Numeracy and mathematics education in vocational education: a literature review, preliminary results

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Numeracy and mathematics education in vocational education is under pressure to keep up with the rapid changes in the workplace due to developments in workplace mathematics and the ubiquitous availability of technological tools. Vocational education is a large stream in education for 12- to 20-years-olds in the Netherlands and the numeracy and mathematics curriculum is on the brink of a reform. To assess what is known from research on numeracy in vocational education, we are in the process of conducting a systematic review of the international scientific literature of the past five years to get an overview of the recent developments and to answer research questions on the developments in vocational educational practices. The work is still in progress. We will present preliminary and global results. We see vocational education from the perspective of (young) adults learning mathematics.

Keywords: Numeracy, mathematics, vocational education, VET .

Introduction

Practical background / Our aim

Vocational education in the main stream of the educational system in the Netherlands (preparatory vocational for 12- to 16-year-olds and specific vocational for 17- to 21-year-olds) is on the brink of bringing the curriculum up-to-date to the needs of the current society and the contemporary workplace. In the 1990s the curriculum was built around four domains: numeracy, algebra, geometry & measurement, and information processing & statistics. In that timeframe the curriculum was considered quite modern and ahead of developments in other countries, mostly caused by the Realistic Mathematics Education movement which was inspired by the “mathematics is a human activity” -approach by Hans Freudenthal (Gravemeijer, 1994).

In the 2010s, however, from an alleged low level of arithmetic skills of the students, a strong top-down ministerial policy was introduced by adding to the existing mathematics curriculum a separate numeracy/arithmetic programme with a digital nation-wide summative examination. After 10 years of piloting and political quarrels, this path was abandoned again.

Now new paths are explored to see whether the vast body of knowledge on mathematics for the workplace and mathematics for the future citizens can provide valuable clues for a modern, relevant and effective numeracy or mathematics curriculum for students who will work with mathematics in very practical situations and who will have to deal with the quantitative world around them. From this perspective the students in vocational education are seen as young adults who can benefit from the body of knowledge collected around adult mathematics education.

From this perspective we started a review of the most recent literature on numeracy in vocational education.

Theoretical background

For a theoretical background, we address the following issues:

- Societal changes
- Shifts in mathematics education
- Previous reviews

To start with, there are major societal and policy pressures on (mathematics) education to prepare young learners and school leavers for a complex and technologised society. In literature, these new educational goals are referred to as *21st century skills* or *21st century competences (Voogt & Pareja Roblin, 2012)*, *global competences* (OECD, 2016) or the *4th industrial revolution (Schwab, 2016)*. Common among the concepts mentioned above is the acknowledgement that across education, government, and business, the skills and knowledge needed to succeed in work, life and citizenship have significantly changed in the 21st century. As workplaces are being transformed, the skills and knowledge workers now need are intertwined with technology. New means of communication and types of services have changed the way individuals interact with governments, institutions, services and each other, and social and economic transformations have, in turn, changed the demand for skills as well.

These major societal and policy pressures translate also into pressures on mathematics education to prepare young learners and school leavers for a complex and technologised society. For instance, PriceWaterhouseCoopers (2015) reported recently that businesses “competing in a global economy driven by data, digital technologies and innovation will need more employees trained in science, technology, engineering and mathematics (STEM). Research indicates that 75 per cent of the fastest growing occupations now require these skills” (PWC, 2015, p. 4). Similarly, in their recent 2017 review, the National Council of Teachers of Mathematics (NCTM) (2017), stated that “Today mathematics is at the heart of most innovations in the information economy. Mathematics serves as the foundation for STEM careers and, increasingly, careers outside STEM, and mathematical and statistical literacy are needed more than ever to filter, understand and act on the enormous amount of data and information that we encounter every day” (p. 6). Many of the mentioned changes are related to technological developments, particularly information and communications technologies (ICT), and have profoundly altered what are considered to be the key knowledge and skills that individuals need as economies and society continue to evolve.

There is a growing body of knowledge on the desired numeracy and mathematics competences in workplaces (D. Coben et al., 2010; Geiger, Goos, & Forgasz, 2015; Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002; Hoyles, Noss, Kent, & Bakker, 2010; Straesser, 2015; Wake, 2015). Consistent in the reported results are conclusions which boil down to the observation that the mathematics tasks which people undertake at work in the 21st century involve more than plain calculation skills or straightforward procedural proficiency. Nowadays, workplace practices involve sophisticated mathematical problem-solving skills and the ability to recognise and engage with the mathematics embedded within multifaceted, real-life workplace settings. Many 21st century workplace mathematics requirements and practices are integrated with technology. Hoyles et al. (2010) argue that this requirement for mathematical capabilities is driven by the need to improve production processes and productivity, and that there will be greater demand for what they call 'techno-mathematical literacies'. This involves "a language that is not mathematical but 'techno-mathematical', where the mathematics is expressed through technological artefacts" (Hoyles et al., 2010, p. 14). Furthermore, the pressures for moving toward the teaching and learning (and assessment) of 21st century skills include a consistent demand for students to be digitally and technologically competent, to be able to engage with technology in all its guises, and to be highly ICT literate (Voogt & Pareja Roblin, 2012).

There have been a few recent reviews on related topics. At the start of this century Coben (2003) did a comprehensive review on adult numeracy focusing on research and related literature. The results of this review are relevant to our research questions as far as vocational education can be considered as (young) adults who are learning mathematics. This is indeed the perspective we chose.

The main conclusions from Coben's review were:

- Numerate practices are diverse and deeply embedded in the contexts in which they occur.
- The transfer of learning between contexts is problematic.
- The impact of adult numeracy tuition is under-researched and more detailed studies are required.
- Adult numeracy teacher education needs continuing professional development.

At the same time, Falk and Millar (2001) conducted a review of research on literacy and numeracy in vocational education and teaching from an Australian perspective. Their main conclusions were:

> Significant and multiple implications for literacy practice have emerged from forces for change such as globalisation and technological advancement. (…) Adult and Community Education (ACE) and VET sectors have been merged to a large extent. These changes have had important consequences for the way practitioners carry out their work. (Falk & Millar, 2001, p.3)

The overall picture of adult education and vocational education and training (VET) is that it is a rapidly developing field with a strong focus on connecting mathematics education to the world around us. Effective practices to incorporate these ideas in courses and educational programmes are still under-researched.

Research questions

In the Netherlands a broad curriculum reform has started which includes redefining the mathematics curriculum in vocational education. This review is also intended to collect scientific results of research on vocational policies and practices to support this process and make it more evidence-informed.

To get a better grip on how the concepts of numeracy and mathematics are used in the international scientific community our first research question is:

1. Which concepts of numeracy (or mathematics) are used in research in a vocational context?

Furthermore, we are interested in well-researched practices in mathematics or numeracy education in vocational tracks or streams. Hence our second and third research questions:

2. Which numeracy teaching practices are described in research in a vocational context?

3. Which effects of numeracy teacher practices are reported in research in a vocational context?

The review of literature is still ongoing. The results we report in the results section are preliminary and still quite general.

Method

Search terms

We conducted a systematic review (Gough, Oliver, & Thomas, 2017; Petticrew & Roberts, 2016) of the research literature through the definition of search terms derived from the research questions.

In various countries the concept numeracy is used when referring to the mathematical activities in the vocational classroom, for instance in Australia. In The Netherlands two words are used to distinguish the more basic numeracy as is taught in primary education (Dutch: rekenen) and the more advanced use of mathematics as is taught in secondary education (Dutch: wiskunde). In most countries, however, mathematics is used to refer to all the kinds of activities which deal with the numbers, patterns and structures in the vocational education or in the workplace.

Regarding the specific part of the educational infrastructure we are focusing on, two labels are used most common to refer to this specific kind of education which prepares students for the workplace. These labels are "vocational education" and VET, which is short for vocational education and training. So our main logical string of search terms is:

Search string = (Numeracy OR mathematics) AND ("vocational education" OR VET).

Search engines and databases

We used our search string in a variety of educational databases which together assemble most international educational research: WorldCat, ERIC, PsycInfo, Web of Science, Scopus, and Education Research Complete.

Scope

We narrowed down our search using the following limitations:

- Scientific literature
- Published in peer-reviewed journals
- English language
- Recent, last five years, date of publishing: 2014-2018 or 2014+.
- Search terms present in title, abstract, or keywords.

Further narrowing down

The search-string led to 611 hits in the selected databases. There were several ways in which we narrowed down the amount of initial hits (see Figure 1).

First, the articles in this 'technological catch' were brought together, deduplicated and checked for obvious mishits, such as articles on veterans or veterinarian issues. This resulted in a set of 477 articles to be considered by experts.

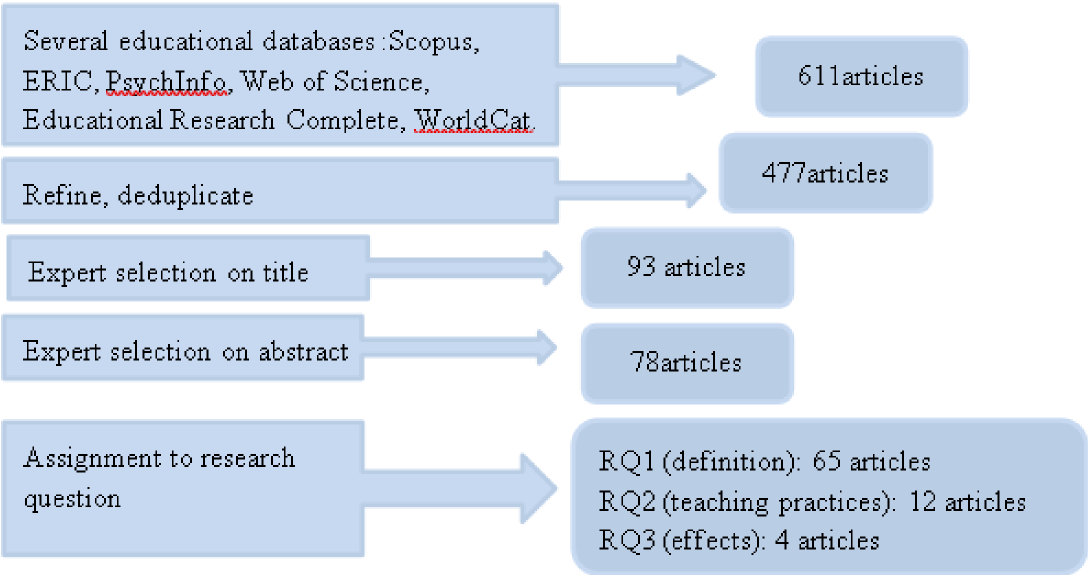

Figure 1: Search strategy and remaining articles after each step

Second, the first expert screening followed, based on the titles of the articles. Three experts scored independently whether the article was supposed to be relevant for the three respective research questions. For each a score 1 (relevant), 2 (possibly relevant), 3 (maybe relevant) or 9 (not relevant) was given. After this, articles with three 9-scores by each experts (i.e., not relevant for any of the research questions) were discarded from the selection. This reduced the set to 93 articles remaining. Third, the abstracts of the remaining articles were scored by three experts, again independently. The experts decided from the content of the abstract whether they supposed the article to be relevant for either of the three research questions. After this, again articles with three 9-scores by each expert (i.e., not relevant for any of the research questions) were discarded from the selection. This reduced the set to 78 articles remaining.

Fourth, the 78 articles were linked to the respective research questions to be examined further: 65 articles were judged to be relevant for research question 1 about the definition of numeracy, 12 articles seemed relevant to answer research question 2 about teaching practices and 4 articles were scored as relevant for research question 3 on the effects of teaching practices.

Fifth, the full text of the remaining articles are being analysed for relevant sections which can be used to answer the actual research questions. This analysis is ongoing.

Cross-referencing and snowballing

In the next phase of our research, we will cross-reference our set of relevant sources with Google Scholar, which is nowadays considered to be the search engine which uses the most comprehensive database of products from the scientific community. However, the ways to refine searches in Google Scholar are still rather limited.

In a preliminary analysis of the remaining articles we found multiple references to specific books and journal specials (for instance, ZDM 2015, 47-4, and Educational Studies in Mathematics 2014, 86-2) of particular interest for our research questions. In a later stage of our research we will add some of these sources to the set of sources we use as corpus to answer the research questions.

Results

The review is ongoing. The results and conclusions in this paper must be read as preliminary findings.

Regarding research question 1 - on the used definition of numeracy - we found that a large part of the articles address policy matters, like comparative studies (for instance PIAAC), country policies, regional and school policies, most of the cases assuming the definition of numeracy from the PIAAC framework as the working definition. In articles, which were not on policy matters, in roughly half the cases the definition of numeracy is not explicitly defined, making it difficult to value the inferences made from the gathered data. This problem will be elaborated in a later article.

Regarding research questions 2 and 3 – on actual practises - , the major conclusion is that from the found hits and relevant articles only a very few are addressing actual educational practices on numeracy in vocational education (12 of 477) and even fewer (4 of 477) report on effects of educational practices or interventions. Most of the 12 articles addressing educational practices describe observations in classrooms, providing conclusions and implications for education based on these observations. These articles tend not to be on describing current teaching practice and their effects, but in most cases report on how the authors would like to see the teaching practice change. The importance of real context in education for transfer of the numeracy-skills and motivation of the students is emphasized.

Some themes are reoccurring in the selected articles. First, all articles describe the importance of connecting numeracy to work-related situations. This transfer or boundary crossing is important since students can solve mathematical problems in class, but often do not recognize these problems in work-related knowledge; the integration of mathematics and statistics learnt in school with work related knowledge is a problem (Bakker & Akkerman, 2014). Wake (2014) speaks about 'hidden mathematics'; workers (and students) do not recognize mathematical situations as such and therefore do not use school knowledge in work-situations. Dalby and Noyes (2015) as well as Coben and Weeks (2014) stress the use of 'real work' problems in which students can use mathematics as a tool, instead of the mathematics they know as a school subject. Contextual math provides motivation since students experience the need of it for their own work. According to Bakker and Akkerman (2014) students themselves report to appreciate a work-related approach and claim they learned a lot in only five one-hour meetings. Second, a reoccurring theme is problematic transfer from numeracy interventions to practice. Ter Vrugte et al. (2015) show in their research how in a math computer game proportional reasoning increases, but analyses of transfer problems showed that there was no measurable transfer. They conclude students in vocational education have trouble applying school knowledge in another context. Van Schaik, Terwel and Van Oers (2014) describe a science workplace in which students have to build a trike. This article shows how numeracy is predominantly hidden in other subjects, like science. And also in science transfer is difficult for teachers to achieve. When given a practical assignment, students seem to forget the need to apply the knowledge they learned before, but also teachers do not always teach their students the missing school-math when they need it and connect the classroom knowledge with the practical assignment.

Only four articles provide experimental research in which a specific teaching practice, differing from the regular approach is being implemented. These articles are too small in number and too divers to find trend-setting answers to our third research question.

Conclusion and Discussion

When we used the search string (Numeracy OR mathematics) AND ("vocational education" OR VET) is used in Google Scholar for products since 2014, we found 16,500 hits. There is no lack of output around these themes. Refining the sources to a corpus of relevant literature from which some conclusions could be drawn or trends could be discerned is not a straightforward task. The sources are multifaceted and of very different quality, scope and choice of themes.

The articles are from dozens different journals, which reflect the multifaceted character of both the concepts numeracy and vocational education. It also reflects that the research area is young, not well- established and literally 'all over the place'.

The definition of numeracy used in the articles is influenced heavily by the work around the PIAAC Numeracy Framework. In that sense the PIAAC programme has a formatting power on the development of the concept of numeracy.

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