

EIMI 2010

Conference

EDUCATIONAL INTERFACES between MATHEMATICS and INDUSTRY

Proceedings

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Lisbon – April, 19–23

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Proceedings edition by Centro Internacional de Matemática, Portugal



Print production by Comap, Inc., Bedford, MA USA

ISBN-10: 1-933223-64-2

ISBN-13: 978-1-933223-64-2

Researching workers' mathematics at work

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Abstract School versus workplace knowledge is a fundamental issue in mathematics education. Mathematics is integrated within workplace activities and often hidden in technology. The so-called “transfer” of mathematics between school and workplace is not straightforward. However, lifelong learning assumes that learning takes place in all spheres of life. This paper discusses terminological and methodological issues related to reversing the one-way assumption from school knowledge to workplace knowledge and to learn from workplace activity what might be appropriate for adult vocational education. It is argued that any working model for researching the dynamics of workers' mathematics has to combine a general approach with a subjective approach.

A broad perspective on education, knowledge and technology

The perspective in the idea of lifelong learning, which structures today's educational system, demands a rupture with the limited conception of education, learning and knowledge. Individual and collective learning processes do not only take place as schooling within formal education, and the focus has now shifted from teaching to informal learning in the workplace and everyday life (Salling Olesen, 2008). This is also the case with mathematics and workers develop to a great extent their mathematics-containing competences through participation in the workplace communities of practice (FitzSimons & Wedege, 2007). In "World education report 2000", UNESCO (2000, p. 41) presents a terminology where this idea is set out explicitly with the distinction between informal, formal and non-formal education. *Informal education* means "the truly lifelong process whereby every individual acquires attitudes, values, skills and knowledge from daily experience and the educative influences and resources in his or her environment – from family and neighbours, from work and play, from the marketplace, the library and the mass media." For the most part, this process is relatively unorganized and unsystematic. *Formal education* refers to "the highly hierarchically structured, chronologically graded 'educational system', running from primary school through the university and including, in addition to general academic studies, a variety of specialized programmes and institutions for full-time technical and professional training." *Non-formal education* is defined as "any educational activity organized outside the established formal system – whether operating separately or as an important feature of some broader activity – that is intended to serve identifiable learning clienteles and learning objectives". However, this broad perspective on education is not reflected in the Discussion Document *Educational Interfaces between Mathematics and Industry* (2009) where education is recognised as formal education within the educational system or with non-formal education in the workplace (p. 3).

School knowledge versus everyday knowledge – such as workplace knowledge – is one of the fundamental issues in educational sciences in general and in mathematics education research specifically. In the educational discourse, *everyday knowledge* has the double meaning of (1) knowledge acquired or developed by an individual in her/his everyday life, and of (2) knowledge required in the individuals' everyday life as citizens, workers, students, etc. By *workers' mathematics at work* I mean mathematics acquired and developed by the individuals in their working life on the basis of previous experiences with mathematics in everyday life and formal education. Previous research mapped workplace mathematics onto school mathematics curricula where simplistic interpretations of mathematics used in the workplace were implemented (FitzSimons, 2002). During the last 15 years more sophisticated interpretations have taken into account social and cultural, even political contexts,

but in the EIMI Discussion Document (2009) there is an implicit assumption of a one-way development from school knowledge to workplace knowledge. The document identifies mathematics with academic mathematics and does not acknowledge any importance of the workers' mathematics. Just after the definition of mathematics as "any activity in the mathematical sciences", it is stated that "Workers at all levels utilize mathematical ideas and techniques, consciously or unconsciously, in the process of achieving the desired workplace outcome" (DD, 2009, p. 2). Moreover, in the document, the learning of mathematics is always mentioned side by side with the teaching of mathematics. Thus, the only form of workplace knowledge occurring in the document is mathematics required by the workers.

In order to investigate the relationship between mathematics education and technology in the workplace, it is necessary to have a broad conception of mathematical knowledge and of technology as well. In the Discussion Document (2009, p. 4), it is stated that "Technology' is understood in the broadest sense, including traditional machinery, modern information technology, and workplace organisation." However, my understanding of technology is even broader and more dynamic. I see *technology* on the labour market as consisting of three elements: technique, work organization, human competences and vocational qualifications – and of their dynamic interrelations. *Technique* is used in the broader sense to include not only tools, machines and technical equipment, but also cultural techniques (such as language and time management), and techniques for deliberate structuring of the working process (as for instance in Taylor's 'scientific management' and ISO 9000 quality management system). *Work organization* is used to designate the way in which tasks, functions, responsibility, and competence are structured in the workplace. *Human competences* are worker's capacities (cognitive, affective, and social) for acting effectively, critically and constructively in the workplace. *Vocational qualifications* are knowledge, skills and personal qualities required to handle technique and work organization in a work function (Wedeg, 2000, 2004). Thus, in the third dimension of technology, one finds the two types of workplace knowledge mentioned above and a possible tension between them: knowledge developed in the individual's working life, in human competences, and knowledge required by the labour market, in vocational qualifications.

With a broad definition *artefacts* is "anything, which human beings create by the transformation of nature and of themselves: thus also language, forms of social organisation and interaction, techniques of production, skills" (Wartofsky, 1979, cited in Strässer, 2003, p. 34). The understanding of technology presented above involves three types of mathematics-containing artefacts. This is an important statement for me as it expresses my overall view on technology and on mathematics as both created by human beings. Thus, I welcome the EIMI study with its focus on educational interfaces between mathematics and industry be-

cause it reflects the need of and opens for an updated view on the relation between education, knowledge, mathematics, humans and technology.

In the international research project *Adults' mathematics: In work and for school*, we seek to explore the development of school knowledge and of workplace knowledge as a two-way process. The objective is to describe, analyze and understand adults' mathematics-containing work competences – including social and affective aspects – complementing studies of mathematical qualifications in formal vocational education in ways that will inform vocational mathematics training and education. This will be done through empirical investigations – quantitative as well as qualitative – in interplay with theoretical constructions¹.

The question to be discussed in the last part of this paper is the following: How is it possible to study semi-skilled workers' mathematics at work in a way that enables the researcher to learn from workplace activity what might be appropriate for vocational education and training? Thus, I discuss methodological issues related to reversing the one-way assumption from school knowledge to workplace knowledge. But first, I present a brief summary of previous research on adults' mathematics in the workplace.

Adults' mathematics in the workplace

In education research, the overall interest in studying adults' mathematics *in* the workplace is mathematics education *for* the workplace. Inter-disciplinarity is a significant feature in the field and researchers are drawing on research on mathematics education, adult education and vocational education (FitzSimons, 2002, Wedege, 200, 2004). Within mathematics education, the research field of vocational education and training has been cultivated internationally since the mid 1980s (Bessot & Ridgway, 2000; Strässer & Zevenbergen, 1996), and the research field of adults learning mathematics since the mid 1990s (FitzSimons et al., 1996). Concepts which recognise people's social competences, like ethnomathematics and folk mathematics, as well as concepts of adult numeracy, mathematical literacy and of mathemacy, have expanded the problem field of mathematics education research (Jablonka, 2003). Today it is scientifically legitimate to ask questions concerning people's everyday mathematics and about the power relations involved in mathematics education, and anthropological studies such as those of Scribner (1984), Lave (1988), and Nunes, Schliemann, & Carraher (1993) are paradigmatic when studying adults, mathematics, school and work.

In the international literature on mathematics in and for work, there are two problems that researchers agree upon, of which the Discussion Document (2009) has only acknowledged the first problem:

- Mathematics is integrated in the workplace activities and often hidden in technology (Bessot & Ridgway, 2000; Hoyles et al. 2002; FitzSimons, 2002; Wedege, 2000; Strässer, 2003; Williams & Wake, 2007).
- The so-called “transfer” of mathematics between school and workplace – and vice versa – is not a straightforward affair (Alexandersson, 1985; Evans, 2000; FitzSimons & Wedege, 2007; Hoyles et al. 2001; Wedege, 1999).

In summary, these studies with their focus on differences between mathematics in school and mathematics in the workplace show that mathematical elements in workplace settings are highly context-dependent. They are subsumed into routines, structured by mediating artefacts (e.g., texts, tools). It is the working task and function, in a given technological context, that control and structure the problem solving process. Some of these problems look like school tasks (the procedure is given in the work instruction) but the experienced workers have their own routines, methods of measurement and calculation. Thus, mathematics is intertwined with professional competence and expertise at all occupational levels, and judgments are based on qualitative as well as quantitative aspects. Circumstances in the production might cause deviations from the instruction or might for example raise or reduce the number of random samples in a quality control process in industry. Unlike students in the majority of school mathematics classrooms, workers are generally able to exercise a certain amount of control over how they address the problem solving process, albeit within the parameters of the expected outcome of the task at hand, regulatory procedures, and available artefacts. In the workplace, solving problems is a joint matter: you have to collaborate, not compete; and the activity of solving problems always has practical consequences: a product, a working plan, distribution of products, a price etc. Finally, because the focus is on task completion within certain constraints (e.g., time, money), mathematical correctness or precision may be somewhat negotiable, according to the situation at hand (FitzSimons & Coben, 2009, Wedege, 2002). One of the consequences of these differences between mathematics in work and mathematics in school is that the workers do not recognise the mathematics in their daily practice. Mathematics is invisible in technology but this is not the only reason. Workers do not connect the everyday activity – and their own mathematics – in the workplace with mathematics which most of them associate to the school subject or the discipline (Wedege, 2002).

Methodology

The worldview guiding thinking and action in a study of semi-skilled workers’ mathematics at work – in a way that enables to learn from workplace activity what might be appropriate for

vocational education and training – can be described as the *transformative paradigm*. Within this paradigm, research places central importance on the lives and experiences of groups (in this case semi-skilled workers) that traditionally have been marginalised (in this case in relation to mathematics education) and on issues of power relationships (in this case between academic mathematics and workers’ mathematics). According to Mertens (2005), within the transformative paradigm, multiple realities shaped by social, political, cultural, economic and gender values are recognised (*ontology*). The relationship between the researcher and participants is viewed as interactive and knowledge is seen as socially and historically situated (*epistemology*). Finally, the approach to systematic inquiry includes qualitative, dialogical methods but quantitative and mixed methods can also be used (*methodology*).

In a study of workers’ mathematics in the workplace two different lines of approach are possible and intertwined in the research: a *subjective approach* starting with people’s competences and subjective needs in their working lives, and a *general approach* starting either with societal and labour market demands to qualifications and/or with the academic discipline mathematics (transformed into “school mathematics”) (Wedege, 2004). The subjective approach is to be found in studies like the one that I did in 1997-98 where the focus was competent semi-skilled workers mathematical activities in different work functions within four lines of industry: building and construction, commercial/clerical, metal industry and transport/logistics (Wedege, 2000). The methods used in this study were inspired by a project initiated by the Australian Association of Mathematics Teachers in 1995-1997, but the approach was different. The starting point in the Australian project was that workers used mathematical ideas and techniques (Hogan & Morony, 2000). The aim was to generate 40 stories with rich interpretations of workers use of mathematics, and the people shadowing and interviewing workers in a long series of different workplaces were mathematics teachers. Thus, their lens was school mathematics and the approach was general. Two of the workplace studies in mathematics education research illustrate the conflict between the general and the subjective approaches. In a study on proportional reasoning in expert nurses’ calculation of drug dosages Hoyles et al. (2001) compared formal activities involving ratio and proportion (general mathematical approach) with nurses’ strategies tied to individual drugs, specific quantities and volumes of drugs, the way drugs are packaged, and the organization of clinical work (subjective approach). In their large project involving 22 case studies, Hoyles et al.’s, (2002) research questions were about employers’ demands for mathematical qualifications, competencies and skills (general societal approach) and about what skills and competencies the employees felt were needed for the job, and what they currently possessed (subjective approach). However, to understand the cognitive, affective and social conditions for adults’ knowing mathematics one has to take both dimensions into account (see Fitzsimons, 2002; Wedege, 1999; Wedege & Evans, 2006).

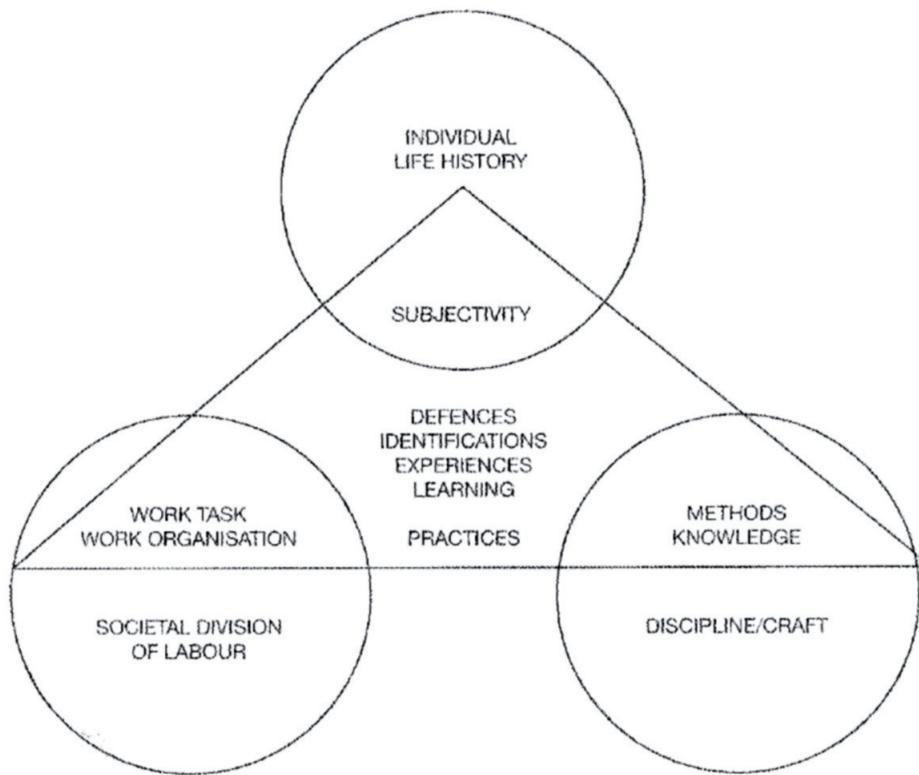


Figure 1—Workplace learning (Olesen, 2008, p. 119).

In Salling Olesen (2008) we find a working model for researching the dynamics of workplace learning in general which includes and combines the general and the subjective approaches. “It mediates the specific relation between three relatively independent dynamics: the societal work process, the knowledge available and subjective experiences of the worker(s)” (p.118) — see Figure 1.

When researching adults’ mathematics in work, this model focuses on the cultural and societal nature of the knowledge and skills (competences) with which a worker approaches and handles a mathematics-containing work task, whether they come from the discipline (mathematics), a craft (vocational mathematics), or just as the established knowledge in the field (ethnomathematics).

Qualitative research is necessary to capture the complexity of the worker’s cognitive, social and affective relationship with mathematics. We will use observations in the workplaces in combination with semi-structured and narrative interviews. We will also combine theoretical perspectives to capture different aspects of mathematical competence and take the importance of the institutional frame seriously into account for recognizing what are important mathematical qualifications in the particular context (FitzSimons, 2002; Wedege, 1999).

Quantitative research in the shape of a survey can provide an overarching picture of the workers’ social and affective relationships with mathematics. Supporting this, the voices of

the adults have already been heard in a series of qualitative studies (e.g. Evans, 2000; Hoyles et al. 2001; Wedege, 1999). With this information it is possible to create test batteries based on prior knowledge to find dimensions in the worker's conceptions about mathematics. Based on our assumption that the importance of knowing mathematics is experienced differently by men and women, gender will be an explicit dimension throughout the whole study (Henningsen, 2007).

Perspectives

As stated above, one of the fundamental issues in mathematics education is school mathematics versus out-of-school mathematics. In the context of the study *Educational interfaces between mathematics and industry*, this topic should also be talked about in terms of power in the labour market. In his book "The Politics of Mathematics Education", Mellin-Olsen (1987) stated that it is a political question whether folk mathematics, like workers' mathematics, is recognized as mathematics or not. Similarly, FitzSimons (2002) claims that the distribution of knowledge in society defines the distribution of power and that, in this context, people's everyday competences do not count as mathematics. The research project *Adults' mathematics: In work for school* is innovative in that it seeks to reverse the one-way assumption from school knowledge to workplace knowledge and to learn from workplace activity what might be appropriate for vocational education and training.

Salling Olesen (2008) asserts that "every work situation has elements of subjective engagement, cognitive construction and social interaction" (p. 126). In the context of their individual life histories and social experiences, workers can decide to develop new qualifications while resisting or neglecting others. This is critical in the case of mathematics learning, because many workers at all levels have experienced the institutional culture of formal schooling as alienating and have made little or no identification with the teaching and the texts. They tend to lack confidence in using formal mathematics because of the traditional focus on the discipline as absolute and infallible, which is in marked contrast to the negotiability (when reasonable) and commonsense being valued attributes in the workplace. Moreover, there is an apparent contradiction between many adults' problematical relationships with mathematics in formal settings and their noteworthy mathematics-containing competences in working life. These are some of the phenomena causing resistance to learning mathematics (Wedege & Evans, 2006). Our research project has the potential to help adult workers to overcome some of the cognitive and affective obstacles if they can recognise their own realities reflected in the official mathematics instruction in general schooling and vocational education and training.

Conclusion

In summary, I believe that the theoretical foundations of the Swedish research project discussed above, together with the evolving literature review and preliminary findings, have much to contribute to the EIMI study. The perspective of focusing on the workers' mathematics rather than the discipline has the potential to open up the discussion and offer new insights to mathematics educators and mathematicians alike.

Notes

- 1 The research project "Adults' mathematics: In work and for school" will involve 12 academics from 11 universities in 6 countries. Tine Wedege (Sweden) is the research leader of the project. Gail E. FitzSimons (Australia) will be involved in all phases of the project. Inge Henningsen (Denmark) will assist in designing the survey and in handling and analyzing of the quantitative data. Lisa Björklund Boistrup (Sweden) will assist in developing new methods for investigating adults' mathematics in work and participate in the qualitative study. An international reference group consists of researchers from adult and lifelong learning, mathematics education, learning in the workplace, mathematics in and for work, and vocational education & training. Among the members are: Corinne Hahn (France), Eva Jablonka (Sweden), Henning Salling Olesen (Denmark), Rudolf Strässer (Germany), and Geoff Wake (UK).

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