Numeracy as a Basic Qualification in Semi-Skilled Jobs

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'Using mathematical ideas and techniques' is usually pointed to as one key/core competence among others in international policy reports concerning the requirements of technological change in society. The general categories of competence are here described in isolation from the technological contexts of workplaces. Thus, mathematical knowledge as such, referring to the formal disciplines such as algebra and geometry, is seen as a key competence. I see two problems with this framework. On the one hand, use of mathematical knowledge in workplace situation is seen as a simple question of knowledge transfer (Kanes, 1997). On the other, isolation from the context reduces the complexity of workplace competence (FitzSimons, 2000; Wedege, 2000a).

Within the subject area of 'adults and mathematics', two different lines of approach are possible in research: the objective (society's requirements with regard to math-containing competences) and the subjective (adults' need for math-containing competences) (Wedege, 1998). There is a possible conflict between the two approaches: "I know that mathematics is important in society, but I don't use it and I don't need it in my life"

In this article, I shall present and discuss numeracy as a *math-containing competence* in the labour market, i.e. an everyday competence in which mathematics is an integrated but identifiable part. This discussion is based on a definition of technology and vocational qualifications. In the light of a study of semi-skilled workers' tasks and functions, differences between numeracy at work and mathematics in school are described and, finally, some possible consequences for adult vocational education are outlined.

Mathematics in Danish adult education

As one of the so-called basic skills, 'mathematics' is the most widely-present general subject in the educational programmes available. In Denmark, more than 100,000 semi-skilled workers participate every year in mathematics education or training and even more in math-containing further education. [1] The adult education system offers a wide-ranging set of learning opportunities to adult early school leavers. Each of these has its own legislative foundation, regulating content, organization and financing, as well as its own institutions. The objectives of the different adult and further education programmes range from a purely job or training perspective, over a broad vocational one to a societal perspective.

Our two biggest national programmes are *Adult Vocational Training* (AVT) and *Formal Adult Education* (FAE), which until recently were to be found in two different sectors (the Ministry of Labour and the Ministry of Education respectively). The aim of AVT is to provide semi-skilled and skilled workers with math-containing qualifications. The courses are aimed at work functions in a great number of industries (building and construction, the commercial and clerical areas, the metalwork industry, transport, etc.). FAE is general adult education at the lower secondary level, consisting of single subjects such as Danish, Mathematics, History, Physics, English, etc. The aim in regard to mathematics is to provide the participants with numeracy as well as mathematical study skills.

Mathematics instruction can be found in both programmes, but the point of departure in each for the curriculum, its objectives, as well as the participants' learning perspectives, is different. In adult vocational training, the students are often surprised at or sceptical about the fact that mathematics is a subject of study in their programme. Their learning perspective is that of a vocational qualification, not to learn mathematics (Strässer and Zevenbergen, 1996; Wedege, 1999).

In Formal Adult Education, the starting point is mathematics as system and method and the objective is knowledge and abilities concerning mathematics as a subject in itself and in relation to its uses in everyday life. Roughly speaking, reality is a pretext to do mathematics. However, there exists a firm belief in providing the participants with general qualifications in the FAE system. By contrast, in Adult Vocational Training, the curriculum is based on an assessment of the need for mathematics knowledge in different job functions and the objective is knowledge and abilities concerning mathematics in relation to other subjects. Again, roughly speaking, reality gives rise to using mathematics.

Technology and qualifications

Let us take a closer look at the concept of qualification [2] as an important link between the social and pedagogical research fields where studies in the subject area of 'adult education for mathematics in the workplace' were situated. As such, the concept provides a framework for didactic reflection on the relation between adult education and work (Wedege, 2000b)

During the last twenty years, we have experienced two opposing trends in the labour market: while the pocket calculator and information technology, on the one hand, mean that the need for manual calculations and constructions has been reduced, on the other, the same technology opens the possibility for forms of work organisation where the unskilled worker takes on planning functions which make new demands on their mathematics knowledge.

I shall define *technology* in the labour market as consisting of three elements - technique, human qualifications and work organization - and their dynamic interrelation.

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 the deliberate structuring of the working process (as, for instance, in Taylor's (1914) 'scientific management' and ISO 9000 quality certification) *Work organization* is used to designate the way in which tasks, functions, responsibility and competence are structured in the workplace (Wedege, 2000b).

I define *qualifications* as the knowledge, skills and properties that are relevant to technique and work organization, as well as to their interaction in a work function. In my definition of the concept of qualifications, I speak of *relevant* knowledge, skills and properties rather than of *necessary* knowledge, etc. This makes it possible to perceive qualifications from two different points of view: subjective and objective. In other words, they can be seen from the point of view of individual workers as well as from the point of view of the labour market.

I distinguish analytically between two types of qualification:

- *specific professional qualifications*: technical-professional knowledge and skills that are directly and visibly present when the individual work function is being carried out;
- *general qualifications*: general and professional knowledge, abilities and competences, such as literacy and numeracy, that are (often indirectly) present when a wider range of work functions are being carried out.

A third type of qualification is introduced as a quality inherent in the two others:

- *social qualifications*: personal traits/attitudes that are present in the work process such as precision, solidarity, flexibility and the ability to co-operate. (Wedege, 1995, 2000b)

Empirically, these types of qualifications are interwoven in the single individual. A skill or understanding might be analysed as a specific professional qualification in a work context and as a general qualification in another For example, skill in reading diagrams and applying this knowledge is a specific qualification for the driver of a fork-lift truck, while skill in reading and understanding a chart of absence due to sickness is a general qualification for workers.

Human qualifications constitute a central element in technology where they are used, challenged and developed at work, in co-operation with and in contrast to technique and work organization. On the basis of this conception of technology and technological development, it is necessary to distinguish between necessary and relevant qualifications in analyses which are to be used for the purpose of educational planning. For example, a given technique with different methods of organizing work may require different types of qualifications (Wedege, 1995).

Numeracy in the labour market

It is a basic assumption in my present research that there is a need in the Danish labour market for functional numerical understanding and mathematics skills in the same way as for skills in reading, writing and using information technology. Thus, numeracy is an everyday competence parallel to, and overlapping with, literacy We define *numeracy* in the labour market as math-containing competences which everybody in the labour force needs in principle. Thus, numeracy changes over time and place: it depends upon the development of society and technology (Lindenskov and Wedege, 2001). [3]

As an everyday competence, numeracy cannot be identified as a collection of mathematical skills and understandings alone, isolated from the context in which they are used. It does not merely comprise the four basic arithmetical operations and other mathematical topics: the skills and understandings have to be functional In the workplace, it is not enough to know the multiplication tables from 2 to 10, if this arithmetical skill cannot be applied to measuring and to calculating the materials necessary.

For example, the formula for measuring the circumference of a circle, 2π x radius, is mathematical knowledge that can only be used for calculating the materials that are necessary when the formula is converted to π x diameter and one knows how to measure the diameter of the object. Nor is numeracy just an ability such as 'calculating a dosage'. In the workplace, calculations are always influenced by what they are to be used for and how precisely they should be performed. At a hospital, there is a difference between dosing medicine and detergent (see also Noss, 2002).

In the definition of numeracy, the term 'needs' should not be read as an expression of necessity, rather of relevance. Thus, this is not just a matter of given labour-market demands concerning the individual's skills and understanding, but also whether they might be relevant in relation to technological changes (in technique and/or work organization), or the individual's perspectives in his or her working life or further education. The term 'in principle' makes possible general assessments of adult numeracy and planning of general numeracy courses. Every adult participant in numeracy courses has his/her own perspective (Why am I here?), background and needs (What do I want to learn?), and strategies (How do I learn?)

In policy education reports, there are often confusions between the two terms 'qualification' and 'competence' (Fragnière, 1996). Thus, I shall give a brief discussion of competence and qualification which are analytically distinguished and operate at different levels of analysis but, empirically, are embedded in each other

The term 'competence' usually appears in everyday language as a term for expertise and/or authority at the same time. However, the term is widespread in the world of education with the more closely defined specific meanings of a target in the learning and development processes With the concept of competence, just as with qualification, the classical dichotomy of knowledge versus skill is avoided. This allows the recognition of 'tacit knowledge' and 'knowing and learning in practice' in educational frameworks.

'Competence' is related to the individual and combines capacity with activity in specific contexts (education, family and societal life, etc), while the context used to determine 'qualification' is the labour-market technology where the concept combines the worker's competence with work organization and technique. Qualifications are directly and objectively linked to specific working tasks.

In vocational education, it is meaningless to talk about qualification without thinking of the demands of the factual or ideal labour market. On the other hand, it is meaningless to talk about competence in education without thinking of competent people.

Investigating numeracy as a general qualification

In 1997-98, I conducted a study of semi-skilled workers' mathematics activities at work under a research project which focused on numbers and professional mathematics in the Danish adult vocational training programmes. The study is based on a series of working hypotheses including the following

(1) In every semi-skilled job, problems arise that can only be solved by quantification and use/evaluation of quantitative units

(2) Tasks and functions of semi-skilled workers require relatively simple formal skills and understanding in mathematics, but, informally, they are developed in complex working situations.

(3) There are systematic differences between mathematics in the workplace and mathematics in traditional teaching.

(4) While semi-skilled workers think mathematics is very important in the labour market, they do not regard mathematics as something of personal relevance to them

(5) Semi-skilled workers are not conscious of their mathematics activities in their daily work and, thus, of their 'mathematical' competence. This awareness only appears in a situation where there is a job they *cannot* manage due to their *lack* of mathematics skills

In order to analyse and describe numeracy in the labour market, I have investigated selected firms within four lines of industry: building and construction, the commercial and clerical area, the metal industry and transport. My objective was to identify and describe mathematics in semi-skilled job functions and to analyse how mathematics knowledge at work is interwoven with specific qualifications and social qualifications. [4]

I shadowed a core worker from one of these areas for half a day to describe the action taking place. At the end of the day, I interviewed the worker to explore any issues that had arisen. Then I wrote up these observations as a descriptive story with examples of particularly interesting incidents, which I call *episodes*. Furthermore, I photographed interesting situations and tools, and collected written materials with figures, formulas, diagrams, etc. (such as working drawings, plans and statistics)

In processing these data, I use an operational tool with four analytical dimensions which Lena Lindenskov and I have constructed to describe and analyse numeracy. One is *media*, where we have found our inspiration in the reading surveys; the relevant numeracy depends on whether it is to be applied to written/oral information and communication, concrete materials, time or processes, even if the figures and the four basic arithmetical operations are the same.

Context is another dimension; what one knows and what one should know depends on whether one is in a supermarket, at work or in a test situation. In a workplace study, the work function is seen in its specific technological context. A third dimension comprises *personal intention*; it is crucial whether one wishes to obtain information, to fill in a form, to plan production, to check the quality of the product, to pass the time, etc.

The fourth dimension we are working with is *skills and understanding*: handling and sense of quantity and number; dimension and shape; pattern and relationships; data and chance; change; mathematical modelling (Lindenskov and Wedege, 2001).

In the first place, the study has shown that the methods and analytical tools are operational in relation to the subject area and problem field of the study. Second, data have been collected for close descriptions of numeracy in a number of semi-skilled job functions (operating a cash register, technical insulation, sewerage, receiving goods and quality control, stock management and cutting, baggage handling, quality control and packing, computerised turning, polishing and spot welding). Thirdly, the study has contributed to illustrating the working hypotheses and resulted in minor reformulations of them. In this article, I shall just present some findings concerning the third hypothesis, i.e. differences between work and school

Six episodes

In order to give the reader an idea of the kind of data I have collected in the study, I have chosen six episodes from my observations of semi-skilled workers' mathematical activity. The context is their job functions in workplaces with different technology. The first and second episodes took place, respectively, in a bus in Copenhagen during the rush hour and in a canteen at a large working place:

> *Episode 1*. At the bus stop, the driver opens the door and an older woman gets into the bus together with a lot of other people. She has a yellow ticket coupon in the one hand and a blue one in the other. She shows the yellow one to the driver asking him "I am going to the Town Hall Square. Is it necessary to add a blue punch hole to the yellow one?" The driver takes the yellow ticket. He studies it for a moment and answers: "Yes, a blue punch hole". At the same time, ten to fifteen passengers push their way onto the bus, all showing their monthly season ticket to the driver

> *Episode 2*. "The milk will arrive in fifteen minutes." This information is a signal to the canteen employee that she has to start to shape things up at the cold counter. Doing this, she follows a specific system. Normally, the dates on the milk cartons have to be checked, but she does not do this today, because the sale has been

enormous during the last days In between the attendance (customers arrive in groups), she checks that the delivery matches both the order and the invoice when she fills up the cold counter.

These two episodes illustrate workers' checking numbers, which refer to dates, prices and traffic zones, with passengers and customers rushing around them.

The next episode took place in a large metalwork factory.

Episode 3. A semi-skilled worker is turning shields for pumps on a CNC machine. She checks each item individually. The measurements are within the limits of tolerance, but she is not personally satisfied with the quality: there is a dark ring left at the bottom of the item she has turned. The worker adjusts the machine (the tool has to be moved further in to correct this fault) by trying out different adjustments: first by 5/10 and then by 2/10. She does this by subtracting 0.5 and 0.2 on the screen and she later says that it is always necessary to consider whether to add or subtract.

The tolerance varies from trade to trade and from product to product In this case, the tolerance is +/- 0 1 mm In a work situation, considerations of units such as m, cm or mm will be involved and the worker must be able to mathematize a problem and decide whether the numbers must be added or subtracted (Wedege, 2000b)

The fourth episode was in a large electronics factory producing aircraft components

Episode 4. A semi-skilled worker with many years of experience in production is now working in the department where blanks from a sub-contractor are subjected to quality control She takes a bag containing nine small connectors for flat cables, which must be checked in relation to various standards It is a new brand and one of the measurements, taken with a digital slide gauge, does not quite fit in with the drawing. It is 15 58 mm and should be 16.00 mm according to the drawing. The tolerance is 0.01, but the worker's experience from the production department now benefits her - and the factory. She knows that the discrepancy in this measurement and this connector has no practical significance Had the measurement been over 16 01 she would have rejected the items

The workers' general knowledge about reading and understanding workshop drawings should be applicable in a specific professional qualification which comprises knowledge about using the items that have been checked In practice, this means that she does not merely reject items because they do not meet the requirements but she uses critical judgement in the situation in her translation of the specifications She can also see on her computer screen that during the day the production department will be short of this type of connector (Wedege, 2000b). Thus, her intention is not only to check the quality of the items but also to coordinate with the other department. Later, she demonstrated how important the context is by saying, "There is a difference between the consequence of a mistake in an aeroplane and a television set. It could be a matter of life and death."

The fifth episode took place at Copenhagen airport, where different function groups in the handling of luggage co-operate by means of a computer. When the aircraft are being loaded and unloaded, the loading group and the load planner are in constant computer contact We followed the foreman of the loading group.

Episode 5. In the loading instructions, the planner has placed baggage, cargo and mail in the four cargo compartments in front of and behind the wings. The ideal balance factor (38.0) and the limits (5.9/51.6) also appear from these instructions. The foreman reads the balance factor of the aircraft on the screen during loading: in the loading report for this specific aircraft, it is 28.2 This figure is automatically calculated when entering the cargo and the weight on the computer during loading.

When decisions are being made at the airport about loading an aircraft, the priorities are 1) safety, 2) keeping to the timetable and 3) service. Time is often scarce when loading and unloading an aircraft and keeping to the timetable means that some cargo may have to be sent on a later plane. However, the foreman tells me that, as the first priority is safety, this can mean that the flight may be delayed and the level of service may not be so high if the balance factor is not within the permitted limits.

This is an example of how the working tasks are defined and structured by technology (Wedege, 2000b). It is a general trend in the labour market that semi-skilled workers now assume planning functions that were previously management tasks.

The sixth episode illustrates what competence is needed of a worker when production is organized in autonomous groups The worker is a CNC operative at a metal company. There is no job rotation at the lathe he operates and this suits him very well

Episode 6 On a joint noticeboard in the department, there are graphs showing the service grades of each of the production groups The service grade is calculated as a percentage and equals: (number of items delivered) x 100/(number of items to be delivered according to the production plan). Today, at the end of November, his group is 45 hours behind. The service grade is down to 80. The production leader suggests that they should organise the work in shifts, so that they can come up to 100 during December and not work between Christmas and New Year The operative takes no part in the conversation of the group about organising the work so that the service grade can be maintained, and he has no intention of doing so. He just knows that it is a matter of working hard

At a workplace like this one, with autonomous groups, the operative is not qualified to take part in decisions about work organisation caused by a low service grade (Wedege, 2000a). These episodes illustrate that numeracy is a math-containing competence and not just a collection of mathematical skills and, at the same time, how numeracy at work differs from mathematics in school in several ways.

Solving tasks in the workplace and in school

"Do you use mathematics in your work?" Although many adults use numbers and formulas in their daily life, "No" is the most common answer to this question (Harris, 1991; Wedege, 1999). Mathematics is interwoven with technology - in technique, work organization and qualifications. However, modern computer technique hides the use of mathematics in the software and mathematics as a visible tool disappears in many workplace routines But that is not the only reason for the negative answer. The adults just do not connect their everyday activity with mathematics, something most of them associate with the school subject or the discipline. As mentioned, a working hypothesis in the investigations has been that there are systematic differences between mathematics (or numeracy) in the workplace and in traditional teaching.

This statement is developed and documented on the basis of my own and others' research (see the references below) In Figure 1, the well-known activity 'solving tasks' serves as an example

Numeracy at work	Mathematics in school
All numbers have units of meausrement (mm; kg; kr) or refer to something.	The numbers often appear as pure numerical quantities.
Numbers and tasks have to be constructed.	Numbers and tasks are given
A task often has different solutions	A task has only one correct solution
Accuracy is defined by the situation. Right/wrong can be negotiated.	Accuracy is defined by the teacher Right/wrong cannot be discussed
Solving tasks is a joint matter - collaboration.	Solving tasks is an individual matter - competition.
Tasks are full of 'noise', the numbers are often 'ugly'	Tasks are cleared of 'noise', the numbers are 'pretty'.
Reality requires the use of mathematical ideas and techniques	Reality is a pretext to use mathematical ideas and techniques.
Solving tasks has practical consequences	Solving tasks has no practical consequences.
Working tasks are defined and structured by technology.	Mathematical tasks structure the teaching

Figure 1: Solving tasks in the workplace and in school

In traditional mathematics instruction, the task constitutes a central element and structures the teaching. The task is primarily used to practice skills (use of algorithms and concepts) and to test skills and understandings Thus, the task is often solved by the individual student and it might be conceived as cheating to hand in a joint solution. The task is formulated by the teacher, the textbook or the computer program. The task has one correct solution and many wrong solutions (Accuracy in the school and tolerance at the workplace are two different things.) Solving tasks has no practical meaning: the results are not used for anything except, maybe, solving more tasks. In so-called 'problems', the task-context [5] is often that of practical problems, but the aim is to find the correct result by using the correct algorithm, not to solve the practical problem

In the workplace, the 'tasks' result from solving a working task where the numbers are to be found or constructed with the relevant units of measurement (hours; kg; mm). It is the working tasks and functions in a given technological context which controls and structures the process, not the 'task'. Some of these tasks look like school tasks (the procedure is given in the work instruction), but the experienced worker has his/her own routines, methods of measurement and calculation. Circumstances in the production might cause deviations from the instruction or the number of random samples in the quality control to be raised or reduced. It is characteristic that tasks are solved in different ways and that different procedures and solutions might be acceptable In the workplace, solving tasks is a joint matter: you have to collaborate, not compete. Solving tasks always has practical consequences: a product, a working plan, the distribution of products, a price

Conclusion

Differences between informal mathematics (street mathematics, folk mathematics) and school mathematics (that people learn and practice in formal education) have been investigated in a series of studies (e g. Mellin-Olsen, 1987; Schliemann and Acioly, 1989; Hoyles, 1991; Nunes *et al.* 1993; Hahn, 1999; Wedege, 1999). In this article, one point is to suggest that these differences are the reason why adults do not recognize the informal mathematics in their everyday life as mathematics Thus, they are not conscious that their competences are math-containing. They see mathematics only in a situation where there is a job they *cannot* manage due to their lack of mathematics skills, and, thus, mathematics is confirmed to them as something they are unable to do.

If adult numeracy, as personal math-containing competence instead of academic mathematics is seen as a basic general qualification in the technological context of semi-skilled work functions, then there are some possible consequences for teaching practice in adult vocational training and education programs On the one hand, some have to do with making mathematics visible (in the math-containing everyday competences of adults with brief schooling and in math-containing vocational adult education): on the other, with a clarification of the relevance of mathematics in vocational adult education The reason for teaching mathematics is found outside, not within, the subject of mathematics. Thus, teaching practice has to be interdisciplinary and teacher training programs should include investigations in workplace practice

Notes

[1] With the German term *mathematikhaltigen Weiterbildung,* Jungwirth, Maasz and Schlögmann (1995) paved the way for research on vocationally-oriented adult education where mathematics is an integral part They invented the term, but the definition here is mine By *mathematics instruction,* I mean organized communication of a mathematical subject area, either as single-subject teaching (in a formal or informal context) or as part of an educational programme as an independent subject or module By *math-containing instruction,* I mean organized communication of a single or interdisciplinary subject area where mathematics is an integrated but identifiable part The instruction can be informal (for example, learning from one's colleagues at a place of work) or be part of a course or a study programme

[2] The English term 'qualification' covers both actual qualification(s) and the process of becoming qualified I use 'qualification' in both senses

[3] This is an open and descriptive (not normative) definition of numeracy Richard Noss (1998) has analysed the definitions given of numeracy from the first in the Crowther Report in 1959 to the latest U K governmental one in 1997 His diagnosis of the underpinning vision of mathematics is 'utilitarianism' According to my definition, numeracy is a relative conception Thus, it does not make sense to talk about 'new numeracies' as Noss does Neither do statements like the following, for example, make sense: 'Numeracy is increasingly important and indeed essential in modern knowledge-based societies' or 'Numeracy is always important and new!'

[4] In organizing my investigation, I have followed the approach developed in the Australian project 'Rich interpretation of mathematical ideas and techniques' (Hogan, 1997), but I apply a different theoretical framework Kanes (1997, p 263) points precisely to the implicit essentialist bias in the project's description of mathematical knowledge

[5] In mathematics education, two different meanings of the concept of 'context' are to be found I call the one *task-context* (that context which represents reality in tasks, problems, examples, textbooks, etc) and the other *situation-context* (historical, social, psychological context for teaching, knowledge and learning) - see Wedege (1999). When I only speak of 'context', I mean situation-context

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