

# The Role of Contexts in the Mathematics Classroom: Do they Make Mathematics More “Real”?

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Mathematical awareness appears to develop differently in different situations. This, in itself, is interesting but not extraordinary; what is remarkable is the *degree* of discontinuity of understanding in a subject which many regard as immutable and totally objective. This discontinuity is not only interesting but, to a large extent, unexplained. There seems to exist for each individual a complex of relations between the world in which mathematics is developed and the world to which it is applied. Yet widely held opinion still lends itself to the belief that mathematics can be learned in school, embedded within any particular learning structures, and then lifted out of school to be applied to any situation in the real world. A number of research projects now challenge these perceptions with the observation that mathematical performance is markedly inconsistent, particularly across what may be termed “school” and “everyday” situations. These inconsistencies suggest that it is the environment in which mathematics takes place, not the problem to which it is applied, which determines the selection of mathematical procedures. If this assertion is true then the implications for teaching, learning, and assessment are great. Furthermore if the context of an assessment task is capable of determining, to some extent, mathematical performance and procedure then the degree of mathematical specificity which can be maintained within and across contexts and, more importantly, the processes which determine this should certainly be examined.

For many years proponents of learning transfer theory have stated that students will be able to demonstrate their knowledge and understanding of mathematics in situations outside the classroom when three contributory processes have taken place. Firstly, the student needs to recognise that the requirements of the task are represented in previous learning, secondly this information needs to be retrieved, and thirdly the student needs to translate this information to fit the demands of the situation. Opponents of learning transfer argue that this theory, the form and existence of which has gone unchallenged for many years, is based upon insubstantial and patchy evidence and is derived from fallacious assumptions. The assumptions suggest that the processes of socialisation are passive and that knowledge is a pool of information transmitted from one generation to the next. Many researchers (for example Lave, Rogoff, Walkerdine) have attempted to demonstrate that a static representation of the transfer of learning overlooks the complex interrelationship between individuals and their settings.

Lave’s “Adult Math Project” (AMP) compared adults’ use of mathematics through test and *in situ* observations and, as with similar research [Scribner, 1984; Carraher, Carraher and Schliemann 1982], confirmed the discontinuity of mathematical performance and choice of procedure between settings. The project observed performance in a supermarket and a test environment and concluded from these observations that the choice of mathematical procedure was related more to the setting than the mathematical requirements of the task. It is widely believed in mathematics education that the likelihood of situation specificity is reduced if school mathematics is learned in real life contexts and the links between the requirements of mathematics in school and in real life are made explicit. Lave challenges this notion and in another study demonstrates that the use of a shopping context in school has little effect upon performance in the supermarket [Lave, 1988]. Probably the most interesting area of Lave’s work is her exploration of the relationship between the use of a context like shopping in mathematics lessons and the use of mathematics in relation to an everyday activity like shopping. She argues that in school the shopping context serves only to disguise mathematical relations. In the supermarket the mathematics used suits the context of buying food and neither of the two experiences has “symmetrical organising effects” on the other. Lave’s research is one of a few studies that suggest the use of context is less useful in facilitating links than consideration of the underlying principles and processes which form mathematics.

I would like in this paper to challenge the polarisation of views represented at one end of the spectrum by proponents of learning transfer and by Lave *et al* at the other, particularly in relation to the use of contexts in mathematics lessons. It seems that learning transfer proponents have, for many years, been promoting a theory which at best is oversimplistic. I agree with Lave’s argument that it is inappropriate to assume that students can learn something, retrieve it from memory, and transfer it to a new situation, and that this process will happen independently of the activity, setting, or processes of socialisation. Where I disagree with Lave is in her suggestion that because all learning is situation-specific, transfer cannot be enhanced by any factors of the learning environment. I can believe that learning through a shopping context did not aid transfer in Lave’s experiments, but the complexity of issues relating to context, transfer, and a student’s learning, do not allow the usefulness of contexts to be dismissed because of this. I

would like to suggest in this paper that contexts *may* be useful in relation to learning transfer even though contexts as they are generally used are *not* useful, and that the factors which determine whether a context is useful or not are numerous and complex and have little to do with a description or depiction of real world events which students will eventually encounter.

### The context effect

Numerous misconceptions seem to be current in the use of contexts in school mathematics textbooks and assessment schemes. Possibly the most interesting of these is the notion that task contexts influence the motivation of students yet have little effect upon mathematical procedures and performance. This results in the random insertion of contexts into assessment questions and classroom examples in an attempt to reflect real life demands and to make mathematics more motivating and interesting. This strategy ignores the complexity, range, and degree of students' experiences as well as the intricate relationship between an individual's previous experience, mathematical goals, and beliefs.

I would suggest that the degree to which the context of a task affects students' performance is widely underestimated. When context is recognised as a powerful determinant, misconceptions still prevail, as in the belief that mathematics in an "everyday" context is easier than its abstract equivalent, and that learning mathematics in an everyday context can ensure transfer to the "everyday" lives of students. Lave [1988] has suggested that the specific context within which a mathematical task is situated is capable of determining not only general performance but choice of mathematical procedure. Taylor [1989] illustrated this effect in a research study which compared students' responses to two questions on fractions: one asking the fraction of a cake that each child would get if it were shared equally between six, and one asking the fraction of a loaf if shared between five. One of the four students in Taylor's case study varied methods in response to the variation of the *word*, "cake" or "loaf". The cake was regarded by the student as a single entity which could be divided up into sixths, whereas the loaf of bread was regarded as something that would always be divided into quite a lot of slices—the student therefore had to think of the bread as cut into a minimum of, say, ten slices with each person getting two-tenths of the loaf.

Examples such as this challenge long-held beliefs in mathematics education that abstract calculations involve higher level skills than calculations in context. They also suggest that students probably encounter similar difficulties transferring from task contexts to school and to "real world" problems. Certainly the context in which the mathematics is placed seems to be a factor in determining mathematical procedure and therefore performance.

One response to the problems of learning transfer has been to teach mathematics "in context" in the hope that students will perceive the links between problems encountered in school and the "real world" and between different task contexts. It is interesting to reflect upon this development in order to consider the actual processes employed by

students when encountering a question "in context", why the context is capable of determining or even affecting mathematical procedure, and whether learning in context enhances transfer to real world situations.

### Learning in context

In the early 1970's increasing awareness of employer dissatisfaction with school leavers, as well as general reports of adults' inability to transfer mathematics learned in school, prompted a vocational shift toward the "everyday" use of mathematics, particularly aimed at low attainers. Advocates of everyday mathematics say that this focus not only prepares students for the specific content studied but that real world problems provide learners with a bridge between the abstract role of mathematics and their role as members of society [Broomes, 1989]. Thus a strand of school mathematics was developed which resulted in publications like ILEA's "Mathematics in context: a handbook for teachers" (Inner London Education Authority, 1983). This offered schemes of work which focused upon budgeting, bills, banking, salaries, income tax, reading electricity meters, and so on. More generally a move away from abstract mathematics and towards mathematics in context was deemed to reflect the demands of real life problems and to prepare students for the mathematical requirements they would face in their everyday lives.

The move away from teaching mathematics as a complete series of abstract calculations has also been supported by a number of assertions regarding the enhancement of mathematical understanding. The abstractness of mathematics is synonymous for many with a cold, detached, remote body of knowledge. It is argued that this image may be broken down by the use of contexts which are more subjective and personal. Using real world, local community, and even individualised examples which students may analyse and interpret, is thought to present mathematics as a means with which to understand reality. This, it is suggested, allows students to become involved with mathematics and to break down their perceptions of a remote body of knowledge. Such a perspective, which includes an awareness of the utility of mathematics and its involvement in the real world is known to motivate and engage students, particularly girls [Walkerdine, 1989]. Fasheh [1982], in proposing that context makes mathematics more meaningful, cites an occasion when he asked Palestinian students to count school absentee rates and give reasons why the biggest number of absentees occurred on Saturdays. He concluded that the success of this exercise in developing understanding was its demonstration that mathematics could be used to discover facts about the community and interpret them, revealing a variety of possible interpretations and explanations of any mathematical fact.

It is also argued that an historical perspective on mathematics may show that axioms are not God-given or Nature-given but statements made by people that evolve with time and through much discussion and debate. Axioms can be partly or wholly changed to produce new systems and models, though students are rarely aware of this. An historical perspective can also play an emancipatory role in breaking down history and by drawing upon African, Indi-

an, Chinese, Arabic and other examples, the distorted view of the history of mathematics which many European students have, may be countered. Discussion of the role that women have played in the history of mathematics may also further this cause—few students (or teachers) are aware of the eminent women mathematicians like Emmy Noether or Sophia Kowalesky whose contributions are ignored in most historical documents.

Contexts are also presented as general motivators, offering students exciting and real life examples that engage their interest. In this role they may counter an image of mathematics which Davis and Hersh [1981] describe as “dry as dust, as exciting as a telephone book, as remote as the laws of infangtheif of fifteenth century Scotland”. Finally, it is argued, contexts help students relate the events or phenomena of the real world to the use of abstract and academic mathematics

The reasons offered for learning in context seem to fall into two broad categories, one concerning the motivation and interest of students through an enriched and vivid curriculum, the other concerning the enhanced transfer of learning through a demonstration of the links between school mathematics and real world problems. As a result of these assertions from mathematics educators, many current mathematics schemes present mathematics “in context”. In the UK the last twenty years has seen wide-scale adoption of mathematics textbooks and schemes made up from numerous examples of mathematical content in supposedly real world situations, as epitomised by the SMP 11-16 scheme used by around 85% of secondary schools in many parts of England and Wales (CATS, 1991). Yet research findings still suggest that students perform differently when faced with “abstract” and “in context” calculations aimed at offering the same mathematical demand. This suggests that assumptions regarding enhanced understanding and transfer as a result of learning in context may be oversimplistic.

### How real is real

One difficulty in creating perceptions of reality occurs when students are required to engage partly as though a task were real whilst simultaneously ignoring factors that would be pertinent in the “real life version” of the task. As Adda [1989] suggests, we may offer student tasks involving the price of sweets but students must remember that “it would be dangerous to answer (them) by referring to the price of the sweets bought this morning” [1989, p 150]. William [1990] cites a well known investigation which asks students to imagine a city with streets forming a square grid where police can see anyone within 100m of them; each policeman being able to watch 400m of street (see Figure 1.)



Figure 1

Students are required to work out the minimum number of police needed for different-sized grids. This task requires students to enter into a fantasy world in which all policemen see in discrete units of 100m and “for many students, the idea that someone can see 100 metres but not 110 metres is plainly absurd” [William, 1990; p30]. Students do however become trained and skilful at engaging in the make-believe of school mathematics questions at exactly the “right” level. They believe what they are told within the confines of the task and do not question its distance from reality. This probably contributes to students’ dichotomous view of situations as requiring either school mathematics or their own methods. Contexts such as the above, intended to give mathematics a real life dimension, merely perpetuate the mysterious image of school mathematics. Evidence that students often fail to engage in the “real world” aspects of mathematics problems as intended is provided by the US Third National Assessment of Educational Progress. In a question which asked the number of buses needed to carry 1128 soldiers, each bus holding 36 soldiers, the most frequent response was 31 remainder 12 [Schoenfeld, 1987; p37]. Maier [1991] explains this sort of response by suggesting that such problems have little in common with those faced in life: “they are school problems, coated with a thin veneer of “real world” associations”

### Whose metaphor?

A second criticism levelled at the use of everyday mathematics contexts concerns the extent to which children can actually identify with contexts which are extracted from the adult world. Students may *engage* in tasks which require them to consider wage slips and household bills, which may be a worthwhile goal in its own right; the tasks are however a lot more “real” to the adults who teach them. Such activities take on the status of another mathematical exercise and do not really allow students to appreciate the reality of the task or to perceive Broomes’ “bridge” between the mathematics of the classroom and its role in society [Broomes, 1989]. Contexts are often used in an attempt to motivate and stimulate students while often they only act as distracters or even barriers to understanding. William [1990] considers the use of a chess game in providing a context for an investigation and suggests that a context like chess may attempt to capitalise upon scripts which a student does not have, thus presenting a barrier to understanding rather than the intended bridge.

A constructivist perspective suggests that no one task context can offer a universal application which is familiar and, more importantly meaningful, for all students. William [1988] pursues this point by suggesting that the intended mathematical task is often very different from that received; he goes on to suggest “open beginningness” as a means to personal familiarity. In this approach activities start with a context but are open enough for students then to follow their own directions. In this way students attain personal meaning, not only from their own development of the context but from their own methods of application. Discussion and negotiation of open activities also allow students to extend and apply methods to contexts of their own. These suggestions recognise the limitations of theo-

ries which assert the use of contexts on the grounds of their general familiarity; contexts cannot be assumed to offer *unique* meaning and theories which promote the use of contexts should also take on board the range and complexity of individual experience and interpretation.

It is probably safe to assume that transfer is not enhanced by contexts unfamiliar to students, nor by contexts which are perceived by students as another sort of school mathematics. It also seems likely that an activity which engages a student and enables her to attain some personal meaning *will* enhance transfer to the extent that it allows deeper understanding of the mathematics involved. This is why I believe Lave's dismissal of contexts as an aid to the transfer of understanding is short-sighted. For if an activity that enhances a deeper mathematical understanding can lead to transfer, then this transfer must at times be enhanced by the context of the task. At other times an activity may allow the personal development of meaning in some other way, for example by requiring the students to determine their own routes through the task. Meaning is unlikely to be achieved through the sort of use of context demonstrated by the question below:

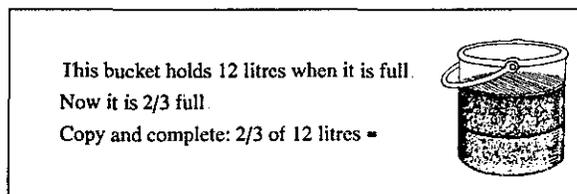


Figure 2

Lave [1988] states that shopping examples in mathematics lessons are treated by students as having “no substantive significance” and only serve to disguise mathematical relations. Tasks similar to the one shown in Figure 2 are now common for all students, at least in the UK, and I believe these activities offer a view of context that substantiates Lave's claims. In these questions students are not asked to discover, use, challenge, or discuss a “real world” example, they are expected to generalise somehow from an atomised presentation of content and copy the procedure in a real situation.

I believe that learning in context does go some way toward enhancing transfer, but not through the replication of situations to be faced in “real life”. Considering the infinite number of variables offered by real life problems it seems unlikely that classroom activities can replicate the range of real life demands. What is important is the appreciation and understanding of the potential generalisability of what is learned and the resemblances to future problems. This appreciation can only come from an examination and reflection of the underlying structures and *processes* which connect experiences. This to me is the important issue which pervades the discussions of context. If students are failing to transfer across contexts because they are unable to generalise from their learning then their initial learning did not induce perceptions of underlying connections. Contexts can encourage these perceptions, but

only through a stimulation of interest in the mathematical idea, or the generation of discussion and negotiation of the activity and its underlying structure.

This ties in with the ideas about the nature of mathematics which seem to be being offered by much of the research into learning in context. Fasheh said that mathematics became more meaningful through discussing school absentee rates, but in analysing the success of his example he cites the opportunity to interpret facts and to demonstrate the many interpretations and explanations of the mathematics. This analysis seems to say more about the nature of mathematical activity than it does about the particular context. The realisation that there can be more than one answer, that mathematics can involve discussion, negotiation, and interpretation, seems to be critical to the success of the example. Many of the reasons given for the use of contexts in learning depend upon a certain view of mathematics. It is suggested that contexts encourage students to discover, “explore”, “negotiate”, “discuss”, “understand”, and “use” mathematics, but these activities are not intrinsically related to the use of contexts; they seem to be related more to a process-based view of mathematics. I would assert that contexts can, importantly, motivate students, engage their interests, and combat underachievement, but they will only enhance learning transfer to the extent that they make mathematics more meaningful to the individual.

Probably the most interesting and influential research in the exploration of activities which enhance the attainment of personal meaning has emanated from considerations of mathematics and culture. Researchers in this field suggest that individuals fail to utilise school-learned procedures because they are not encouraged to relate school experiences to life outside school: “school children recognise that school mathematics is not a part of the world outside school, the world most important to most people” [Maier, 1991; p 63]. This research suggests that individual meaning will be achieved not through the presentation of “real world” contexts but through the recognition of students' own cultural values in the mathematics classroom.

### Mathematics and culture

A number of researchers have considered the mathematics which is commonly used in “real life” situations and which may usefully be brought into the mathematics classroom for discussion and exploration. Maier has suggested that mathematical methods are used by a wide cross section of people in society whilst D'Ambrosio has drawn attention to the different types of mathematical activity shared by more specialized subgroups of society, such as weavers and carpenters. In 1980 Maier put forward the concept of “folk mathematics” as the mathematics that “folks do” in their everyday lives. An example related by Maier [1991] typifies the procedures described in this area of research and involves somebody calculating 85% of 26: “10 per cent of 26 is 2.6, and half of that is 1.3, he said. So that's 3.9 and 3.9 from 26 is—let's see 4 from 26 is 22—22.1 is 85 per cent of 26.” [1991, p.64]. Mellin-Olsen [1987] refers to folk mathematics in children's games involving gambling, buying, and selling, and in adult's work involving

building and design. Other studies have compared performance on test situations with: working arithmetic in a dairy [Scribner, 1984]; an open-air produce market [Carragher, Carragher and Schliemann, 1982] and junior school children's everyday methods [Herndon, 1971]. All of these studies confirmed a discontinuity both in mathematical procedures and in performance between settings.

D'Ambrosio [1985] distinguishes between "academic" mathematics and "ethnomathematics", using the prefix "ethno" broadly to cover the mathematics used by all culturally identifiable groups and individuals with their "jargons, codes, symbols, myths and even specific ways of reasoning and inferring" [1991, p.18]. Academic mathematics, by contrast, is the mathematics which is learned in institutions like schools and colleges. D'Ambrosio and Maier both suggest that if students discuss their own "ethnomathematics" in the classroom then the problems of transfer and the distance between students' perceptions of "school" and "real" mathematics will be reduced.

It is, I feel, necessary to divide D'Ambrosio's ethnomathematics into two strands for comparison. Ethnomathematics is most often quoted for its "cultural" affiliations, to refer to the mathematics generated by a particular cultural group. This, to me, obscures the essential aspect of ethnomathematics, the fact that it is generated by the particular individuals who use it. Ethnomathematics, according to D'Ambrosio's definition, is the mathematics used by individuals or groups who are outside academic institutions; as such it may be associated with local community groups and in D'Ambrosio's home country of Brazil this involves culturally and mathematically rich activities like basket weaving and market trading. These examples are now so commonly cited as typical of "ethnomathematics" that, for many, they have *become* ethnomathematics. This mathematics is also, by its nature, individually generated, but the status acquired by the examples has often hidden this and provided an opportunity to critics of ethnomathematics. Langdon, for example, writes that "if we recognise that many, perhaps the majority of, artisans who create the baskets of the boats are operating in an *instrumental* way, we can see a danger in assuming too much about the existence of ethnomathematics within a culture" [1989, p.179]. Langdon suggests that students acquire a better understanding of mathematics by discovering that it is already a part of their environment than by studying local cultural examples. He assumes that learning ethnomathematics is synonymous with learning the mathematics used by a specific cultural group, though D'Ambrosio's assertions do not seem to require this. D'Ambrosio emphasises the importance of students' coping mechanisms, the way that individuals manage situations in life. He is surely referring to the social and cultural environment in which all mechanisms are based for all individuals. Unfortunately it seems that mathematics educators' acceptance of ethnomathematics in the classroom has taken a restricted view of culture and of cultural mathematics and therefore of its relevance for all students.

Abraham and Bibby [1988] assert that the great insight of ethnomathematics is its acknowledgements of the indi-

vidual and group generation of mathematical problems. I believe that in his use of the term ethnomathematics, D'Ambrosio is referring to an individually-generated mathematics which may have derived from cultural groups, not a mathematics used by cultural groups which may also be individually generated. I believe that this distinction is important if ethnomathematics is to be given a central role in curriculum that bridges the gaps between school and the real world.

Two concerns are raised by the consideration of folk or ethno mathematics. The first acknowledges that the mathematics classroom is itself a place of values with its own cultural perspectives. The second acknowledges that the "cultural" solutions to problems offered by students in the real world are also mathematical. Thus, mathematics is a part of students' social and cultural lives, and the mathematics classroom has its own social and cultural life.

Both concerns can be acknowledged by the use of ethnomathematics in the classroom. My perspective is similar to that offered by Wiliam and by Fasheh, who both suggest that if students are encouraged to use their own methods and explore their usefulness, general mathematical understanding will be deepened. Ethnomathematics in this light is not an influx of new content or context in the curriculum, rather a different perspective and starting point. The essence of this approach is that through discussion and analysis of individually-generated methods there is a development of awareness of all the mathematics that is meaningful in specific and general situations. Ethnomathematics is not the replacement of school methods by those that are individually generated, but schools must at least acknowledge the latter and consider why they are used when the former are not. In doing so the elegance of school-taught algorithms may come to be appreciated as well as their underlying structure—why they work and how they may work as usefully as students own folk or ethno mathematics. This must encourage connections between the mathematics of the classroom and the mathematics of the real world, and in forging these connections make the usefulness of both transferable.

## Conclusion

Consideration of the context of a task, activity, or example seems to show that students do not perceive school mathematics tasks as "real" merely because they have been given real world "vener" [Maier, 1991], yet their mathematical procedures and performance are largely determined by context. This suggests that students interact with the context of a task in many different and unexpected ways and that this interaction is, by its nature, individual. Students are *constructing* their own meaning in different situations and it is wrong to assume their general familiarity with or general understanding of the context. This acknowledgement does not preclude the use of contexts, but suggests that a consideration of the individual nature of students' learning should precede decisions about the nature and variety of contexts to be used.

Burton [1989] suggests that problem solving can enhance discovery and active learning, but that personal

meaning is only attributed when students are able to determine the direction of activities. Activities must be genuinely open and allow students to move in the directions appropriate to their perception of the problem. William [1988] says that if students are able to make problems their own in this way, their learning, by virtue of its possession of meaning, will be available for use in real life problems.

Freedom to take their own direction does not mean that students have to decide their own context or problem; the process is more subtle than that. Thus whilst the start of an activity may have a specific context, the development of the activity must enable students to follow routes which are their own. Problems and investigations which are open can connect with a student's meaning and allow the attainment of personal goals; problems and investigations which are structured, by contrast, can only demonstrate methods which are essentially impersonal.

Students will transfer from one task to another, even when the external cues are different, when they have developed an understanding of the underlying processes which link the problem requirements and their significance in relation to each other. School mathematics remains school mathematics for students when they are not encouraged to analyse mathematical situations and understand which aspects are central.

Links between school mathematics and the real world will not be demonstrated by perfectly-phrased questions involving buses and cans or paint. These misleadingly suggest that similar problems with a comparable simplicity exist in the real world, rather than arising out of the learner's interaction with the environment. If the students' social and cultural values are encouraged and supported in the mathematics classroom, through the use of contexts or through an acknowledgement of personal routes and directions, then their learning will have more meaning for them. Their social, cultural, personal, "folk" or "ethno" mathematics will be given enhanced mathematical recognition in a social setting, and this in turn will enable connections to be made with the mathematics of the classroom which may make this more meaningful when students are faced with the demands of the "real world".

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