Linking School Mathematics to Out-of-school Mathematical Activities

Introduction

This research will investigate ways that secondary school mathematics can be done in a manner similar to how it might be done in out-of-school activities. Making school mathematics relevant to life beyond compulsory education is a central theme in current government sponsored papers and inquiries: the Green Paper[1], the Post-14 Mathematics Inquiry[2] and the Advisory Committee on Mathematics Education[3]. The proposal's aims are:

- to understand the problems in linking school mathematics to out-of-school activities;
- to understand how learning activities can be designed so that links between school mathematics and out-of-school activities are made manifest;
- to understand the role of the teacher and of resources in making these links between school mathematics and out-of-school mathematical activities;
- to understand how learning is affected in contexts which attempt to link school mathematics to out-of-school activities.

The application of school mathematics to everyday and work settings is one of the main rationales for the place of mathematics as a core subject in the National Curriculum: "This fact in itself could be thought to provide a sufficient reason for teaching mathematics" (Cockcroft, 1982, paragraph 1). The importance of learning mathematics in school as a prelude to later application remains an education policy priority.

"Mathematics is important in everyday life, many forms of employment, science and technology, medicine, the economy, the environment and development, and in public decision-making." (National Curriculum Mathematics[4]).

"... to enable students to acquire mathematical knowledge and skills necessary to meet the requirements of employers and further and higher education." (From the Aims of *The Post-14 Mathematics Inquiry*)

There appears to be no recent research which addresses this issue. There is related research focused at the primary school level (ESRC Award number L139251078 on the ways in which primary school children's learning is shaped by interaction with adults) and recently funded ERSC TLRP research on techno-mathematical literacies in the workplace (RES 139-25-0119). There is also a Nuffield funded curriculum development project (AS: Use of Mathematics[5]) for post-compulsory schooling with a focus on making mathematics applicable. The proposal thus addresses an under-researched area.

Most research on the use of mathematics in out-of-school activities shows a strong discontinuity between school and out-of-school mathematical practice. According to the situated cognition paradigm, e.g. Lave (1988), this discontinuity is a consequence of the fact that learning in and out of school are two different social practices. Further to this, school mathematics is often ill-suited to out-of-school practices. In some cases the problems are only apparently similar to school mathematics problems, but in reality there is a range of explicit and implicit restrictions which makes school methods unsuitable, and thus other methods are used (Masingila, Davidenko and Prus-Wisniowska, 1996). In other cases (Scribner, 1984) work mathematics may appear to be simple, but there are no simple algorithms or methods to solve the problem and school-learnt procedures are of no use.

Despite the evident discontinuity between school mathematics and out-of-school practices some authors have observed an interplay between them. Saxe (1991) found evidence that school

[1] 14-19: extending opportunities and raising standards. See http://www.dfes.gov.uk/14-19greenpaper/
[2] See http://www.mathsinquiry.org.uk/
[3] See http://www.royalsoc.ac.uk/acme/
[4] See http://www.nc.uk.net/nc/contents/Ma-home.htm
[5] See http://www.education.man.ac.uk/lta/research/nuffieldas.shtml

mathematics and the mathematics of street children's candy-selling practice in Brazil affect each other. Pozzi, Noss and Hoyles (1998) found cases of nurses looking for a mathematical explanation for the conceptually simple mathematical procedures used in their daily practice. Magajna & Monaghan (2003), in a study of technicians designing moulds for bottles, found evidence that in making sense of their practice the technicians resorted to a form of school mathematics.

These studies suggest that school mathematics can be linked to out-of-school mathematical activities. An assumption underpinning this proposal is that such links are unlikely to arise without learning activities being designed to engender this links. Learning activities cannot be separated from the participants (teachers and students) and resources involved in using them. This proposal thus has simultaneous but distinct foci on tasks[6], resources[7] and participants, teachers and students. Tasks are central to making school mathematics relevant to out-of-school activities (or irrelevant, as the case may be, e.g. *If it takes 3 men 4 days to dig a ditch …*). Fitting a carpet to a room, for example, is not a simple area task, as it is in some school mathematics problems, but may also involve metric/imperial conversions, considerations of matching the pattern and where to place the join. The resources used in a task affect the reasoning carried out in completing the task, for example in computer aided design/manufacture, technicians approximate curves by straight lines and circular arcs, because the software only allows straight lines and circular arcs to be used (Magajna & Monaghan, 2003). Carpet fitters use an electronic device for measuring distance, not a tape measure. ICT is an increasingly important part of employment (see Felstead, Gallie & Green, 2002) and it is expected that 'real-life' school mathematics tasks will make considerable use of ICT. Of the participants, teachers, are central agents in making school mathematics relevant to out of school activities: they direct students activities and students 'privilege' the techniques and resources that are privileged by their teachers (Kendal & Stacey, 2001). Many mathematics teachers, however, do not perceive that there is a problem in the application of mathematics – and if no problem is perceived, then involvement in this proposed project is unlikely to affect their practice. Students are the *raison d'etre* of education. It is imperative that this proposal monitors student learning but the learning outcomes embedded in this proposal concern the application of mathematics and this presents problems in assessing this learning. (These problems are addressed below.)

This research proposal sets out to work with High School mathematics teachers who perceive that there is a problem in making school mathematics applicable in out-of-school settings. The principal applicant will work with these teachers for two years to design, implement and refine learning activities which engender links between school and out-of-school mathematics. The significance of this proposal lies in its potential contribution to the 'Knowledge and Understanding' and 'Learning and Teaching' strands of the *Knowledge, Communication and Learning* theme of the ESRC's *Thematic Priorities*[8].

Research Questions

The research questions are formulated around four interrelated research themes:

1) Tasks What 'real-life'[9] tasks are currently used in school mathematics classes? How can tasks be designed that engender links between school and out-of school mathematics? What is the role of ICT in designing tasks that engender links between school and out-of school mathematics? What tasks engage learners' interests?

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[6] Tasks are explicit directives, e.g. to solve a problem or produce a report. Tasks direct learning activities, the sum total of actions carried out in doing the task.

[7] 'Resources' in this proposal refers to non-human resources. 'Resources' includes 'tools' but may include other materials such as communications.

[8] See http://www.esrc.ac.uk/esrccontent/PublicationsList/ThematicP/themefirst.html

[9] The term 'real-life', applied to tasks, is used because of its common usage in the National Curriculum (see http://www.nc.uk.net/index.html). It is placed in inverted commas when I wish to emphasise that such tasks may be pseudo real-life tasks.

2) Resources What resources are currently used in school mathematics that address out-of-school mathematical problem solving? What resources are used in corresponding out-of-school mathematical problem solving? How does the use of resources in school mathematics aid, or otherwise, in engendering links between school and out-of school mathematics?

3) Teachers Do mathematics teachers perceive there to be a problem in linking school mathematics to out-of school mathematical activities? How do teachers, who perceive that there is a problem, view the problem and what do they do to address the problem: in particular how do they go about designing tasks, selecting resources and what are their motives and how do task design, resource selection and motives change over the course of the project?

4) Students What are students' motives in carrying out real-life tasks? How can learning, in carrying out real-life tasks, be measured? How do teachers (and others) influence student learning in this area?

Methodology

Approach

The approach to this research is interpretive (Romberg, 1992) and interactive (Greeno, 1998) with a focus on activities in a domain of practice. The approach to task design will be informed by the methods of design-based research (Kelly, 2003) which respects the role of the teacher. The research questions on resources and students will be approached in a broadly activity theoretic (Leont'ev, 1978) manner, as this approach takes the tools used in an activity and the motives people have for doing an activity as central features in analysis. These approaches are chosen for practical data collection and analysis purposes and are consistent with each other. Further notes on the approach to task design and on measuring learning are provided below.

Tasks design must be undertaken in collaboration with project teachers because, for teachers to implement innovation meaningfully, "a dialogue needs to be established instead of compliance" (Olson, 1992, p.90). Specific tasks cannot be specified in advance of work with teachers as teachers must feel confident that they are relevant for their students' curricula needs. The initial stage of the project (see *Data collection and analysis* below) will, however, provide a set of 'real-life' tasks currently being used in school. Critical examination and suggestions for improvements of these tasks can be used in early dialogues with teachers. Design experiments develop theory "in that they target domain-specific learning processes" (Cobb, Confrey, diSessa, Lehrer & Schauble, 2003, p.9) and the role of the researcher is crucial. Research (Saxe, 1991; Masingila et al., 1996) provides strong evidence that a problem in linking school mathematics to out-of-school activities is that participants' motives and goals in the two activities are not aligned. Every effort will be made to make teachers aware of this, including enlisting the support of local business and industry to talk to teachers and, if possible, project classes about how practitioners approach specific tasks.

A challenge for this research will be to measure learning. This is a challenge because intended learning in project classes is not simply learning mathematical skills and concepts but involves the learner developing an appreciation that the mathematics done in class is relevant to out-of-school activities. Activity theory provides a way that such learning may be measured. Activity theory differentiates between activity, actions and operations with regard to the objects to which these processes are oriented. Activities are oriented to motives. Actions are directed at specific conscious goals. Actions are realized through operations determined by the conditions of the activity. In the applications of mathematics in classrooms it is important to differentiate between motives, goals and conditions. If these are aligned, then the application of school mathematics is possible. If these are not aligned, then what the students are doing, though it may appear meaningful, may not have unity of purpose. In the data collection and analysis section below I outline a set of measures, based on Stevenson (2003), which may be used to evaluate this wider conception of learning.

Sample and duration
This research proposal has an initial stage of collecting data on current practice and views and a main stage where the school-based work will be carried out. The initial stage will occupy the months at the end of the 2003-04 school year and the main stage will commence at the beginning of the 2004-05 school year. The initial stage will consist of collecting and analysing questionnaire data from the Head of Mathematics of about 60 secondary schools. Due to the need to work closely (task design and observations of lessons) with each participating teacher in the main stage, a small number of teachers will be selected. An initial analysis of time and cost factors determined that six teachers would be the optimal number to work with. There is research evidence that innovative practice in schools works better the second time around (Brown & Clement, 1993). The school-based work proposed is thus designed over two school years. Given that some teachers may not be able, for a variety of reasons, to continue with the project in the second year it is proposed to work with seven teachers initially. Invitations to take part in the research will be sent to a large number of school in the West and North Yorkshire Area. It is anticipated that many schools will bid to be involved[10]. Schools will be selected to represent a range of characteristics including location, governance, size and examination group. Teachers will be selected on the basis that they perceive links between school and out-of-school mathematics to be a problematic issue and on the basis of their avowed intentions to undertake substantial classroom activities aimed at making these links.

Data collection and analysis
Data collection and analysis will directed at answering the research questions identified above. Research themes 1 – 3 include an initial focus of describing current practice and views. All research themes are concerned with analysing activity in the school-based part of the research. The themes are presented discretely, but are interrelated.

1) Tasks
In the initial stage, questionnaires will be used to collect details of 'real-life' tasks currently being used in school mathematics classes. A descriptive analysis of questionnaire returns will result in a short report. In the main stage tasks will be designed that attempt to engender links between school and out-of school mathematics. It is expected that tasks will be substantial tasks (taking several weeks) focused on a single application of mathematics and a specific subdomain of mathematics. The principal applicant will work with each participating teacher in the preparation of each task[11]. For each task a log will be kept. Each log will have a preparation, implementation and retrospective analysis section. It is expected that the structure of these logs will develop during the course of the research. Initial expectations for details kept in the logs include: the source of the ideas for the task; influences on the choice or foci of the tasks, e.g. discussions with the business community; resources used; teachers' motives for choosing these tasks; if, and if so where, the tasks fit in to work prescribed in published curricula; the suitability of tasks for individual or group work; students' interpretation of and interest in the task; and how tasks may be amended for subsequent use (and comparison with prior use when the tasks have been tried before). It is expected that categories, other than those detailed above, will emerge from analyses of these logs. Codings within each category will be generated so that a summary analysis of these logs may be produced. Categories and codings will be subjected to project team scrutiny for comment on their reliability and validity.

2) Resources
In the initial stage, questionnaires will be used to collect details of resources currently being used in school mathematics that address out-of-school mathematical problem solving. A sample of these

[10] It is not anticipated that there will be a shortage of volunteer teachers. Incentives for the teachers will include financial allowance for teacher cover for time out of school and intrinsic interest of the project. The principal applicants has conducted three teacher-researcher projects over the last five years and is well known in the area for advancing practical teacher development work.
[11] If teachers undertake a limited number of such tasks, then it is expected that the principal applicant will be involved in the preparation and analysis of every task. If teachers undertake a large number of tasks, then time constraints on the principal applicant will force him to be involved in the preparation and analysis of a selected number of tasks.

questionnaires will form a basis for a discussion with members of the business, industry and leisure communities to establish similarities and differences in the use of resources in and out of school. This discussion will be extended to include the Award holders for ERSC TLRP Award RES 139-25-0119 who are investigating 'techno-mathematical literacies in the workplace'. Questionnaire returns and discussions with these parties will lead to a short interim report on the use of resources in school mathematics and out of school mathematical activities. This report is expected to generate constructs used in subsequent analysis. In the main stage classroom observations will note students' use of resources. The foci of observations with respect to student use of resources is expected to develop over the period of the project but initial foci include: students' mathematical reasoning with tools; comparison (where possible) of students' use of resources with experienced practitioners' use of similar resources; shared use of resources; and the influence of social relationships (teacher-student and student-student) on the use of resources. These foci will provide initial categories for analysis of the use of resources and how they affect reasoning and social interactions. It is expected that categories will emerge in the course of analysis. Codings within each category will be generated so that a summary analysis of resource use and its interrelation with other aspects of the research can be produced. Categories and codings will be subjected to project team scrutiny for comment on their reliability and validity.

3) Teachers In the initial stage, questionnaires will be used to collect details of teachers' opinions on the problem of linking school mathematics to out-of-school activities and, for those who perceive that there is a problem, how this may be overcome. A descriptive analysis of questionnaire returns will result in a short report. Project teachers will also complete this questionnaire. At the start of the main stage project teachers and a similar number of non-project teachers who completed the questionnaire will be interviewed with a focus on clarifying questionnaire responses. In the main stage project teachers will be interviewed at the end of each school year in order to obtain their views on emerging themes arising from the research. Interviews will be read and thematic categories will be generated independently by the principal applicant and the research assistant. These categories will be compared, a joint categorisation will be established and the interview will be reread and coded with the aim of obtaining a valid and reliable account of project teachers' views. Teachers' ongoing task design, resource selection and motives will be monitored by building an ongoing profile for each project teacher which will include materials, fieldnotes and interviews components. The materials component will include lessons plans, worksheets, artefacts and software. Fieldnotes will include observations of selected lessons and records of meetings and in-class discussions. Trajectories of teachers' motives, strategies and realisations of their plans over the two project years will be traced. Categories and hypotheses will be generated and subjected to validity checks. The final analysis of the set of profiles is expected to provide a detailed account of teachers intentions and their realisation (or not) in their practice.

4) Students

All data on students will be collected in the main stage. The main objective will be to develop and apply a set of measures to evaluate learning. The following set of three measures will be initially employed and may be refined over the course of the project:

Measure 1	Are students' motives consistent with the intended learning outcomes?
Measure 2	Does the mathematics employed by the students in realising specific goals assist them in realising the overall aim(s) of the activity?
Measure 3	Are the material resources available to the students consistent with the requirements of the activity?

Qualitative data (which may be turned into Likert scale data) will be used for these measures. This aspect of this proposal requires further work. The validity, reliability and usefulness of these measures will be evaluated during the course of the project and they may be amended. Data will be collected by in-class observation and discussions with students and by interviews with selected students on the final products of their work. It is expected that task sheets will contain questions which will provide relevant data on these measures.

Personnel
The team will consist of:

- The principal applicant, who will be the project leader. He will design all data collection tools, assist teachers as required, check data collection, conduct data analysis, lead the team in the dissemination of outcomes and write the project report.
- Seven teacher-researchers who will work with the principal applicant, keep a record of their preparations for (and outcomes of) project work, attend training sessions and project team meetings, write a report of their work and participate in the dissemination of outcomes.
- A 30% FTE research assistant who will be in charge of day-to-day running of the project, communication between project team members and the production and updating of a project web-site. S/he will be responsible for all data collection other than that collected by the teacher-researchers, will archive all data collected and prepare data for analysis. S/he will also participate in aspects of iterative design of learning activities to ensure her/his data collection is consistent with the aims of the project.

Timetable
The detailed timetable is presented in appendix 2. It consists of five phases and two cycles (years) of school-based work. Phase 1 consists of setting up the project and preparation work. Phases 2 is the first cycle of school-based work. Phase 3 is a mid-project evaluation period. Phase 4 is the second cycle of school-based work. Phase 5 is the period for final data analysis and preparation for dissemination and writing up.

Expected Outcomes and Dissemination
This proposal will produce:

- An account of teachers' perceptions of problems in linking school and out-of-school mathematics and their strategies to overcome these problems. This account will contribute to knowledge on implementing innovation in teaching mathematics and to further understanding how school mathematics may be made more relevant to the needs of the individual and of industry.
- The production of materials (lesson plans, resources and assessment) relevant to specific applications of mathematics. These materials will be made available through the project web-site.
- The production and evaluation of a set of measures to evaluate the learning outcomes of designed learning activities.
- Publications and presentations from the teachers and the principal applicant on issues of linking school mathematics and out-of-school mathematical activities.

Dissemination will be through education journals and conferences. In the main the principal applicant will direct himself to academic journals and assist the teachers in writing for professional journals. The experiences of the team are expected to contribute to INSET courses for teachers. Every effort will be made to disseminate results to policymakers.

Appendix 1 **References**

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Appendix 2 **Timetable** (Cycles, phases and activities within phases, in chronological order)

Date	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Description
May 2004	|					Phase 1 (May, 2004 - September, 2004)
June	|					♦ Setting up the project team and refining initial data collection tools
July	|					♦ Initial full day meeting with teachers (input from principal applicant and di
August	|					♦ 'Initial stage' questionnaire distribution, analysis and follow-up interviews
September	|	|				♦ Employment and induction of research assistant
October		|				♦ Individual meetings with teachers in their schools on initial ideas for activit
November		|				Phase 2 (September, 2004 - June, 2005)
December		|				♦ Developing tasks with teachers (face-to-face meetings and e-mail communi
January 2005		|				♦ Supporting teachers who require specific training to implement activities
February		|				♦ Teachers implementing activities
March		|				♦ University researchers observing activities
April		|				♦ In class data collection and analysis
May		|				♦ Teacher and researcher evaluation and refinement of activities
June		|	|			Phase 3, review of first year (June, 2005 - August, 2005)
July			|			♦ Two day team meeting, each teacher to present a case study from their wor
August			|			♦ Review of the first year and planning for the second year
September				|		♦ University researchers write end of year report
October				|		Phase 4 (September, 2005 - May, 2006)
November				|		♦ Developing tasks with teachers
December				|		♦ Supporting teachers who require specific training to implement activities
January 2006				|		♦ Teachers implementing activities
February				|		♦ University researchers observing activities
March				|	|	♦ In class data collection and analysis
April				|	|	♦ Teacher and researcher evaluation of activities
May				|	|	Phase 5 (March, 2006 - November, 2006)
June				|	|	♦ Final data analysis
July					|	♦ Dissemination
August					|	♦ Commence writing of scholarly publications
September					|	♦ End of Award report
October					|	
November					|	