Changes in Society: Challenges to Mathematics Education from Workplace Research

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Introduction

I recently visited several suburban workplaces in Victoria, Australia, in order to learn how mathematical knowledges and skills derived from formal education were transformed into numeracy practices of adults. The research was based on a theoretical foundation of activity theory (Engeström, 1987, 2001). This paper will briefly review the kinds of mathematics used industrial workplaces. It will then elaborate on findings from my own research into how numeracy is developed in the workplace, particularly in relation to technology. Finally, it will draw implications for school mathematics as well as for formal adult numeracy courses.

Adult Numeracy and Workplace Mathematics

As an activity, adult numeracy is a practice quite distinct from learning mathematics in school or other formal sites of learning. The most important difference is the objective: major goals in formal school education are to learn more mathematics in order to successfully complete assessment tasks for a variety of purposes, and to develop a body of disciplinary knowledge as part of enculturation into a given society. Formal vocational education is often similar, but with a focus on workplace textual 'applications' — often implying an unproblematic notion of transfer and usually with grossly oversimplified portrayals of workplace activity. However, the production of workplace artefacts could also be a goal — albeit in a teaching/learning context, rather than under the pressures of the workplace, such as time and money. On the other hand, in the workplace the goal is to achieve the satisfactory completion of workplace tasks in a timely and efficient manner, in order to keep one's job, satisfy internal and external customers, and so forth. Drawing on sociocultural activity theory, it is possible to make further comparisons between formal education and workplace activity in terms of the tools or mediating artefacts which come into play, the community of practice, the rules which govern the activity, and the division of labour — that is, who does what.

Learning in the workplace, on-the-job, is best described as informal learning (Eraut, 2004). Accordingly, it differs significantly from formal, institutional learning. An analysis of these differences in learning, as well as of the different activity systems, has the potential to offer challenges to formal mathematics education in schools and vocational education. Numeracy in the workplace is much more complex than the simple application of mathematical knowledge and skills learned in school or vocational education. Although the knowledge and skills developed in compulsory education or in formal adult and vocational education courses play a foundational role, they are inevitably transformed within workplace or other contexts. This is in order to address the novel and ever-evolving problems that may require timely and creative solutions, not necessarily the neat mathematical solutions typically found in formal educational texts. Even though the actual mathematics levels appear to be relatively low when mapped onto school curriculum frameworks, these need to be understood as situated within often pressured situations in relation to time, money, and safety, and almost always involve dealing with other people in the process. This last point, together with explicit or implicit environmental considerations, brings an ethical element into consideration — one which is frequently avoided or ignored in formal mathematics education.

The effect of technological changes on people's lives in terms of increasing the complexity of mathematical or numeracy demands at work and beyond has been observed by many authors. I now draw on selected research on how mathematics is used in everyday life and at work —for reasons of space the research is confined to the USA. For example, Lesh (2000) noted that the *USA Today* newspaper contains editorials, sports, business, entertainment, advertisements and weather sections which are filled with tables, charts, graphs and formulas "intended to describe, explain, or predict patterns or regularities associated with complex and dynamically changing systems; and the kinds of quantities that they refer to go far beyond simple counts and measures …" (p.179).

Based upon studies of numeracy in workplaces of the USA, Lloyd and Mikulecky (1998) noted that in the banking industry

> mathematics was usually called for to solve problems while gathering information from several sources, often requiring the use of technology (i.e., computer or calculator), and with a good deal of speed and accuracy since customers were often waiting for answers to questions. (p.4)

In terms of actual worker skills, they found that typical of changing workplaces, tasks call for problem-solving, setting up computations, and estimating to check the reasonableness of answers.

Another workplace numeracy study in the USA was conducted by Smith (1999). In the automobile manufacturing industry, spatial and geometric reasoning, including visualisation, and problem-solving are essential skills. He observed that:

- Mathematical work in manufacturing is tool rich. Workers who are thinking mathematically use manual and digital tools to measure, compute, represent, or program.
- Numbers and computations come from measuring physical quantities that really matter in production.
- Workers need to know the conceptual qualities of averages in times of problematic data.
- Assembly work does not require 'more mathematics' but mathematics that is used and interpreted in context.
- Some high-volume sites directly involve production workers in improving productivity and quality. When the level of workers' responsibility increases, so does the range and sophistication of the mathematics required. Similarly for workplaces that produce small numbers of precision parts and tools for high volume assemblers — machining. Almost no room for error exists in setup.

In summary, workers are operating in tool-rich environments, often with technology, under pressures of various kinds. Situations are highly contextualised, with real data, and solutions that really matter. Workers need deep conceptual understandings of number and measurement, together with skills of problem solving, spatial and geometric reasoning.

Findings from Australian Research

Findings from my fieldwork supported those above. The people I observed were doing jobs ranging from semi-skilled through to para-professional; they generally had between 9 and 12 years of school mathematics. The workplaces visited included a fund-raising 'trivial challenge' production office, a modular shed construction company, a local post-office, a short-term home rental company, a graphic design company using CNC machinery, a local playgroup, a small hairdressing salon, a wholesale power tool warehouse, and an aged-care hostel. In each of these workplaces technology played an important role in structuring the work, explicitly or implicitly, and as a tool for calculation and communication. For example, accurate record keeping is an essential requirement, even if data is initially entered onto paper printouts, for the purpose of stock control in production and retailing operations, records of staff activities, and accountability to government departments such as Health and Children's Services. The ability to deal efficiently and effectively with cash and credit transactions, using modern technologies, in sales and service industries is also important. Customised and/or generic software packages were used in the fund-raising organisation, the home rental business, the hairdressing salon, the warehouse, and the graphic design company for planning and reporting. The last depended heavily on its specialised computer program for cutting three-dimensional forms to meet the specifications of the client; this also involved making fine adjustments to the program in response to visual and measurement observations. Design and location skills were particularly evident in the post office and hair salon in terms of the layout of products for sale, and in the shed construction job. Mathematics is now included in the qualifications for child-care workers as they are required to introduce young children to the basic concepts of counting, pattern and order, space and shape.

In another research project studying the numeracy task of preparing and applying chemicals for spraying in weed control and fertiliser application, I found that it requires that the person responsible must take into account a complex set of variables, well beyond the calculation of the actual chemicals to be used. Numeracy in chemical spraying and handling is always a social-historical and cultural practice, dependent on communication with a range of workplace personnel, and texts both in print and on the internet. Environmental considerations are paramount in order to adhere to strict safety legislation requirements, as well as the pragmatics of keeping soil and water resources viable, not to mention the sustainability of the crops under cultivation (e.g., vineyard grapevines, fruits & vegetables, flowers, golfing greens) or the natural parkland to be protected. In these workplaces, apart from specialised computer training, most learning seemed to be 'on-the-job'. The notion of direct transferability of the mathematical skills learned in school is problematic, as each workplace had its own contextualisation and a need for transforming prior knowledge to meet the specific needs of the task at hand. Inevitably new problems will arise that require creative, efficient and timely solutions — see FitzSimons (in press) for a description and analysis of locating a missing consignment from the power tool warehouse.

The findings from both projects support the messages from the international literature on mathematics/numeracy in the workplace. For example, mathematical elements in workplaces are subsumed under workplace routines, structured by mediating artefacts (e.g., tools & equipment, calibration templates, record sheets), and are highly context-dependent. In other words, the priority is to get the job done as efficiently as possible — not to practise and refine mathematical skills. Although solutions to calculations and eventual measurements and operations for chemical spraying must necessarily be error-free, unlike school the actual methods used allow some discretion with respect to the manner and relative accuracy by which these are achieved and, more importantly, they involve the collaboration with or validation by at least one other person with experience of the task as well as historical records. The ability to communicate is of the essence, and this incorporates mathematical understandings — including estimation, approximation, and reasonableness of answers — even though they may be largely invisible most of the time. Unlike school, the results really matter in terms of public and personal safety, and environmental protection.

Curricular and Pedagogical Issues

Certainly, the mathematical demands of workers in a technological era are different from the past. Even though certain mathematical skills are rendered invisible by technologies, other skills are becoming critical. It may be possible to substantially reorient school and vocational mathematics curricula and pedagogy in order to allow students to develop more useful skills for work and other life situations in which they find themselves — now and in the future. But this does not mean a reduction to the lowest common denominator of visible numeracy skills — rather an increased recognition of the complexities of the workplace and the interconnectedness of tasks. However, this ability to learn 'on-the-job' requires a strong general mathematics education — one which aims at developing deep understandings of concepts such as number and measurement (together with their fundamental inter-relationships), statistics and space, in association with practical modelling and problem solving — in order that the workers can transform their existing mathematical (and other) knowledge and skills to adapt to the idiosyncrasies of their particular workplace contexts.

The findings from the literature and both projects suggest that new workers need to learn exactly how particular processes operate. As they become experienced, they may be enabled to participate fully in the social, cultural, and technological processes of the workplace, possibly even contributing to new knowledge as conditions change. The development of authentic communication skills should form an integral part of any mathematics or vocational numeracy education. Logical thinking and problem solving are examples of mathematical competences that can develop over the compulsory years and be refined by further formal education in numeracy as well as on-the-job participation. Communication skills, planning, and teamwork may be enhanced by genuine collaboration via projects, local and global, and supported by multimedia conferencing where possible.

With reference to changing conceptions about mathematics, it is true that internationally tertiary students are choosing more vocationally-oriented courses, many of which are indeed reducing their mathematical content, and this is a reflection of the trend towards transdisciplinarity in the workplace (Gibbons et al., 1994). For the great majority of learners in senior school, vocational and higher education, mathematics education needs to focus on meaning-making, using mathematics and relevant technologies to understand, manipulate, and transform concepts to solve real problems and interpret solutions within their contextual setting. It also needs to support reflection and critique of the learning process and of the uses to which mathematics and the technologies founded on it are put. In the workplace this would correspond to workers having the ability to question existing procedures and to respond creatively to the tensions and contradictions which arise — described by Engeström (1987, 2001) as *expansive learning* at a systemic level.

Whether online, off- or on-campus, learners who have been away from formal education for some time and others who did not succeed in the school environment may need some assistance in learning to learn; including how to use new learning technologies. Most importantly, they need to have their existing skills and knowledge acknowledged, and built upon. They need to become reflective on their own practice and their own learning, able to use those reflections to inform practice, and understanding that learning is ongoing and that practice is always developing. They need to learn thinking skills to manage information, to pose useful questions, and to solve problems, especially in co-operation with others. They need to learn how to be in control of their own learning, rather than dependent on others.

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