What can a re-analysis of PIAAC data tell us about adults and mathematics in work?

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In this study our aim was to investigate possibilities and constraints when analysing data from the international study *Programme for the international assessment of adult competencies* (PIAAC), 2012, with an interest in adults and mathematics in work. Similarly to PISA, the PIAAC study is conducted by OECD, but targeting 16–65 year olds, investigating adult literacy, numeracy and problem solving. We present findings for adults and mathematics in work through patterns that were possible to identify in a quantitative reanalysis of the Swedish background data. We also present an analysis of the background questions per se, drawing on Bernstein's competence and performance models.

In society today there is a great interest in learning, not only formally such as in school, but also in informal learning settings as in workplaces. Moreover, there is a great societal interest in trying to measure mathematics learning and knowing, e.g. through studies like TIMSS and PISA. The political effects of such investigations are criticised in educational research (c.f. Kanes, Morgan & Tsatsaroni, 2014). Simultaneously, outcomes from international comparisons inform discussions of the way forward with regards to, for example, mathematics education (Skolverket, 2014). Time, money and effort are spent in society on such large scale assessments. The most recent international comparison on mathematics and adults where Sweden took part is PIAAC, *Programme for the international assessment of adult competencies,* in 2012 (OECD, 2013) that investigated skills proficiency among adults. These comparisons would be possible to perform without the use of ICT and we address the role of ICT briefly at the end of the paper.

Our interest in this paper is on adults' mathematics in work in relation to PIAAC. Our warrant for this is that there are data sets publicly available for research, such as the answers to the background questions in PIAAC. In these questions, adults are asked about different spheres of life, including working life. The endeavour we undertook in this study was to explore the possibilities

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for learning about mathematics in work from a reanalysis of a selection of the available data, while simultaneously investigating possible constraints in what may be revealed in such analyses. More specifically, our aim was to investigate possibilities and constraints when using data from PIAAC 2012 with an interest in adults and mathematics in work, with these two questions:

1. What patterns concerning adults and mathematics in work are possible to identify through a quantitative reanalysis of Swedish data from the PIAAC 2012 background questions?

2. What characteristics of mathematics in work ”according to PIAAC” are possible to construe through an analysis of the background questions, specifically in relation to the notion of competence?

Mathematics and numeracy

Our interest in this paper is in *mathematics* both as a school discipline and as part of workplace competence (see e.g. FitzSimons, 2002). The term adopted in PIAAC is *numeracy* (OECD, 2013), which is a contested term (e.g. Jablonka, 2015; Sträβer, 2015). In short, we draw on O’Donoghue (2003) who argues for the importance of not reducing mathematics for adults to numeracy in a limited sense, such as basic calculation skills used in out-of-school contexts. He also writes that ”mathematics education should not be defined exclusively in terms of school mathematics. School mathematics cannot be treated in isolation from adult domains such as ’everyday mathematics’ and ’workplace mathematics’ ” (p. 39).

We have chosen to generally adopt the term ”mathematics in work” with an interest in mathematics taken in a broad sense (FitzSimons, 2002, 2014).

> There is not one single mathematic, absolute and infallible (Davis & Hersh, 1980/1983; Ernest, 1991; Kline, 1980, 1987) but rather a plurality of mathematics which operate on a pragmatic basis, linked to time and place. (FitzSimons, 2002, p. 15).

PIAAC presents and extensively discusses the application of skills at work. For the *numeracy test*, Swedish participants performed above the OECD average, with Sweden as number three of 22 participating countries. What is in focus in this paper, however, is an analysis of the potential application of numeracy skills in the workplace based on answers from the *Background questionnaire* in PIAAC (OECD, 2014b). Numeracy is in the framework of PIAAC described as:

> the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of a range of situations in adult life.
>
> (PIAAC numeracy expert group, 2009, p. 21)

The skills variable *numeracy* is derived from five background questions (see table 1). In the answers from the PIAAC background questionnaire, men report that they use numeracy activities in work (as they are conceptualized in PIAAC) more often than women (see table 4.5, OECD, 2013, p. 150). In most countries, workers with permanent contracts report that they apply numeracy skills more often than workers with temporary or short-term contracts (see table 4.14, OECD, 2013, p. 159). Clerical support workers, technicians, professionals, and managers report using numeracy more often than average. On the other hand, in occupations like machine operators and assemblers; craft and trades workers; service and sales, workers report use of numeracy skills less often.

From the background questionnaire (OECD, 2014b), PIAAC also reports results on use of numeracy at work from the individual countries participating in the survey. The following are a few pertinent results. One is that Sweden (together with Norway) reports the lowest average use of numeracy at work. Another result is that Sweden has a larger than average gender difference in the mean use of numeracy, although it is smaller than in the other Nordic countries. And, thirdly, Sweden reports an average level of use of problem solving at work on a par with the other Nordic countries.

Mathematics as part of workers' competence

Competence is in this paper understood as a wholeness which is seen as something other than *competency* which reflects a more fragmented perspective on knowing (Wedege, 2001). According to Wedege (2001), competence is always linked to a subject (person or institution) and it concerns a readiness for action and thought, based on knowledge, know-how, and attitudes/feelings. Furthermore, competence is a result of learning processes in both everyday practice and education and it is always linked to a specific situational context.

In analyses of workplace data, it is clear that one dimension of mathematics as part of workplace competence is the notion of *being critical* (see Askew, 2015, pp. 707–709). One example is the way that lorry loaders in a study by Björklund Boistrup & Gustafsson (2014) remained critical of the plans in a loading list set up by administrators, since the plans were not always possible to accomplish due to reasons of security, dimensions of goods, etc. In parts of the literature there is also an emphasis on respect for the complexity of mathematics in work (Askew, 2015; FitzSimons, 2002, 2014; Sträβer, 2015) and the role of mathematics in adults' life worlds (Henningsen, 2006; Wedege, 2001, 2013).

Data collection and analytical framework

The analyses for question 1 are based on data from PIAAC public use files (OECD, 2014d). The Swedish PIAAC dataset comprises 4469 persons. Tables are created with the SAS-system using the Swedish dataset prgswep1.sas7bdat. Variables are identified from the *International codebook PIAAC public use file methods and variables* (OECD, 2014a). Information on use of mathematics in work was contained in the six items GQ03_b–GQ03_h used by PIAAC to create the skills variable *numeracy*. We also included the item GQ01_h (reading of tables and graphics) from the literacy panel.

Table 1. *Items for the measuring of mathematics use at work*

G_Q03b:	How often – Calculate prices, costs or budgets
G_Q03c:	How often – Use or calculate fractions or percentages
G_Q03d:	How often – Use a calculator
G_Q03f:	How often – Prepare charts, graphs or tables
G_Q03g:	How often – Use simple algebra or formulas
G_Q03h:	How often – Use advanced math or statistics
G_Q01h:	How often – Read diagrams maps or schematics

In the PIAAC survey the two items ”simple algebra or formulas” and ”advanced math or statistics” were explained as follows:

> By simple algebra or formula, we mean a mathematical rule that enables us to find an unknown number or quantity, for example a rule for finding an area when knowing length and width, or for working out how much more time is needed to travel a certain distance if speed is reduced, and more advanced math or statistics such as calculus, complex algebra, trigonometry or use of regression techniques.
>
> (G_Q03g and G_Q03h, OECD, 2014c)

For question 2 the data consists of the same questions in the background questionnaire as were analysed for question 1, but here we focused on the *wordings* of the questions themselves. We discuss the findings in relation to the framework of PIAAC as described above. In the analysis for question 2 we have compared background questions of PIAAC drawing on the competence and performance models from Bernstein (2000; see also FitzSimons, 2002; Tsatsaroni & Evans, 2015). The two models are described here albeit, by necessity, briefly. Likewise, ours is not a complete sociological analysis, but can be seen as an initial analysis and discussion of what can be learned, or not, from results of background questions in a study like PIAAC. Bernstein (2000, p. 45) presents the discourse of *competence model* the following way:

> Pedagogic discourse issues in the form of projects, themes, ranges of experience, a group base, in which the acquirers apparently have a great

> measure of control over selection, sequence and pace. […] [The evaluation orientation has an emphasis on] the realisation of competences that acquirers already possess.

The competence model of Bernstein (2000) is coherent with how we described workplace competence in a previous section. Drawing on FitzSimons (2000), our assumption is that the competence model as a learning discourse is dominant within many workplaces. The discourse in this model is often in the form of *projects*, including a range of practical *experiences*, along with theoretical underpinning knowledge. The term project can here refer to everyday work-tasks where mathematical aspects are interwoven with others. The lorry loaders mentioned previously, drew on various knowing to accomplish the loading of a trailer (as an example of project at work), such as estimation of space, length, calculations, as well as knowledge about rules, logistics for the driver, and also about compression of the load, etc. In the competence model, learners (including adult workers) generally have *control* over the situation within the framing of the work-task. The *performance model* by Bernstein is quite different from the competence model:

> Pedagogic discourse here issues in the form of the specialisation of subjects, skills, procedures which are clearly marked with respect to form and function. […] [The evaluation orientation has an emphasis on] explicit texts. Acquirers have relatively less control over selection, sequence and pace. Acquirers texts (performances) are graded, and stratification displaces differences between acquirers. (Bernstein, 2000, p. 45)

The *performance model* of Bernstein is most often what characterises formal mathematics education (FitzSimons, 2002). In this model it is not about what a person can accomplish as part of a wholeness, but rather about *skills* that are *clearly marked with respect to form and function*. Learners do not have much *control* over the situation (e.g., in selection, sequence and pace) and, when it comes to evaluation, the focus is on what is missing rather than what is present.

Patterns concerning adults' mathematics in work

Table 2 shows the self-reported use of mathematics at work for the employed sector of the Swedish population 2012.

In table 2 *often* is defined as *at least once a week*. Use of a calculator is the most common activity at work reported, with more than half of the respondents answering that they use a calculator at least once a week and one third using it on a daily basis. One third of the respondents report that they use or calculate fractions or percentages, i.e. engage in some form of arithmetic, and one third report that they *often* read diagrams, maps or schematics at work. More than half of the respondents report that they *never* use simple algebra or formulas at

Table 2. *Self reported use of mathematics at work (%)*

How often	Calculate prices, costs or budgets	Use or calculate fractions or per-centages	Use a cal-culator	Read diagrams maps or schema-tics	Prepare charts graphs or tables	Use simple algebra or formu-las	Use advanced math or statistics
Never	45,7	34,8	21,8	30,3	58,0	52,9	81,9
Less than once a month	16,1	15,4	12,5	20,4	19,4	15,2	11,0
Less than once a week but at least once a month	12,1	12,1	13,1	15,8	12,5	10,3	3,9
At least once a week but not every day	12,8	18,4	23,8	18,8	7,6	11,5	2,3
Every day	13,4	19,4	28,8	14,6	2,4	10,2	0,9
Often*)	**26,2**	**37,8**	**52,6**	**33,4**	**10,0**	**21,7**	**3,2**
Often (men)	29,5	45,4	60,0	42,3	13,1	26,7	4,8
Often (women)	22,5	29,4	44,7	23,8	6,7	16,3	1,5

Note. * Often is defined as at least once a week. Source: PIAAC Public Use Files prgswep1.sas-7bdat, G_Q03b–h, G_Q01h

work (as explained previously). One respondent out of five uses simple algebra or formulas at least once a week; and four out of five of the respondents report that they never use more advanced mathematics or statistics, such as calculus, complex algebra, trigonometry or regression techniques. Three per cent use advanced mathematics at least once a week and less than one in ten prepare charts graphs or tables at least once a week.

To get a richer picture, we have examined how the answers on use of mathematics in work are related to *gender* (see table 2). For all mathematical activities men report a more extensive use of PIAAC-mathematics than women. One could surmise that the difference between men and women stemmed from the gender segregated labour market where men and women come from different areas of study and work in different sectors of the economy. A gender gap in favour of men using mathematics is found in almost all countries (OECD, 2013) but, as previously noted, Sweden has a larger than average gender difference in the mean use of PIAAC-mathematics, although it is smaller than in the other Nordic countries

We also analysed the reported use of mathematics in work in relation to answers on questions about *problem solving* at work. It is not possible to determine whether respondents use mathematics (simple or advanced) in problem solving from the PIAAC data, but it is possible to examine the extent to which respondents who state that they solve problems at work also indicate that they use mathematics (calculations not shown). Use of advanced mathematics and statistics does not seem to play a major role in either complex or simple problem solving. Among those who indicated that they often dealt with advanced problem solving, only 5.5 % in total used advanced mathematics at work and only one out of three uses simple mathematics. For simple problem solving the corresponding figures are 4.0 % who use advanced mathematics and only one in four use simple mathematics. Conversely, almost half of the respondents who reported that they often used advanced mathematics, rarely solved complicated problems at work. Self-reported use of advanced mathematics has thus, in the PIAAC study, only a weak link to problem solving.

PIAAC-mathematics: competence or performance

As noted above, the analysis for question 2 about the characteristics of the background questionnaire utilised a selected aspect of Bernstein's (2000) framework. Tsatsaroni and Evans (2015) conducted a related analysis on the items in the numeracy test, whereas we have not examined the items themselves, but only the background questions.

As we noted above, the competence model by Bernstein (2000) appears as the most relevant for many workplaces, where ”projects” in which different knowing is integrated into a wholeness are common and where experience and contextual knowledge are essential. Generally, adult workers have far more control of the situation and work task at hand than a student still in school. Following this, it could be expected that questions to adults about mathematics in work would share the characteristics of the very same competence model. However, this is not the case.

Looking at the PIAAC-definition again, we analysed this as vaguely reflecting a competence model (our insertions in italic): ”the ability to access, use, interpret, and communicate mathematical information and ideas, in order to engage in and manage the mathematical demands of *work-life as one of many contexts*” (OECD, 2013). This describes something very similar to Wedege's (2001) definition of competence (discussed above), and it is also close to the competence model of Bernstein (2000).

When analysing the background questionnaire we cannot find any questions that reflect mathematics (or numeracy) as part of complex workplace situations. More often the focus is on *separate, disconnected skills* which are vaguely described, such as calculating prices, using a calculator, preparing charts, or using simple algebra. There is no clear connection to *projects* such as those commonly found in working life; decision making is included but with only a focus on limited *procedures*. On the whole, our analysis finds that the background questions in PIAAC on the mathematics supposedly reflecting work actually fit more closely to Bernstein's (2000) (school mathematical) *performance model*.

Our findings from this limited analysis correspond to a great extent with those from the study by Tsatsaroni and Evans (2015), and hence we can conclude that both tasks and background questions fit the performance model of Bernstein (2000). Here we find a tension between the PIAAC performance model and the actual competence needed in work where mathematics knowing is just one aspect of any worker's workplace competence.

Finally, in this section we want to draw the attention to the name of the PIAAC study: Programme for the international assessment of adult competencies. The last word, *competencies*, may be misleading to, for example, policy makers since it has a resemblance to the word competence. On the contrary, competencies (*competency* in singular), as opposed to the term *competence*, are (drawing on Wedege, 2001) actually about the performance of skills and procedures, which align closely with the performance model of Bernstein (2000) rather than the competence model.

Concluding discussion

In this discussion we return to the aim of our study which was to investigate possibilities and constraints when using data from PIAAC 2012 with an interest in adults and mathematics in work. We emphasise that there are possibilities in such a reanalysis, especially for finding new areas for further research. In the study, patterns were revealed regarding adults' possible use of mathematics in work. One such pattern is the low number of respondents reporting use of PIAAC-mathematics in work, and where Sweden (together with Norway) reports the lowest average use. This can be compared to the findings of several qualitative studies. One example is the lorry loaders, described previously, who adopted various mathematics containing activities in their work (see e.g. Björklund Boistrup & Gustafsson, 2014).

In the background questionnaire, PIAAC includes the reading of diagrams, maps, or schematics in the literacy domain (OECD, 2014b). However, a number of the problems in the domain of mathematics in work are also concerned with the reading of graphs and tables. This might reflect an ambivalence in the PIAAC investigation, that the reading of graphs and tables is classified to be in both the literacy and the numeracy domains. Accordingly, an area of future research could be the reading of graphs and tables in school mathematics and/or language studies, and how this is connected to out-of-school contexts such as workplaces.

A noteworthy pattern arising from our analysis in question 1 concerns gender. Men generally reported a more extensive use of PIAAC-mathematics than women. We contend that this analysis of the responses to the PIAAC background questionnaire reveals a pattern, which really is important to investigate further.

The constraints in our reanalysis are clearly captured in our analysis for question two, on the characteristics of mathematics in work ”according to PIAAC.” In our findings we have described how limited the conceptualisation of ”PIAAC-mathematics” is in comparison with the complexities that are part of actual work and of the competences of workers. We construed related constraints when we did the analysis of reported problem solving in the analysis for question one. As described in our findings, there was a weak link between reported problem solving at work and use of PIAAC-mathematics. We certainly do not claim that all problem solving is clearly based on mathematics. Drawing from research such as Björklund Boistrup and Gustafsson (2014), we do assume a stronger link than shown by PIAAC. However, since the questions posed in the background questionnaire – and in the items in the numeracy test (Tsatsaroni & Evans, 2015) – do not reflect the complexity of mathematics in work, and thereby not the actual realities of workplace contexts for the respondents, these results are what might be expected. More research is needed in order to problematize how investigations like PIAAC continue to maintain a limited view on adults and mathematics in contexts such as workplaces.

It would be a considerable challenge to construct a questionnaire which truly reflected a competence model of mathematics in work (which would actually mean higher validity (see Tsatsaroni & Evans, 2015)), rather than a performance model, while also meeting the demands of reliability. ICT creates the possibility to perform these kinds of international comparisons but the demands of measurement create a discourse where what is possible to measure becomes the most important consideration (and also act as a constraint), at least, in the case of this paper, for how mathematics in work is "viewed." A question worthy of further problematisation is whether the practices of large international studies like PIAAC are worth the costs in comparison to what might otherwise be gained.

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