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“It was all led by them”: opening up opportunities for making mathematics through a children’s exhibition

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The *Mathematics in the Making (MiMa)* project drew on Pestalozzi's model of learning - from *hand* to *heart* to *head* - and that of Bruner in which understanding develops from the *enactive* to the *iconic* and thence to the *symbolic*. It also recognised that learning is fundamentally social and that worthwhile learning is democratic. The *MiMa* partners produced practical activities for 8 to 10 year olds. Participating teachers experienced the activities themselves before running ‘laboratories’ with their children. Throughout, the teachers and children knew that they were preparing their objects and activities for public exhibition. We describe the exhibition in Sheffield and draw on our own reflections and those of participating teachers to argue that *MiMa* gave the children an opportunity to exercise responsibility and autonomy with respect to their own mathematics and that this led to many, particularly those previously low attaining, becoming successful and more confident learners.

Keywords: hands-on activities; responsibility; communication

Introduction

The *Mathematics in the Making (MiMa)* (<http://www.mathematicsinthemaking.eu>) project upon which this paper draws was funded through the European Union (EU) and was based on a primary school mathematics intervention carried out in five EU countries - England, Germany, Hungary, Italy and Portugal. (The partners were Università degli Studi di Perugia, P3 Poliedra Progetti in Partenariato, Eotvos Lorand University, Mathematikum, Universidade Nova de Lisboa and Sheffield Hallam University.). Fundamental to the project was the conviction that concrete, hands-on practical experience of mathematical objects and the opportunity to discuss the artefacts created enhances mathematical learning. Also central was the awareness that for many children mathematics is experienced as hard, separated and abstract, as a subject of fear and anxiety, without meaning and one only accessible to a few. And it was acknowledged that the problems that students of all ages have in learning mathematics are widespread (Organisation for Economic Co-operation and Development 2009). Thus the aims of the project were:

- to help primary school students develop a stronger interest and competence in mathematics;
- to enhance their social and civic skills, so contributing to an increase in students' chances of success, both in school and in life; and
- to achieve a higher self-confidence and thus an increased possibility of continuing to study mathematics in the future. (MiMa, 2015a)

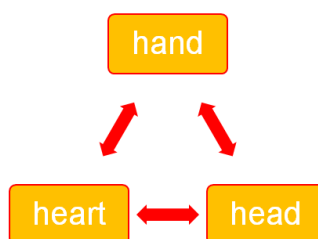
The *MiMa* partners produced ten sets of practical activities designed with eight to ten year olds in mind (MiMa, 2015b). These were introduced to the project

teachers who themselves experienced and worked on the activities before running ‘laboratories’ in their classrooms with their children. Throughout, the teachers and children knew that they were preparing their objects and activities for public exhibition. In later sections of the paper, we describe the exhibition in Sheffield and draw on our own reflections and those of participating teachers to explore the opportunities for learning to which the exhibition gave rise. We make use of ideas of responsibility and autonomy to analyse what we observed.

We now consider the theoretical approach to learning embraced by the *MiMa* project and the principles on which the development of the materials was based. The next two sections draw extensively on chapter one of the final project publication: *MiMa: The Project* (MiMa, 2105a).

The approach to learning

The approach taken in the MiMa project to the learning of mathematics drew on the ideas of the Swiss educationalist, Johann Heinrich Pestalozzi (1801), who proposed that learning should be from *hand* to *heart* to *head*. He argued that knowledge is gained sustainably by providing first hands-on-activities in order to ground understanding. Such activity fosters joy and motivation, so that the new experiences enter the heart. In this way the new knowledge finally finds its way into the brain of the learning child. Learning from the senses was central to Pestalozzi who believed that such learning is morally sound and enriching and also useful and instructive for life. He valued group learning which is both self-paced and hands-on, with children working together and supporting each other’s learning. The *MiMa* methodology grew out of and supports such ways of working. In the *MiMa* project, we came to see these three - *hand*, *heart* and *head* - as always available rather than fundamentally sequential and as interconnected.



We can see all three at work in the children’s exhibition that is the focus of this paper.

The project also drew on the work of Jerome Bruner (1966) who advocates teaching that recognises three steps which mirror the development of understanding: from an *enactive* level to an *iconic* level to a *symbolic* level. Hands-on activities provide this first step of an enactive approach to new knowledge or new capabilities: children experience the concrete in order to understand. Sufficient practical experience enables the child to move to an iconic (pictorial, graphical, representational) level, reflecting on the experiences of the concrete and beginning to abstract from them. Both these stages are essential to enable the final stage in which children can act at the symbolic level, creating, understanding and using systems of symbols. To deepen or scrutinize their knowledge, or to resolve uncertainties, children can go back to their first hands-on activities for help. These remain as metaphors in the mind to support symbolic thinking. The *MiMa* hands-on activities enable children to comprehend mathematics with their hands and to build reliable

knowledge for contemporaneous and subsequent iconic and symbolic mathematical thinking.

Finally, we drew on Lev Vygotsky's theories that stress the fundamental role of social interaction in the development of cognition as children and their partners co-construct knowledge (1962; 1978).

The principles on which the materials were based

In designing the curriculum materials and in planning the children's exhibitions, a number of interconnected themes and principles were borne in mind. The first was that the learning should be **democratic**. Following John Dewey (1949), the *MiMa* activities were designed to support active, experimental engagement in enquiry based learning with the children developing and organising the activities, being actors not spectators in their own learning. The children were to make both things and knowledge, to see themselves not simply as passive receivers of knowledge but as actively making it their own (Povey & Burton, 2004) and sharing it with others. Knowledge itself is shaped by the way in which it is acquired: with democratic learning, the children can develop a sense of epistemological authority, building self-esteem and a sense of self-worth.

Second, the materials should embrace a commitment to **attainment for all**. This was to be enabled by an emphasis on **learning together**. We wanted materials which

- promoted appropriate practical classroom arrangements that supported group work;
- provided group-worthy tasks that warranted talk; and
- emphasised sensitivity, trust, inclusion and mutual respect between the members of the group.

The *MiMa* activities were to offer extended time and space for the children to work together (including interacting with other people during the final exhibition), building in this way a social learning environment.

Lastly, we wanted the *MiMa* materials to open up space for **dialogic learning** (Alexander, 2008). In particular, they were to promote learning which is *collective*, with the children working on common tasks together; *reciprocal*, with the students listening to each other's ideas and exploring alternative points of view; and *supportive*, with the students feeling free to express their ideas without being worried about being wrong, working together to achieve shared understandings.

The exhibition

Over 150 children and 20 adults from five primary schools in South Yorkshire participated in the exhibition which took place in the Winter Gardens, a public venue, in the centre of Sheffield. The exhibition was an overwhelming success with the children talking about, explaining and doing mathematics with a group of distinguished guests, friends, family and the general public; they also shared their mathematics with each other. The children impressed the visitors through their energy, their talk about the mathematics and the sense of fun in what they had been doing.

The work displayed incorporated different aspects of the mathematics activities and included technology as the children from one school had designed mathematics trails around the school using ipads. All schools included activities for visitors to try including playing games the children had devised, paper folding,

creating tiling patterns and solving logic mazes with some schools bringing along floor size versions.



Data collection

Teachers who took part in the *MiMa* project in England were invited to participate in a small-scale study of the experience. Semi-structured telephone interviews were conducted with four teachers at the end of the project. Interviews were transcribed and analysed thematically. Teachers were asked about the professional learning they experienced through the *MiMa* project, about the experience of *MiMa* in school and about the exhibition.

Findings

All of the teachers interviewed noted the significance of the exhibition for the children's learning. We discuss themes emerging from the data below. (The school names are pseudonyms.)

Responsibility and autonomy

The opportunity for children to take responsibility and act with autonomy emerged as a theme throughout the data, particularly in relation to the exhibition. Preparation and participation in the exhibition at one school was led by the children: they considered what might attract members of the public to the exhibition, decided which activities they would exhibit and how best to show them and planned what they would say.

They talked through all of that and they'd even written scripts for themselves, ... they'd actually written questions and prompts ... Planning something, thinking about it and then executing it, and adjusting as you go ... it's something that they'd not really done before, so I think it was a unique opportunity for them. (Teacher, St Edmund's School)

This opportunity for the children to take responsibility was evident in the way they prepared to communicate their mathematics. Children talked through what would attract passers-by to an exhibition and how they would engage them in discussion about the mathematics they had done.

They did some advertising for it, they did flyers for it and posters and they had to write instructions as to how were they going to explain to someone what their activity was (Teacher, Broadriver School).

Success and confidence

With this increased responsibility and autonomy came success and confidence. Some of the teachers noted how the activities enabled the children to succeed in a way they were not expecting. One teacher described how a child had engaged in the *Many colourful triangles* activity (MiMa, 2015b):

[She is] working at a level three in her maths when she's in a class of children who are all working at level five and six, for her the self esteem that she got from that was amazing and meant that she was sitting with the most gifted mathematician in the class going "Well, if you try it this way you'll see it works better and then if you do this bit next you'll see that works better", and that was lovely to watch and see.

It enabled them to excel in a way that you don't always see in a more traditional sort of teaching environment. (Teacher, St Edmund's School)

In contrast to usual practice, children in this school had been working in all-attainment groups for the *MiMa* activities; this practice together with the focus and design of the activities provided new opportunities for children to experience success. They were able to build on this success as they developed the classroom activities for the exhibition:

They gained a confidence that they hadn't had before, and having positive feedback ... about their vocabulary and the way that they explained ... was really positive for them. (Teacher, St Edmund's School)

Community

Although in several of the participating schools only one class worked on the *MiMa* activities, the project permeated the whole school. In addition to sharing their work in assemblies and school exhibitions, children set up activities for other classes to engage in, such as a school maths trail or a playground logic maze (see MiMa, 2015b). The culmination of their work, the final exhibition at Sheffield's Winter Gardens, expanded their sense of being part of a wider community.

They enjoyed the fact that they were part of something bigger than their school. (Teacher, Bluefields School)

They liked the idea that they were going to share what they'd done with the general public, that it wasn't just something that we'd been doing with school, we can go and show this and we can look at what other schools have done. (Teacher, Broadriver School)

Children appreciated seeing how others had tackled the same activities and 'enjoyed looking at what the other schools had done...going round the other tables and listening to the other children and then explaining what they'd done to others' (Teacher, High Close School).

Concluding comments

Communication is an important feature of all the above themes. Throughout their engagement in *MiMa*, children were called upon to explain and communicate their mathematics to others, initially to their classmates and teachers, then beyond this to the wider school community as they shared their work with other classes and with parents and carers, and finally to the general public. Knowledge of the public exhibition motivated the children to produce their best work and helped them to see the value in this work.

What was really good ... why they put a lot of effort into what they were doing, they knew [their work] was going to be exhibited at the end. The public were going to see it, their parents were going to see it and that really gave them that push to get on and do it and try their best. (Teacher, Bluefields School)

The exhibition provided the opportunity for an expanded space for dialogue and dialogic teaching, one that moved beyond the boundary of the classroom to encompass the school community, the local community through the Sheffield exhibition and, for some, a European dimension through communication with schools in partner countries. Reciprocity was evident as children visited the exhibition stands of other schools, engaging in activity and dialogue. We reflected on the energy and confidence of the participating children and heard the teachers speak with pride and some surprise of what the children had achieved. The teachers were all planning to build on the experience of the *MiMa* exhibition in the future.

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