Developing numeracy in the workplace

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Internationally, adult literacy and numeracy are in general recognized as cultural techniques. However, the two competences and their development are contested among politicians and researchers. Numeracy is often subsumed under literacy and/or described in isolation from the situational context. Adult numeracy at work is often described unproblematically as transfer from school to workplace. With reference to Bernstein's theoretical framework, we claim that adult numeracy on the labour market is a horizontal discourse, in contrast to the vertical discourse of mathematics. This article draws on the findings from an Australian study into numeracy in the context of chemical spraying and handling, utilising a methodology based on activity theory. The main findings are that mathematically straightforward skills become transformed into workplace numeracy competence, when the complexities associated with successful task completion as well as the supportive role of mediating artefacts and the workplace community of practice are taken into account.

Over the past decades, the notion of adult numeracy has risen to prominence in many countries in an attempt by governments to raise economic performance and improve social well-being. However, the term 'numeracy' is contested (FitzSimons, 2002) in relation to both literacy and mathematics, with the result that it has been largely subsumed under literacy in policy reports and international surveys concerning adults (OECD, 1995), or used synonymously with 'mathematical literacy', as in the PISA project[1] (OECD, 2002), for example. (See also Hoyles et al., 2002, which recommends that mathematical literacy be the term used to describe workplace mathematics/numeracy.) A recent Australian

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research project entitled "Chemical spraying and handling: teaching and learning numeracy on the job" shifts the emphasis firmly back to numeracy. The background of the project noted that:

> The activities of chemical preparation, application, transport, handling and storage undertaken by operative workers are high risk activities in terms of occupational health and safety of workers, their clients and in relation to environmental damage.

Chemical spraying and/or handling are major issues within the amenity horticulture, rural production, local government, outdoor recreation and warehousing industries. The study looked only at enterprises (small, medium, and large) where chemical handling and spraying was but one job function out of a much wider range of tasks. The sites included parks, vineyards, orchards, plant nurseries, golf courses, and chemical warehouses. As will be elaborated below, the tasks of chemical spraying and handling also place high demands on workers' numeracy (and literacy) skills, even though the calculations themselves appear at first glance to be relatively straightforward.

From our perspective, concepts of numeracy include computational and functional concepts as well as ideas of numeracy as social practice. Numeracy is often equated with elementary mathematics, and a "limited proficiency" vision of numeracy, with the emphasis on equipping the workforce with the required minimum skills, has proved remarkably persistent. However in the context of adult education research the purpose of adult numeracy is also considered as being for critical citizenship, empowerment and democracy (Coben, 2003).

In this article we will briefly review some of the literature on mathematics/numeracy in the workplace, and on teaching and learning in the workplace. We will then discuss the methodology and findings from the Australian research project in relation to two key questions: What is learned in the workplace, and how can this learning be analysed and described? How can practice-related learning and competence be facilitated in the workplace?

Mathematics/numeracy in the workplace

In the literature, adult numeracy is in various ways linked with mathematics – often synonymously. At the 9th international conference on Adults Learning Mathematics, John O'Donoghue discussed mathematics versus numeracy – asking the question "Mathematics or numeracy: does it really matter?" His answer was clear and affirmative. (O'Donoghue, 2002). A possible interpretation is that adult numeracy and mathematics may be distinguished with reference to Basil Bernstein's (2000) concepts of vertical discourse and horizontal discourse.

Bernstein (2000) distinguishes between two fundamental forms of discourse. In the educational field they are known as: school(ed) vs. everyday common-sense knowledge, or 'official' vs 'local' knowledge. Common sense knowledge is likely to be: "oral, local, context dependent and specific, tacit, multi-layered, and contradictory across but not within contexts" (p. 157). Mathematics is an example of a *vertical discourse* on account of its coherent, explicit, and systematically principled structure. By contrast, the knowledges of *horizontal discourses* are "embedded in on-going practices, usually with strong affective loading, and directed towards specific, immediate goals, highly relevant to the acquirer in the context of his/her life" (p. 159). Gail FitzSimons (2004, July) has argued that the construct of *numeracy* is an example of a horizontal discourse. Bernstein notes that whereas in mathematics there is a well-known hierarchy between so-called common sense and so-called uncommon sense, with numeracy common sense is of the essence. Numeracy is not necessarily explicit or precise, and its capacity for generating formal models may be limited to the context at hand rather than generalisable.

According to Bernstein (2000), the pedagogy of horizontal discourses is usually carried out face-to-face. It may be transmitted by modelling, by showing, or by explicit means. If necessary, the pedagogy is repeated until the particular competence is acquired. Bernstein continues that: "From the point of view of any one individual ... there is not necessarily one and only one correct strategy relevant to a particular context" (p. 160). He concludes that horizontal discourse "facilitates the development of a repertoire of strategies ... activated in contexts whose reading is unproblematic" (p. 160). Our observations of workplace numeracy practices resonate strongly with Bernstein's concept of horizontal discourse and its associated pedagogy.

From Denmark, Lena Lindenskov and Tine Wedege (2001, p. 5) proposed a two-pronged general definition of *numeracy* describing it as a mathematics-containing everyday competence that everyone, in principle, needs in any society at any given time:

- Numeracy consists of functional mathematical skills and understanding that in principle all people need to have.
- Numeracy changes in time and space along with social change and technological development.

Lindenskov and Wedege continue that:

> Whereas ethno-mathematics, folk mathematics, street mathematics etc. are analytically descriptive concepts of competence, numeracy can be both descriptive (what do we actually use?) and normative (what is desirable?), like other concrete concepts of competence (cultural competence, communication competence, social competence, etc.), which involve judgements and estimations based on values and norms. (pp. 15–16)

As noted above, the term numeracy is contested, and the burgeoning corpus of relevant research conducted in workplaces utilises the terms numeracy, mathematics, or even mathematics literacy – according to the orientation of the particular researcher/s. However few reports address the issue of how such competences may be learned on-site. One report by Geoff Wake and Julian Williams (2001) links workplace learning and school-based learning, but it does not address learning in the workplace per se. Up to this point, in Australia at least, several manuals have been produced to support numeracy teaching for the workplace, and in formal workplace training sessions. In Denmark, the term used in Adult Vocational Training is "professional arithmetic". However, these tend to replicate the traditional school texts with what FitzSimons (2002) describes as pseudo-contextualisations and which reflect few if any of the complexities of industrial and other workplaces (see also Wedege, 2004).

Lindenskov and Wedege (2001) propose that:

> Numeracy in the workplace can be perceived as skills and understandings charged with media, context and intention, interwoven with other competences and qualifications, interacting with the organisation of work. An instance would be the counting of items in a work situation:
>
> One does not simply count. There is a work-related aim in counting, and a certain precision is demanded. There are certain limits to the time consumption. Often one already knows the items that are to be counted. Often the shape of the items and the arrangement of the workplace will call for a special way of counting. Finally it is the organisation of work that determines who counts, controls and documents, whether it takes place individually or in co-operation, and who can suggest changes. Counting in a work context is not only counting. (p. 12)

Wedege (2004) identifies four inter-related analytical dimensions of numeracy in the labour market: the situation context (where), personal intention (why), mathematical knowledge and activity (how), and media and data (what). However, she notes that "the translation from qualifications in the workplace into qualification in school and vice versa is not straightforward" (p. 114).

There have been many definitions of numeracy in relation to adults proposed in recent years (see FitzSimons, 2004, for examples), but we identify the definition of numerate behaviour by Coben (2003) as the most appropriate in the specific context of teaching and learning numeracy on the job in the chemical spraying and handling project:

> To be numerate means to be competent, confident, and comfortable with one's judgements on *whether* to use mathematics in a particular situation and if so, *what* mathematics to use, *how* to do it, what *degree of accuracy* is appropriate, and what the answer means in relation to the context. (p. 10)

This definition is consistent with a seminal work on relationships between mathematics, society and technology in relation to school mathematics education, by Christine Keitel, Ernst Kotzmann and Ole Skovsmose (1993).

Research on workplace learning

As a discourse of education, lifelong learning assumes that learning takes place in all spheres of life, not only in schools and institutions: as *formal* and *non formal learning* in education and training programmes, in educational institutions and workplaces, and as *informal learning* in the workplace and the adult's everyday life (UNESCO, 2000).

Jeroen Onstenk (1999) differentiates between learning on the job and on-the-job training. O*n-the-job learning* is structured only by the characteristics of the work activity itself, whereas *on-the-job training* is characterised by specific pedagogical structuring elements. The work itself is affording opportunities (or not) for learning, dependent on whether the work situation constitutes a learning environment. Both the job content and the work environment can open up learning possibilities, according to Onstenk, however tensions may be experienced between work objectives and the achievement of qualifications and learning by workers. He asserts that the likelihood of learning processes occurring in a particular job situation will depend upon: (a) the available skills and learning abilities of the employee, (b) the employee's willingness to learn, (c) the on-the-job learning opportunities, (d) the availability of on-the-job training, and (e) the relationships and mutual influences of all of these. Onstenk notes that "management often still lacks an imagination for an integration of work and learning" (p. 14).

In relation to learning on the job, Michael Eraut (2004, p. 247) notes that informal learning:

- is in contrast to formal learning, suggesting ”greater flexibility or freedom for learners”,
- recognises the social significance of learning from others but implies greater scope for individual agency than socialization,
- attends to ”learning that takes place in spheres surrounding activities with a more formal overt purpose”,
- takes place in a wide variety of settings,
- can be considered as complementary to learning from experience, which is more personal than interpersonal.

Adopting an activity theoretical perspective, Toni Griffiths and David Guile (2003, pp. 58–59) offer some ideas about learning associated with work, albeit from a work experience perspective:

1 ”… [the] context (i.e. the historical organisation of curricula and work), and therefore the access provided in different contexts to artefacts and people, influences learning.”

2 ”… learning through work experience involves mediating the relationship between different kinds of knowledge and experience developed in school and work (i.e. theoretical and everyday).”

3 ”… opportunities to participate in forms of social practice, for example, using context-specific language to clarify understanding and resolve problems associated with different workplace 'communities of practice' are central to learning through work experience.”

4 ”… work experience should assist learners and educators to create new knowledge and new educational and workplace practices.”

In other words, current and historical contexts are important, as are mediating artefacts in the form of tools, equipment, conversations, manuals, and records. New workers must learn to transform knowledge gained in school and vocational education communities of practice, via social participation, into their workplace community of practice. At the same time, it is recognised that new knowledge is being created as continually evolving problems arise in the workplace.

However, Eraut (2004, p. 249) identifies some of the main problems in conducting research on informal learning:

- informal learning is largely invisible, because much of it is either taken for granted or not recognized as learning,
- the resultant knowledge is either tacit or regarded as part of a person's general capability, rather than something that has been learned,
- discourse about learning is dominated by codified, propositional knowledge, so respondents often find it difficult to describe more complex aspects of their work and the nature of their expertise.

The work of Wedege (2000, 2002, 2004) has focused on a combination of the kinds of numeracy or functional mathematical skills and knowledges (i.e., competences) required in the workplace and how adults actually learn them. In her studies, invisibility to the workers of their mathematical activities was characteristic. At a large electronics factory, Wedege observed a semi-skilled worker with many years of experience in production. She was now working in the quality control and when interviewed after the observation about the mathematics found in her work, she said: "... that's just the logic of battery hens." In this context, common sense was seen as instinct or intuition as opposed to that which has to be learned, or as self-evident as opposed to serious knowledge. Wedege (2002, p. 25) postulates five working hypotheses for study of semi-skilled workers:

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.

Having considered a selection of the literature relevant to the conduct and findings of previous research into workplace numeracy/mathematics, we now address the methodology and findings of the chemical spraying and handling project.

Methodology

The purpose of the project which is the subject of this article was to investigate numeracy practice in relation to Chemical Spraying and Handling by operative workers within the amenity horticulture, rural production, local government, outdoor recreation and warehousing industries. The research project set out to address a series of questions, e.g. including: what calculations does the chemical sprayer and/or handler need to undertake and what are the underlying mathematics concepts? How do the methods used relate to "school" mathematics? The two questions most relevant to this article are:

1 How do workers learn to do these calculations?

2 How did the workplace setting impact on how the calculations were done and how the processes were learnt by workers?

The project adopted a methodology based on activity theory, following the work of Yrjö Engeström (2001). He argues that activity theory is useful as a conceptual model in overcoming the reductionism apparent in other research paradigms, by linking the subject and object dialogically through the inclusion of culturally-based mediating artefacts, and incorporating social relations implied in the (often invisible) contexts of rules, community, and division of labour. Engeström elaborated five principles (activity system as a unit of analysis; multivoicedness; historicity, contradictions; expansive cycles) to summarise activity theory and cross-tabulated these with four questions central to any theory of learning (who are learning, why do they learn, what do they learn, and how do they learn it). In this context, the concept of learner is taken broadly, to include *all* participants in the dynamic process – not just the worker/students.

Findings

The numeracy aspects of the tasks of preparing, applying and handling chemicals require that a complex set of variables – much more complex than the simple application of mathematical skills learned in school or vocational education – must be taken into account, not only by the person responsible, but by all those workers involved in such situations. Workers need to have (and to further develop) generic competencies such as team-work, planning, communication, problem solving, and so forth. They also require basic mathematics skills of using the four processes (+, –, x, ÷), ratio, proportion and percentages; measurement and location. Critical job-specific tasks include the calculation and measurement of chemicals, taking into account variables of space, time, carrying capacity of particular tanks, and environmental scans; the calibration of equipment (with associated calculations); accurate record keeping and consultation with previous records; and efficient location of chemicals in warehouse situations.

Most of the basic calculations are taught initially in school prior to the post-compulsory years. Most, if not all, of the workers have a specialised chemical spraying certificate and the relevant calculations are revised and practised here, in (semi-) contextualised settings. That is, the students get to observe and experience actual measurement skills, but what they lack are the ongoing records of any one particular site which provide a deep sense of meaningfulness to their calculations. New workers are 'scaffolded' into the appropriate practices relevant for each of their workplaces. For example, at one large golf course, newcomers were only allowed to spray areas far removed from the greens (where mistakes could have been catastrophic) until they were considered competent in this task. At other sites, they were strictly supervised, initially, until everyone was confident that the tasks would be carried out without error.

In these workplaces, calculations are always checked in some form by another person, whether the supervisor or the tractor driver, for example. Previous experience and historical data play a big role in determining reasonableness of answers. It also determines whether and how to approximate answers. Most importantly, learning in the workplace varies from school mathematics education in that workers are always reminded to check their calculations for reasonableness, to ask repeatedly if they are not sure, and to consider their own and others' personal safety.

Estimation is always absolutely necessary, based on prior experience of the kind of spraying needed, or even of just sensible results for the novice. Common sense is of the essence. Judgements are needed as to when it is appropriate to approximate the chemical mixture and when it is not, and how this approximation may be usefully made. It is never acceptable to make a mistake in the actual process. It may threaten not only public safety but also the livelihoods of the operators and their managers. Workplace numeracy tasks are always a social-historical and cultural practice – previous experience and historical data play a big role in determining reasonableness of answers.

Discussion

In relation to learning on the job and on-the-job training, field work for the chemical spraying and handling numeracy project revealed that formal on-the-job training was in operation at some sites only. Some employers preferred new workers to complete an off-the-job certificate course; others found them to be of little relevance and conducted their own in-house training. However, informal learning on-the-job was undertaken by all participants – and took place at all levels, albeit relevant to the different levels of responsibility, and for ever-evolving problems such as experimenting with a new chemical product. This learning, directed towards the goal of correct application of appropriate sprays under optimal conditions, could take place mediated by work colleagues or supervisors; aided by product labels, manuals or internet sites, or artefacts to expedite calculations, such as ready-reckoners.

Learning in the workplace

The question "What is learned in the workplace, and how can this learning be analysed and described?" was studied in the numeracy project utilising an activity theory methodology in order to capture the range of social, cultural, and historical perspectives on activities involving all relevant participants in relation to its aims. This is in marked contrast to many earlier studies where observers and/or respondents sought to describe workplace mathematics within the parameters of lists of topics from current or experienced school mathematics curricula (FitzSimons, 2002). It is conceivable that such studies were premised on an unproblematic notion of transfer from school to workplace – in other words, a 'toolbox' mentality. More recent studies (e.g., Beach, 1999, 2000; Kanes, 2002) support the view that knowledge is not transferred but transformed, newly created in the context of use.

The experienced quality control worker from Wedege's study, mentioned above, worked in a large electronics factory producing aircraft components. The worker's general knowledge about reading and understanding workshop drawings should be applicable in a specific professional qualification which includes knowledge about subsequent use of the items that have been checked for quality. 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 particular situation, depending on her translation of the original specifications. At the time of Wedege's observation, she could also see on her computer screen that during the day the production department would be short of a certain type of connector which she is currently checking. Thus, her intention is not only to check the quality of the items, but also to co-ordinate with the other department. Later, during the interview, she demonstrated how important the context is by saying: "There is a difference between the consequence of a mistake in an air plane and a television set. It could be a matter of life and death" (Wedege, 2002).

Underlining the importance of workers having an awareness of the 'bigger picture', that is, activity systems upstream and downstream, is the work of Nicholas Boreham (2004). Discussing work process knowledge, which he describes as "a systems-level understanding of the work process in the organization as a whole, enabling employees to understand how their own actions interconnect with actions being taken elsewhere in the system" (p. 209), adds that:

> ... the knowledge that employees use in the workplace can be found in social artefacts that exist there, such as the language in use, the work routines and the organization's symbols. Human beings develop concepts collectively by using artefacts to make sense of their experiences of work, and decide how to act in these situations by following social norms that embody these concepts. (p. 214)

In the chemical spraying and handling workplaces visited, it was clear that each worker, from operator to supervisor needed to understand the interconnection of their actions within the total system of production. Observations and interviews supported the importance of artefacts, including human communication, in the learning and knowledge creation processes, as also noted by Engeström and Middleton (1996):

> Cognitive action incorporates the manipulation of artifacts and representational media in the communicative construction of socially intelligible meanings. Work practices are ineluctably communicative practices .... Work practices are mediated by technological artifacts. Artifacts range from notational systems and special vocabularies to machines and buildings. (p. 4)

They continue that expertise is viewed as an "ongoing collaborative and discursive construction of tasks, solutions, visions, breakdowns, and innovations" (p. 4).

According to Engeström (1987), incidental learning consists of non-conscious *learning operations*, embedded in the daily participation in joint work. This kind of learning happens all the time, but was not specifically part of the Australian or the Danish research questions. *Learning actions* come about through what Engeström terms 'specialized forms of transmission of knowledge' and experience. Moving from actions to activity, he notes that people must become aware of the contradictory nature of their present work activity and relate it to a future form of the work activity. This cannot be accomplished without 'a certain, special activity' – learning activity. He claims that the essence of learning activity is the production of objectively, societally new activity structures (including new objects, instruments, etc.) out of actions manifesting the inner contradictions of the preceding form of the activity in question. In Engeström's words, learning activity is *mastery of expansion from actions to a new activity.*

Clearly, the competence of numeracy is not developed and used in isolation from other generic and specific technical competences and qualifications (see, e.g., Perrenoud, 1999), but integrated with them (Wedege, 2000). Accordingly, the teaching of numeracy for and in the workplace should reflect this. In our research, workplace supervisors utilised the concept of contradictions as an implicit or explicit teaching methodology. For example, if novices were assigned the task of spraying a certain trial area and their calculated amount of spray was clearly far too little or too much, this presented a contradiction. The supervisor would then ask the novice to identify the problem and, if successful, a learning action could be said to have taken place. A learning activity would occur when the whole team managed to achieve a successful outcome under varying initial conditions, such as initiating the use of a new product, spraying around new crops or relatively unknown – and unknowable because of ever-evolving growth of weeds and indigenous species – park areas, taking account of ever-changing weather patterns, and so forth.

Facilitation of practice-related learning and competence

Drawing from the extensive range of exemplars in Eraut's (2004) eight-category typology of aspects of informal learning in the workplace, FitzSimons and Mlcek (2004) identify outstanding impressions of integral components of successful workplace numeracy learning in chemical spraying and handling as including: (a) having an awareness and understanding of the problems and risks; (b) having the confidence and knowing when to seek and gain information and confirmation from other workers, manuals, package labels, historical records, and even the internet; (c) being able to cope with the complexity of information potentially available; (d) having the ability to learn from experience; and (e) developing the teamwork skills of joint planning and problem solving.

The research shows that supervisors allowed novices restricted parameters for decision making, always under guidance, until they had a proven record of safe practice. In this way serious mistakes could be avoided, yet opportunities for reflection on misjudgements could be provided as learning experiences. This is in striking contrast to the individual focus typical of formal mathematics/numeracy education where mistakes are commonplace but without any serious consequences.

The workplace supervisors who volunteered for this research project were clearly interested in the promotion of improved workplace numeracy and, related to this, in optimal outcomes in terms of production as well as personal and environmental safety. Accordingly, they were cognisant – implicitly, if not explicitly – of the importance of workplace teaching and learning which incorporated many of Eraut's tenets on informal learning such as those listed above. Drawing on his own earlier work, Eraut posits a triangular relationship between challenge, support and confidence. Certainly support and confidence were absolutely vital in the facilitation of workplace learning for novices in chemical spraying and handling; the challenge aspect could come into play in the process of the novice becoming familiar with workplace numeracy (and other) routines or as the team works together to solve the ever-evolving workplace problems, some of which were highlighted above.

Conclusion

In this article we have utilised an activity theory perspective in the context of chemical spraying and handling to illustrate how the competence of numeracy could be developed through practice-related learning in the workplace. Drawing on Bernstein's notions of vertical and horizontal discourses, we have differentiated between mathematics and numeracy; the former encompassing skills and knowledges – generally, but not always, learned in formal education situations – which then become transformed in the creation of new knowledge in a particular context, such as the workplace or other personal or community setting. Learning in the kinds of workplace described in this article differs significantly from formal institutionalised education in that it is rich in context, supported by historical records, and mediating artefacts such as tools, equipment, manuals, charts, and so forth, as well as direct human communication of a qualitatively different kind from the school classroom. It also differs from the formal institutional learning environment in that the object is satisfactory task completion, with attention paid to ethical and legal issues of personal and environmental safety, as well as the over-riding economic issues associated with staying in business.

The literature reviewed for the project reveals that more detailed studies on the learning processes associated with the development of the competence of numeracy in the workplace are needed. One of the main factors contributing to differentiation of learning in the workplace from institutional learning is that the object of the former is the successful completion of the task at hand, with numeracy as a tool; whereas, in school and much vocational education, the object is the development of mathematical skills and knowledges, with context generally peripheral or even spurious (FitzSimons, 2002). As noted by Wedege (2002), semi-skilled workers generally only become conscious of their mathematics skills when they are not able to manage a situation; otherwise they are treated as commonsense (see also Coben, 1997).

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References

Beach, K. (1999). Consequential transitions: A sociocultural expedition beyond transfer in education. *Review of research in education*, 24, 101–139.

Beach, K. (2000). Mathematics in transition between work and school. *Adults Learning Mathematics Newsletter*, 11, 1–4.

Bernstein, B. (2000). *Pedagogy, symbolic control and identity: theory, research, critique* (Rev. ed.). Lanham, MD: Rowman & Littlefield.

Boreham, N. (2004). Orienting the work-based curriculum towards work process knowledge: a rationale and a German case study. *Studies in Continuing Education*, 26 (2), 209–227.

Coben, D. (1997). Mathematics or common sense? Some reflections on research into adults' mathematics life histories. In G. E. FitzSimons (Ed.), *Adults returning to study mathematics: papers from working group 18, 8th International Congress on Mathematical Education, ICME 8* (pp. 37–48). Adelaide: Australian Association of Mathematics Teachers.

Coben, D. (2003). *Adult numeracy: review of research and related literature*. London: National Research and Development Centre for Adult Literacy and Numeracy. [Available at www.nrdc.org.uk]

Engeström, Y. (1987). *Learning by expanding: an activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Engeström, Y. (2001). Expansive learning at work: toward an activity-theoretical reconceptualization. *Journal of Education and Work*, 14 (1), 133–156.

Engeström, Y. & Middleton, D. (1996). Introduction: studying work as mindful practice. I Y. Engeström & D. Middleton (Eds.), *Cognition and communication at work* (pp. 1–14). Cambridge University Press.

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education*, 26 (2), 247–273.

FitzSimons, G.E. (2002). *What counts as mathematics? Technologies of power in adult and vocational education*. Dordrecht: Kluwer Academic Publishers.

FitzSimons, G. E. (2004). *Adult numeracy and workplace learning*. Retrieved February 7, 2006, from http://www.statvoks.no/emma/Unpublished%20 lit%20review.pdf

FitzSimons, G. E. (2004, July). *An overview of adult and lifelong mathematics education*. Keynote presentation at topic study group 6, 10th International Congress on Mathematics Education, ICME-10, Copenhagen.

FitzSimons, G. E. & Mlcek, S. (2004). Doing, thinking, teaching, and learning numeracy on the job: an activity approach to research into chemical spraying and handling. In J. Searle, C. McKavanagh & D. Roebuck (Eds.), *Doing thinking activity learning: proceedings of the 12th annual International Conference on Post-Compulsory Education and Training* (Vol. 1, pp. 149–156). Brisbane: Australian Academic Press.

FitzSimons, G. E., Mlcek, S., Hull, O. & Wright, C. (2005). *Learning numeracy on the job: a case study of chemical handling and spraying. Final Report*. Adelaide: National Centre for Vocational Education Research. [Retrieved October 12, 2006, from http://www.ncver.edu.au/publications/1609.html]

Griffiths, T. & Guile, D. (2003). A connective model of learning: the implications for work process knowledge. *European Educational Research Journal*, 2 (1), 56–73.

Hoyles, C., Wolf, A., Molyneux-Hodson, S. & Kent, P. (2002). *Mathematical skills in the workplace. Final report to the Science, Technology and Mathematics Council*. Institute of Education, University of London and Science, Technology and Mathematics Council, London. (Available at http://www.ioe.ac.uk/tlrp/technomaths/skills2002/)

Kanes, C. (2002). Delimiting numerical knowledge. *International Journal of Educational Research*, 37 (1), 29–42.

Keitel, C., Kotzmann, E. & Skovsmose, O. (1993). Beyond the tunnel vision: analysing the relationships between mathematics, society and technology. In C. Keitel & K. Ruthven (Eds.), *Learning from computers: mathematics education and technology* (pp. 243–279). Berlin: Springer Verlag.

Lindenskov, L. & Wedege, T. (2001). *Numeracy as an analytical tool in mathematics education and research* (Publication no. 31). Centre for Research in Learning Mathematics, Roskilde University.

O'Donoghue, J. (2002). Mathematics or numeracy: does it really matter?. In J. Evans et al. (Eds.), *Policies & practices for adults learning mathematics: opportunities and risks. Proceedings of the 9th conference of ALM* (pp. 34–43). London: King's College.

OECD (1995). *Literacy, economy and society. Results of the first international adults literacy survey.* Washington: OECD Publications and Information Centre.

OECD (2002). *PISA, Programme for international student sssessment*. (Available at http://www.pisa.oecd.org)

Onstenk, J. (1999, August). *Competence development and learning at work.* Paper contributed to the European Association for Research in Learning and Instruction (EARLI 1999) symposium 'Learning and working', Göteborg, Sweden.

Perrenoud, P. (1999). Gestion de l'imprévu, analyse de l'action et construction de compétences. *Education permanente*, 140 (3), 123–144.

UNESCO (2000). *World education report 2000. The right to education, towards education for all throughout life*. Paris: UNESCO Publishing.

Wake, G. & Williams, J. (2001). *Using college mathematics in understanding workplace practice: summative report of research project funded by the Leverhulme trust*. The University of Manchester.

Wedege, T. (2000). Technology, competences and mathematics. In D. Coben, G. E. FitzSimons & J. O'Donoghue (Eds.), *Perspectives on adults learning mathematics: research and practice* (pp. 192–209). Dordrecht: Kluwer Academic Publishers.

Wedege, T. (2002). Numeracy as a basic qualification in semi-skilled jobs. *For the Learning of Mathematics*, 22 (3), 23–28.

Wedege, T. (2004). Mathematics at work: researching adults' mathematics-containing competences. *Nordic Studies in Mathematics Education*, 9 (2), 101–122.

Notes

1 Home Definition: The mathematical literacy domain is concerned with the capacity of students to draw upon their mathematical competencies to meet the challenges of the future. It is concerned with students' capacities to analyse, reason, and communicate ideas effectively by posing, formulating and solving mathematical problems in a variety of domains and situations.

The OECD/PISA definition of mathematical literacy is as follows: "Mathematics literacy is an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded mathematical judgements and to engage in mathematics, in ways that meet the needs of that individual's current and future life as a constructive, concerned and reflective citizen."

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Sammendrag

Internationalt er voksnes "literacy" og "numeracy" anerkendt som kulturteknikker. Men blandt politikere, uddannelsesbureaukrater og forskere er der langtfra enighed om indholdet i de to kompetencer, og om hvordan de udvikles. Numeracy bliver ofte underordnet literacy og/eller beskrevet isoleret fra den situationelle kontekst. Voksnes numeracy i arbejdet beskrives ofte som en helt uproblematisk overførsel (transfer) af matematiske kundskaber og færdigheder fra skole til arbejdsplads. Med reference til Bernstein's teoretiske ramme påstår forfatterne at voksnes numeracy på arbejdsmarkedet er en horisontal diskurs i modsætning til matematikkens vertikale diskurs. Artiklen er baseret på resultater fra et australsk studie af numeracy inden for kemisk sprøjtning og håndtering. Heri er metodologien baseret på virksomhedsteori. Hovedresultaterne er at rene matematiske færdigheder bliver transformeret til numeracy som arbejdspladskompetence, når der tages højde for kompleksiteten i den succesfulde opgaveudførelse ligesom det medierende artefakt og arbejdspladsens praksisfællesskab.