Authentic Artefacts: Influencing Practice and Supporting Problem Solving in the Mathematics classroom

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Authentic artefacts (including brochures, menus, bus timetables and photographs) provide opportunities for students to develop skills in knowing when and how to use mathematical knowledge for representing and solving problems in both practical and realistic situations. This paper examines the influence artefacts can have on Grade 5 children's capacity to make sense of scenarios by applying personal knowledge and experiences to the problem context. In this investigation the children routinely modified the problem when they felt that the context was problematic or not realistic. Moreover, the participants revised or extended the problem in ways that made the task considerably more sophisticated and more closely aligned to their perception of authenticity.

One way to provide children with the opportunity to engage in more diverse and flexible thinking is to encourage them to engage in problem-solving situations that are open-ended in nature. Another approach is to create learning contexts that require students to make connections between their social and personal lives and the mathematics they encounter. Wenger (1998, p. 270), for example, argued that learning is enhanced when students develop a "thirst for learning of the kind that engages one's identity on a meaningful trajectory and affords some ownership of meaning". In order to establish such ownership, teachers often attempt to design problem-solving contexts that relate to real-life situations.

It seems to be the case, however, that students do not intuitively use real-life knowledge or evoke realistic scenarios to contextualise problems—irrespective of how "authentic" they may be. There is a view that children construct a set of beliefs and assumptions about problem solving (often developed by solving routine word problems that simply require the execution of one or more of the four arithmetic operations) that actually reduces the likelihood of connections to realistic contexts. Bonotto (2002) indicated that this only can change if there is a transformation in the teacher conceptions, beliefs and attitudes towards mathematics in ways that alter the culture of the classroom.

It is certainly the case that bringing student's naturalistic out-of-school experiences into more traditional settings has positive effects on problem solving (Clancy & Lowrie, 2002). Affective dimensions of the process, including motivation and task persistence, are more likely to be enhanced in authentic situations. Bonotto (2002) argued that conditions that make out-of-school learning more effective must be recreated in classroom activities by "creating classroom situations that promote learning processes closer to those arising from out-of-school mathematics processes" (p. 3). De Corte, Verschaffel and Greer (2000) maintained that in order for students to make meaningful connections between problem solving and real-life contexts they need to be immersed in innovative learning environments that are radically different to traditional classroom practices. They proposed that tasks should be well structured, diverse and authentic. Authentic tasks reflect the nature of real problems because they are complex, ill-structured, contain multiple perspectives and offer multiple pathways or solutions (Young, 1993).

Authentic tasks provide opportunities for students to develop skills in knowing when and how to use mathematical knowledge for representing and solving problems in both practical and realistic situations. Lesh and Harel (2003), for example, maintained that the kind of problem-solving that should be emphasised in classroom contexts are simulations of real-life experiences where mathematical thinking is useful in the everyday lives of the student or their family and friends.

The connections between students' everyday and classroom mathematics, however, are not always accessible because their personal contexts differ significantly (Lave, 1988; Lowrie & Clancy, 2003). The challenge for teachers is to establish a learning environment that encourages students to personalise learning in ways that allow individuals to extend, adapt, revise and adopt mathematical ideas to a context that they can place themselves within.

Establishing Authenticity through Cultural Artefacts

Bonotto (2002) proposed that classroom-based activities that aim to create connections between reality and mathematics should be founded on the use of concrete materials. In the present study, these *cultural artefacts* included brochures, menus, bus timetables and photographs. Such artefacts were relevant to the children because they allowed them to make connections to real-life experiences, offered significant reference to concrete situations, allowed them to keep their reasoning processes meaningful (Bonotto, 2002) and enhanced their capacity to think metacognitively (Lowrie & Clancy, 2003).

Several educators (including Kaput, 1994; van Oers, 1996) have noted that it is not the artefact (or tool) in isolation that offers support to the teacher—rather the students use of the tool and the meanings they have developed as a result of the activity. In a similar vein, Saxe (2002) maintained that "artefacts take on mathematical meaning only in activity, as individuals organise them as a means to accomplish particular mathematical goals" (p. 290). The capacity of the problem solver to make mathematical meaning of an artefact involves perceptual or schematic processes, where objects that are not inherently mathematical become organised as such in a purposeful activity. Consequently, it could be argued that the more authentic the artefact is, the more likely such engagement will take place.

Bennett, Harper and Hedberg (2002) commented that the quality and nature of authenticity of an artefact will depend on a) the level of sensory fidelity in task representation so that practical skills may be developed, b) the extent to which critical thinking or problem solving can be enhanced, and c) the potential for social interaction and engagement. In the present study, these three elements were considered to ensure that the richness and authenticity of the artefact could be mapped against any changes in the classroom culture.

This study examines the influence the cultural artefacts had on the participants' problematisation of the problem scenario and the way in which they accessed out-of-school experiences to interpret and subsequently apply knowledge to the problem context. Furthermore, this investigation looks at the extent to which the children's different personal contexts influenced mathematics in the classroom.

Development of the Authentic Problem-Solving Environment

Participants

This entire investigation involved 28 Grade 5 children (aged 11 or 12) from a small primary school in a large regional city in New South Wales (Australia). Although the children had limited experience in solving open-ended investigations, it was apparent that many of the participants possessed quite flexible problem-solving skills. Since the investigations were relatively novel, there did not seem to be any “hidden” beliefs concerning the manner in which tasks needed to be solved. Thus, the problem solvers tended to approach the tasks with realistic intentions and were readily able to place themselves into the problem context. This investigation explores the manner in which two children completed the respective tasks. Each of the participants had actually visited one of the two theme parks identified for examination.

The Problem-Solving Tasks

Three open-ended tasks were constructed for the investigation (the participants completed two of the three activities over a three week period). Each task required the problem solver to consider a scenario associated with the planning of a family excursion to a theme park (amusement park with thrill rides and other attractions). One task required the documentation of the amount of money (formulating a budget) that a family would spend at a theme park, the second required the construction of a timetable which identified what a family would do at particular time intervals during the day, while the third task required the students to plan the day by locating rides and attractions and subsequently indicating a sequence of events. Although a broad range of content knowledge and sense making was required to complete the tasks, the first task targeted number sense, the second measurement sense and the third spatial sense. With each task, the problem solver was given a problem scenario, relevant pamphlet (including restaurant menus), and theme park map (see Figure 1 for an example). A range of visual literacies (Clancy & Lowrie, 2002) and information graphics (Harris, 1996) were required to make sense of the respective maps and to problematise the scenario. These realistic resources provided more information than was actually required for the problem solver to complete the tasks but certainly added to its authenticity.

Figure 1. Using cultural artefacts to complete the authentic task.

The participants were randomly assigned one of three tasks. The scenarios were read aloud, with the children given opportunities to ask questions if they did not understand any of the intended outcomes. Support was also provided during problem solving if requested—in order to ensure that the children fully understood the context of the problem. As the children completed the task the researchers made anecdotal observations and audio-taped conversations that arose as questions were posed. Three weeks after completing the first activity the process was repeated with the children choosing one of the two remaining problem-solving tasks to solve.

After completing each activity the participants (all 28 participants) were interviewed (in small focus groups) for approximately 40 minutes in an attempt to encourage them to reflect upon the way they represented the problem and the strategies they used in order to complete the respective problem. The present study presents additional interview data that were collected from two case study participants after completing the second task. These two children were interviewed (on an individual basis) for an additional forty minutes. These children were selected for further analysis because they had both visited one of the two theme parks used to establish the authentic contexts.

Sense Making within the Authentic Context

This section summarises the way in which two students represented and approached the respective tasks. In particular, the data were examined in relation to the extent to which the students modified and adapted the activity to ensure it was "personally" authentic. These children frequently used the park map (and particularly the tables and other graphical information) to solve the problem. Their mathematics sense making was formulated from a desire to create an authentic setting. Furthermore, their problem-solving approaches were strongly influenced by previous "theme park experiences" with out-of-school knowledge influential from both sense making and process perspectives.

Nevertheless, the children did not feel that it was necessarily advantageous to have previously visited one of the three theme parks. Jacob, for example, maintained that some knowledge of the surroundings was beneficial however he found it easier to interpret the map of the park he had not visited.

> Int: Did you think this map, represents the theme park [you have visited] in a realistic way?
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> Jacob: I liked the map, but I think that having been there was more useful. Oh and the map was too because um, a few of the things, like double screamer I had no idea what that was about because it was closed when we were there.
>
> Int: Do you think you would have found this task easier than this one [pointing to the appropriate artefact] because you had been there before?
>
> Jacob: I thought I would have found that one easier [the theme park previously visited], but for some reason I found this one easier. I think it's because it was all new to me and…this one has got more stuff in it, like what it looks like. Being there helps a lot but, I haven't been to Dream World but the map helped enough in that task.

He was obviously motivated by the activity and was able to use many of the "graphical cues" embedded in the map to establish mathematical meaning. Jacob's capacity to make connections between the 2D-3D representations were enhanced by a number of affective dimensions; namely his task persistence, attitude toward the task and self confidence. Jacob indicated that this task was quite different to any mathematics-related activities he had experienced at school. Interestingly, he expressed surprise when told that he had actually completed a mathematics-based activity. Although he was able to make some quite sophisticated connections between spatial and measurement understandings during the investigation, Jacob could not identify any mathematics lessons that helped him successfully complete the problems. By contrast, Matt was able to recollect some activities when commenting that "we had done a bit of maths work on maps before… I remember a bit about the key and, you can match them up, like M8 there. That's about it."

The participants were willing to modify the actual question when they felt that it did not represent a "real" scenario. In the following transcript Jacob was concerned that the timetables were not realistic because they were required to factor in a ten minute transition between rides (set in the initial problem scenario). Interestingly, sequences of ten minutes (between rides), twenty minutes (morning tea) and forty minutes (lunch) were presented so that the children could sequence itineraries within hourly timeslots.

> Int: When were you at Wet-and-Wild was it a long time ago?
>
> Jacob: No I only went there last year….
>
> Int: You may have actually got this map then?
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> Jacob: I knew which rides I liked better, and I remember it was very confusing that, this ride is on for half an hour and this one is on the next half hour, and it was really hard because this one had already been on and then when you wanted to go on the other it had already been on…too
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> Int: So it was hard to get the timing right?
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> Jacob: [agrees] And I couldn't remember all the rides, like first of all I looked at this and I couldn't remember what it was, but then I remembered…you go around in a tube. And…I couldn't remember what this was, and I didn't think I had been on it, but then I remembered that you walk up in this thing and then you've got all the names of the rides you can go down… So it helps because I have been there…

Jacob continually modified the problem context in order to preserve the authenticity of the task. He appreciated that some rides take longer than others and consequently modified his solution to represent more realistic timeframes. On occasions, however, he found it problematic to marry his knowledge of the actual context with some of the information presented in the school-based task. One of the challenges in creating such problem-solving situations is to balance the realism with the information necessary to help scaffold learning. The more open-ended the task the more opportunity the participants have of personalising the problem.

Although such reasoning would make the task more difficult to solve, both children modified the problem to ensure that it was realistic. Moreover, there was evidence to suggest that the students modified and adapted the task to make it more personally authentic. Jacob, for example, elected not to include rides that he knew were presently being renovated. In other words, the children moved beyond establishing an authentic context to formulating a solution that was both realistic and meaningful to their experiences. The personal authenticity created an exciting learning environment that offered the children multiple pathways or solutions that were radically different to their traditional classroom practice.

> Int: What are some of the things that really stood out, that were critically important for you to try and work out what to do?
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> Jacob: The closest things around the entrance…probably from this ride then to this ride and so on…I thought well, first of all I wanted to see where all the rides were, so I went on the helicopter first, and then I went over to the rides that were closest that I liked, then I went on some of the other rides that I didn't like them, but I went on the ones that I liked better first.
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> Int: What else did the helicopter allow you to do?
>
> Jacob: You could see where all the people were if there was a big crowd there and you liked that ride and one over there, you can go to the other ride first until the crowds die down.

The concrete artefacts (brochures and menus) required to complete the problem within this context also encouraged the children to make connections to real-life experiences. The children certainly appreciated having the actual brochure rather than some form of replicated artefact. Matthew commented that it would be difficult to navigate his way through the problem and "visualise" the environment without such detail.

Int: What are some of the strategies you need to know when you are going to a theme park?

Matt: [I] look at the signs and follow the paths and things like that…You can watch where people are going and you can work out that that must be a good ride, and there are a few other strategies like, if you go up a path, you have to try and stay on a budget like when you go to a ride…when it's a fake map, you can't really feel it being there and its hard to visualise how that is actually happening it make the activity twice as hard to do.

Int: What things would be disappointing for you if they weren't there?

Matt: Well I think it would be less fun to do because all the pictures, and you can see the people enjoying themselves there. And you can actually see the rides going. Like that's like a type of action sort of a thing there where it is going around…if it wasn't there…it's a bit hard to understand.

The importance of using artefacts with absolute authenticity not only allowed the students to make sense of a range of spatial concepts it also established a strong motivational intention for the respective activities.

Interestingly, the participants accessed and interpreted visual, spatial and graphical information from the artefacts that were "outside" the scope of the activity. Although the students did not need this information to "solve" the problem, most participants openly used such information to modify and adapt the problem scenario. Moreover, the students accessed important personal knowledge, such as prices going up over Christmas and extended hours over summer, despite the fact that there was no evidence of this on the artefacts supplied. The problematising that occurred not only showed that the students have multiple perspectives and offer multiple pathways or solutions, it also provided the children with the opportunity to create connections between reality and mathematics.

Int: How do you think having this [the artefact] changed the maths activity?

Jacob: I didn't even realise it was maths actually, because it was very fun to do, and I like all the little pictures, and with the people, you can actually see what the ride does, better than like just having the name, because you'd have no idea if it was a ride or a show. With the little person on the tube, it tells you that you can or it shows you that you let children go around.

The notion that it could not be mathematics because it was enjoyable was certainly a common theme throughout the class. Nevertheless, the children extended, adapted and revised mathematical ideas within a personalised context. Rather than fashioning situations that allowed them to easily derive solutions, the children engaged in processes with a level of sophistication beyond that usually encountered in the classroom.

The authentic nature of these artefacts evoked several forms of imagery identified by Presmeg (1986); including concrete imagery, pictorial imagery, dynamic imagery and kinaesthetic imagery. Of particular significance was the extent to which students utilised dynamic imagery (a very powerful form of imagery infrequently utilised by children in Presmeg's observations) to move within the environment represented through the artefacts. The children immersed themselves into the problem scenarios—imagining they were actually at the theme park, gaining a sense of the park's size, the position of attraction, the distance between rides and the actual height of the rides.

Int: You indicated that you tried to visualise what was happening. Can you explain that to me?

Matt: Okay well what I reckon visualising is, you go in there and you think of what would be happening and um, you visualise what's going to happen, because you can see some people going down it, and they are looking at it, and you can actually see what's going to happen…I reckon you can nearly feel it. Especially it was a real hot day when we were doing it.

Int: That's right….I think is was 40 degrees or close to it?

Matt: I think you might be right, it was stinking…

Int: Did you actually try and put yourself in there, in that picture?

Matt: Well seeing how you've got a bird's eye view you can get a pretty good picture of where you are going and…you can see from a bird's eye view you can see the whole thing…the ride near the pool is really high…I was pretty young then, and at the time Mum didn't let me go on it.

Interestingly, the children also used kinaesthetic imagery whilst solving the problems. Both Jacob and Matt (and some of the children who had never visited a theme park) reported feeling their stomach's rumble when they thought about the possibility of going on a "thrilling" ride.

Conclusions

The artefacts described in this study influenced the children's approaches to solving problems. The participants made connections to real-life experiences, offered significant reference to concrete situations, kept their reasoning processes meaningful (Bonotto, 2002) and deeply reflected on the activity (Lowrie & Clancy, 2003). A diverse range of numeracy understandings were accessed and applied to the problem scenario—many from specific out-of-school experiences shaped problem solutions in powerful ways.

It was evident that the students were readily able to make sense of situations by applying personal knowledge and experiences to the problem context. They were willing to modify or reconstruct the problem when they felt that the context was not realistic or practical. Importantly, they revised or extended the problem in ways that made the task considerably more sophisticated and more closely mirrored their perception of authenticity.

The two case study participants (and most of the children in the class) commented that the activity bore no resemblance to the type of mathematical activities they were accustomed to solving in their "regular" classroom environment. De Corte, Verschaffel and Greer (2000) suggested that meaningful connections between problem solving and real-life contexts were more likely to happen in such radically-different situations. One of the most rewarding aspects of the investigation centred on the enthusiasm the students displayed and the enjoyment they shared in discussing their problem-solving approaches and making sense of mathematics in relatively novel situations.

The cultural artefacts provided an opportunity for all of the participants to engage in a problem scenario that was contextually meaningful. All students established their own sense of authenticity by aligning the problem to their personal experiences and understandings. This personal authenticity was established because the artefact was legitimate, convincing and completely authentic. Often the problem modification was strongly influenced by personal experiences that were rarely considered in "typical" problem-solving activities in this classroom.

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