but planning of individual lessons was usually undertaken by one or other teacher. The artefact that I have chosen to focus initially is a worksheet shown as Figure 1.
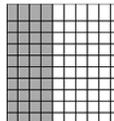

Figure 1. The percentages worksheet (source unknown).

Russ' Percentages Lesson

First Russ drew the children's attention to the worksheet. He talked the children through the explanation and illustration. The children were then asked to "count the squares" shaded in on the four grids shown on the next section of the worksheet, and to "write the percentage of each unit which is shaded". Russ then broke away from the worksheet format to show the students how to write percentages as decimals and common fractions. He said:

> To write each one of those as a decimal is fairly easy, because percent is out of a hundred and decimal is also a hundred. To change ten percent into a decimal becomes zero point one "oh", [child interjected] or, as Craig said, you can do zero point one. And how about 50%, Kate? (etc.) … What about if you were asked to write a percentage as a common fraction? How could you change 10% into a fraction?

The next section of the worksheet attended to conversion of common fractions to percentages. Russ worked through the examples orally. At one stage, he said:

> Seven tenths is not out of a hundred. What do I have to do to make it out of a hundred? [No response.] Remember how we did equivalent fractions? What do I have to multiply the bottom by? [Several hands were raised and the child asked said "Ten".] Okay, so if I multiply the bottom by 10, I have to do the same to the top.

The children were given time to complete the examples at the bottom of the worksheet and on the back of it. Some of these examples involved the use of a calculator. Russ demonstrated how to use a calculator to calculate percentages. Using 8 out of 32 as an example, it was $\boxed{8}\ \boxed{\div}\ \boxed{3}\ \boxed{2}\ \boxed{\%}$. When asked why he used that method, he said, "It's the easiest. They know how to enter a fraction into a calculator by dividing; so then they just press percent to change it into a percentage. However, he had not realised that children used the method shown on the worksheet would have entered $\boxed{.}\ \boxed{0}\ \boxed{8}\ \boxed{x}\ \boxed{3}\ \boxed{2}\ \boxed{=}$

Janet's Percentage Lessons

Although Janet had found the worksheet shown above and made copies for Russ and his pupils, she did not use it in her classroom—setting it instead for homework. Her class time was used to draw out and discuss what children understood of the term "percentage", and during when opportunities arose Janet put a lot of emphasis on "out of 100" and wrote many fractions using 100 as a denominator. She then used several worksheets, and a further two worksheets were introduced during the two following two lessons. Thus the meaning of the term seemed to be embedded in contexts that the children were familiar with.

After an exercise where children coloured in given percentages of 10 x 10 grids, the children were asked to find the percentage button on their calculators. Janet then showed them how to work out 25% of $60. First she asked them what the correct answer should be, then demonstrated the method outlined on their worksheet: $\boxed{6}\ \boxed{0}\ \boxed{x}\ \boxed{2}\ \boxed{5}\ \boxed{\%}$, pointing out that "the 'of' can be changed to a 'times' sign".

A second method was demonstrated in the same lesson when Janet explained that 95% of 500 is the same as $\frac{95}{100}$ x 500.

> With the calculators, this has to be done in steps: 95 divided by (because that's what that sign means) one hundred; and then times it by 500.

A worksheet used in the following lesson introduced a third method: "For 8% of 140, put in zero point zero eight times one hundred and forty". As the children were working, Janet came back twice to a boy who described his methods as "160, by 15, percent". Janet said "No" and then directed her attention to some other students. Coming back to Matthew, she looked over his shoulder and watched him work, but did not say anything. Later, Janet knelt down beside him and asked him how he had worked it out:

Janet [Paused, thinking] Yeah, it would work. But you should be able to work it out now by doing that [pointing to 10% method] in your head. Ten percent would be?
Matthew Sixteen dollars.
Janet Five percent would be?
Matthew $2.50.
Janet No. Halve it again. Eight dollars. So what would fifteen percent be?
Matthew Twenty four dollars.
Janet Okay. 24 off 160 would be …?

Later Janet said that she had not intended to introduce a range of methods. She was somewhat surprised at how these aspects of lessons developed, but was not concerned about the students using several different methods. Her own knowledge of mathematics was strong enough for her to recognise the mathematical basis of the methods used, although she had had to "think twice" about Matthew's method. Later in the lesson, Janet found out that several other children had used their own variations of methods.

Analysis and Discussion

Worksheets encapsulate mathematical ideas and ways that these are commonly explained in our society. Thus they both represent and contribute to society's ways of "being in the world" (Vygotsky, 1925/1979, in Backhurst, 1991, p. 85). The text of a mathematics worksheet includes its words and the ways that these are combined and presented, as statements, questions, instructions and so on, as well as formatting such as spacing and bolding. The text of a worksheet may also includes diagrams. Together, these elements give students messages about what mathematics is and how it should be learned. Thus worksheets are contexts for both mathematical and non-mathematical cognition.

The content of the worksheet provided a discursive model for classroom language. Table 1 shows how text from the worksheet matched Russ' introduction of percentage.

Table 1
Russ' Use of the Worksheet Words

Worksheet text	Russ' words
Percentages [heading]	You have all heard of percentage.
Per cent means per hundred.	[Russ looked at his worksheet, and then most children looked at theirs.] So, *percentages.* Most people have heard of it, but what does it mean? On the top of out sheet here, it says "Percent means per hundred", or out of a hundred.
This diagram shows 20 out of 100.	In the diagram, twenty of the squares are shaded, out of a hundred.
We can write it as a vulgar fraction	And you know that 20 out of a hundred can be written as a common fraction, twenty out of a hundred.

… or as a percentage: 20%	It can also be written as a percentage because twenty out of a hundred means twenty percent.

This closeness to the written text is not surprising. It is sensible to talk students through worksheets to help poor readers, to give children chances to ask questions, to provide assess children's oral and written responses, and so on. The explanations, directions, and examples on the sheet were what he and the children engaged with. However, every reader of this article could think of other ways of introducing the concept—alternatives, but not necessarily better. Russ is an experienced teacher who displayed a good level of mathematical understanding and pedagogical content knowledge, and he too could have thought of other approaches—but the fact remains that he did not. Janet's supplying the worksheet would have constrained Russ' thinking about alternatives.

Janet's "same" lesson resulted in a markedly different learning experience for her pupils. Upon reflection, she had felt that the sheet that she had given Russ "would be better for revision" and "good for homework", so had looked for some sheets "where the activities used calculators". However, until we discussed the methods used she had not realise that the worksheets introduced such a variety. It was interesting that several of the students felt free to invent their own procedures, and that Janet accepted these. In this case, the worksheets did not serve to limit pedagogy but to extend it further than the teacher's plans.

Both approaches had their advantages and disadvantages. Russ's students' common (but restricted experience) would provide a useful foundation for further lessons for the class as a whole. Janet's students had met a number of possibilities and some had used their own approaches—not having a common basis for further work but having been introduced to a range of meanings associated with different calculation methods. In both cases, the influence of the sheets and the ways that the two teachers used them would not be limited only to this lesson, for the interactions and activities set up the potential to shape future understandings and activities of the teacher and the students, both together and in other contexts in the future. This illustrates Vygotsky's proposition that as we meet new objects these are used to create options for new ways of thinking and acting. Thus cognition is not only distributed over people, activity and tools within current settings but is also liable to be distributed to future pedagogical contexts and perhaps other artefacts.

The 10 x 10 Grid

Consider just one of the elements of the worksheets used: the 100s grids used to illustrate percentage. A pre-lesson interview with Janet revealed that she had seen the idea of using a 10 x 10 grid for teaching percentage in a textbook several years beforehand, and thought it was "such a good idea for making it practical instead of abstract". When she had talked with another colleague about the idea, Janet had been given the worksheet that was eventually used by Russ. However, Russ also had some background with the use of a 10 x 10 grid to teach the concept of percentage. He had attended a session during a professional development day "several years ago" where a "hundreds grid" had been used for teaching many ideas, including decimal fractions and area, but not percentages. At that time, though,

he "saw its potential for percents". Here we see evidence of "tangential and overlapping communities of practice" (Prior, 1997, p. 98).

In fact, this representation is used commonly to teach many key ideas of our society's base 10 number system, including counting, place value, area, percentage, and decimal fractions as well as measurement systems. However, these ideas are not built into a physical 10 x 10 grid: they are distributed amongst the population, including teachers who may or may not use the grid to develop such meanings in the next generation. Common communal meaning is attributed to artefacts such as these grids drawn on paper, number charts and number boards, bead frames, and MAB flats, so consistently that these artefacts seem to carry basic social ideas into classrooms. (In comparison, for instance, a 9 x 9 square would be virtually useless in a primary classroom.) The same meaning is attributed to other materials, so that even when concrete materials such as interlocking cubes and counters are not so structured they are commonly grouped together into rows of tens and then squares of 100. Understanding of school mathematics depends very much on children's appropriation of the ways that such social knowledge is represented by, and implicit in actions with, common artefacts (Leont'ev (1972/1981).

The ideas that specific tools represent can only be understood through use of those tools, "and using them entails both changing the user's view of the world and adopting the belief system of the culture in which they are used" (Brown, Collins & Duguid, 1989, p. 32). In observing their use and coming to grips with the ideas and actions involved, children serve a cognitive apprenticeship—not into the world of mathematicians, but into general social constructs as well as into school mathematics as a system of representations and typical activities. Concepts, here, are not abstract entities but are understood through and exist in classroom experience.

I should not leave the impression, however, that this process is merely enculturation through reproduction. Every time such artefacts are used, production (i.e., re-production) of culture is being enacted.

The Presentation

At the top of the worksheet there is a cartoon-like sketch of a smiling gymnast. The picture is quite irrelevant to the topic. It probably relates to the last section of the worksheet labelled "For champions", where the children are challenged to convert 4/4, 3/5 and 0.8 to percentages. Note that "For champions" is the only text formatted in bold. It may have not been assumed by the author of the sheet that all children would progress from the idea of "percent means per hundred" to being able to complete these problems, so perhaps the last section was meant to be completed only by "champion" students. Alternatively, the sub-heading may have been used to motivate children to complete the harder examples. In fact, Russ did not mention this section specifically, merely asking the children to "finish both sides of the sheet". Nevertheless, the social messages were there for students to glean. Whatever the purpose, the extra examples provided a challenge for the children. The purpose of the gymnast is less clear, but the sketch fits with a common social message: that children who work hard at mathematics can become laudable members of society. Exertion and repetition are common characteristics of training for both gymnastics and mathematics.

The setting out of worksheets conveys traditional ways of working. An example from the sheet shown in Figure 1 is the setting out of the equations that the children needed to copy and complete. Russ used the same setting out on the blackboard. The teaching of and learning such traditions is subtle, but repetitive enough to have a lasting influence.

The genre of the worksheet also conveyed what it is to do mathematics in school. The authoritative text was privileged, at the top of the sheet: "Percent means …", and "This diagram shows …". Instructions for activity followed: "Write …", "Shade …", "Complete …". In short, the sheet followed the "listen then do" pattern of traditional mathematics classrooms. There was no sense in the worksheet of percentages being used or useful in the children's lives. Percentages seemed to be just something that one operates with in mathematics classrooms. There was also no recognition that of children of this age have everyday knowledge of percentages that they bring to classrooms, although Russ did draw this out this briefly in two diversions from the script. Further, there was no hint that classrooms might be active mathematical communities, such as would be conveyed by directions to explore, discuss or decide. The children were being acculturated into the positivist hegemony of school mathematics, and a teacher following the sheet was a tool in this process.

Worksheets convey assumptions about what learners will bring to classrooms. For example, the link between the hundred little squares and the factions of tenths, hundredths, quarters, and so on, was not made explicitly. The children's understanding of this idea was also taken for granted by Russ. The idea that the arrangement of 100 squares represented one whole—of which a "tenth" or "three quarters" was shaded—was implicit; yet this is a key idea that underpins the conversion exercises that the children were doing. The network of understandings that children develop through the use of such artefacts can be rich and hence open to such realisations, but students need to understand wider social systems (in this case, the way the base ten system underpins fraction work) before they can learn more about those systems from using the representations. It is ironic that it is only when children understand wider systems that their understanding of key mathematical concepts and the teaching aids used in mathematics classrooms can develop interactively.

These examples seem to support Vygotsky's proposition that beliefs, values and practices are maintained and nourished though the employment of social artefacts.

Conclusion

Newman, Griffin, and Cole (1989) argue that learning tasks are strategic fictions or templates that teachers follow to create an organised context within which relatively unplanned "working together" takes place (p. 135). They discuss the "interpsychological construction" that takes place during the development of classroom curricula—construction "arising from the interaction between people" (p. 93). People, here, include those not present in a room who nevertheless impact on tasks undertaken, and hence on what is learned. For example, in the case of the lesson above, influential people included the authors of the state's curriculum framework who informed Janet and Russ' decisions about content, the two separate authors of the two sides of the worksheet who suggested how the concept of percentage might be taught, Janet's colleague who had provided the worksheet, and the people who provided Russ' in-service course on how to teach ideas

that he recognised as being related to percentage. (Similarly, those people would have had their own professional resource networks.) Of course, a very influential "other" was Janet, who had proposed using the worksheet and made enough copies for Russ' students.

Lave (1988) showed how structuring of the resources used in specific settings modulates activity, resulting in situated forms of engagement. These can constitute linkages across settings, and are "to be found not only in the memory of the person-acting but in activity, in relation with the setting" (Lave, 1999, p. 98). It is important to examine pedagogical developments are they unfold *in situ*, in order to understand more about cultural mediation of pedagogy and knowledge by the tools that teachers employ.

The worksheet shown above is only one example of artefacts that I have identified in the broader research project as having the potential to inform teachers' thinking about practice. It was an artefact, in Vygotsky's sense, that proved to be a very important aspect of the social context that shaped and constrained potentiality for the development of the students' understandings of percentage. It was used by Russ as a template for action, including social interactions and mathematical pursuits aimed at the development of understandings and skills. Such professional artefacts belong both to immediate settings, and to wider contexts such as curriculum and school systems. They form part of a network of tools and understandings that are distributed across our culture, serving to both represent and maintain that culture.

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