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Building bridges between school mathematics and workplace mathematics

Rune Herheim and Suela Kacerja

Western Norway University of Applied Sciences, Norway; rher@hvl.no, skac@hvl.no

In this paper, we investigate three examples from two articles written by lower-secondary students in which they identify school mathematics used in workplaces. Their articles are written as part of a project aiming to help students find mathematics relevant. The students provide documentation on advanced use of graphs, mean values, calculations, and formulas in two occupations, music management and physiotherapy. By using Evans' (1999) approach to transfer, we identify similarities and differences between school mathematics and workplace mathematics. In line with Evans' approach, we aim at building bridges between school mathematics and workplace mathematics.

Keywords: Workplace mathematics, school mathematics, building bridges, transfer, relevance.

Introduction

When doing research and following up student teachers in school practice, we hear students say “maths has nothing to do with my life”, “I don’t need maths”, and “maths is something we do in school”. These statements are in line with Masingila’s (2002, p. 37) study in which a majority of the students “think mathematics is synonymous with school mathematics”. Wager (2012, p. 10) built on this by saying that students often do not see “the connection between the mathematics in which they engage in school and the mathematics they experience out-of-school”. The national curriculum in Norway and other countries, e.g. the US common core state standards, specify that students should be able to apply the mathematics learnt in school to the workplace. However, as English (2010, p. 36) argued, “we need further knowledge on why students have difficulties in applying the mathematical concepts and abilities ... outside of school”.

When doing mathematics in school, students often ask “why do I have to learn this?” (Hernandez-Martinez & Vos, 2018, p. 245) or “when will I use this?” (Willoughby, 2017, p. 877). Answers like “you are going to have mathematics next year as well, you know” and “because we have a test coming up” (cf. Onion, 2004), do not address the core of the questions. On the contrary, they might explain the student statements in the first paragraph. Alrø, Skovsmose, and Valero (2009, p. 15) asked eighth grade students what they used mathematics for outside school, and the most frequent answer was “to do homework”. If the only purpose of learning mathematics is to do homework or to be prepared for future teaching and tests, then it is easy to understand from such circular reasoning why students question the relevance of mathematics. Hernandez-Martinez and Vos (2018) argued that students need answers regarding how, why, where, and what mathematics will be relevant because it is so closely related to their motivation to learn and to what extent they see the usefulness of what they learn. Hernandez-Martinez and Vos see usefulness as a property of the mathematics being learnt, and relevance as the potential connection between the mathematics learnt, its usefulness, and the student.

It might seem odd that mathematics, a field of knowledge so vital for today's society, has difficulties being regarded as relevant. However, being able to give qualified answers regarding the relevance of mathematics involves detailed knowledge of the mathematics required to perform an occupation. One cannot expect teachers to investigate a range of different workplaces in order to always have an answer when students question the relevance of a mathematical topic. Gaining insight into what extent the mathematics learnt in school is relevant to life outside school is a challenge for teachers and educators, like FitzSimons and Boistrup (2017) and Nicol (2002) found in their studies. This relevance challenge and the importance of connecting ideas and building on students' out-of-school experiences and understanding when working with mathematics in school, constitute the rationale behind the *Workplace mathematics project* referred to in this paper. About 60 lower-secondary students, three of their teachers, and a researcher (the first author of this paper) investigated what mathematics their parents/guardians needed in order to perform their work. The students then wrote articles about their findings with the help from their teachers and in collaboration with the researcher.

By investigating two of the student articles, this paper addresses the following research question: *What school mathematics are the students able to identify in the workplaces?* The analysis focuses on identifying and discussing similarities and differences between mathematics at school and at workplaces and provide a foundation for discussing potential transfer and relevance of school mathematics. We do this by presenting and extending the mathematics the students identified in two workplaces, music management and physiotherapy.

Theoretical perspectives and previous research

In the following, we clarify how the national curriculum links school mathematics with the working life and give a brief overview of perspectives and terms for out-of-school mathematics. We elaborate on the concept of workplace mathematics and on the gaps and potential transfer between school mathematics and workplace mathematics.

Links between school mathematics and working life in the national curriculum

In the Norwegian mathematics curriculum, mathematical competence is considered important for understanding and influencing what happens in society and for “pursuing further education and for participation in working life and recreational activities” (Ministry of Education and Research, 2010, p. 2). Problem solving and modelling are emphasised, and rich experiences with mathematics are regarded as an important foundation for lifelong learning. In addition, the ability to work with mathematical concepts, methods, and strategies to solve problems also “involves learning to pinpoint and describe situations where mathematics is involved” (p. 5). This is defined as an important part of mathematical competence. Thus, being able to identify the use of mathematics is considered as vital for strong mathematical competence in the national curriculum. The workplaces investigated in the project serve as rich contexts for identifying and making sense of the mathematics used.

Perspectives and terms for out-of-school mathematics

There are multiple perspectives and terms in mathematics education research regarding the contextualization of school mathematics and links between school mathematics and out-of-school experiences. *Realistic mathematics* is used to focus on creating meaningful and realistic situations in which students can learn mathematics (Freudenthal, 1991). *Genuine* or *authentic mathematics* concerns real-life situations brought into the mathematics classroom, strongly, but not necessarily, linked to mathematical modelling (e.g. Palm, 2008). *Everyday mathematics* focuses on identifying everyday situations where mathematics is used (e.g. Nunes, Schliemann, & Carraher, 1993; Masingila, 2002). *Workplace mathematics* is used by researchers who study the mathematical knowledge and skills required to do certain work processes (e.g. Hoyles, Wolf, Molyneux-Hodgson, & Kent, 2002; Wake & Williams, 2001; Wedege, 2006). The perspectives presented have a key aspect in common – they study the potential links between school mathematics and out-of-school mathematics. The project presented in this paper takes the workplace mathematics perspective.

Workplace mathematics and transfer

In UK, two groups of researchers have investigated mathematics in workplaces from different points of view. Hoyles et al. (2002) studied seven different workplaces focusing on the mathematical knowledge and skills required of the employees and identified several mathematical skills as important in different occupations. Wake and Williams (2001) identified general mathematical competences applied in many occupations that also could be incorporated in the mathematics curriculum. Summarized, the competences and skills identified by the two groups of researchers were using proportions and percentages, handling data, using graphs, diagrams, and other tools and interpret them, modelling and solving problems, calculating and using formulas, recognizing anomalous phenomena, and doing extrapolations.

On the other hand, there are also hindrances for identifying the use of mathematics outside school. Workplace mathematics is situated and has to be combined with knowledge about the work to perform required tasks (Hoyles et al., 2002). It can be hidden caused by automation of processes and division of labour, and the nature of school mathematics can cause challenges as well (Williams & Wake, 2007). There are several differences between school and workplace mathematics that can hinder students recognizing mathematics in workplaces, Wedege (2006) argued. She identified seven categories that describe a gap several adults had experienced between workplace mathematics and school mathematics. The differences start at the number level. In the workplace, numbers have units of measurement, calculations have to be constructed, and there are often multiple solutions. In school, numbers often occur without units, the numbers as well as calculations are given, and there is only one correct solution. Solving tasks in the workplace requires collaboration and dealing with disturbing factors, it offers opportunities to use mathematics, and solutions have consequences. Solving tasks in school is often individual work without disturbing factors, and real-life contexts are used merely to create a need for using mathematics and solutions have therefore no practical consequences.

However, the hindrances are surmountable. Wake (2013, p. 315) proposed a new mathematics curriculum to overcome the challenge of transfer “by placing the study of how mathematics models

reality at the core of the curriculum". This curriculum should give students the possibility to make sense of, and develop further, the models of others. Wake considered the research done in workplace mathematics as rich initial contexts to be used by teachers who support inquiry in the classroom. Evans (1999, p. 23), when writing about transfer between mathematics in school and everyday life, linked relevance with transfer by arguing that "if schooling is to be relevant ... we need some account of how learning from the school can be ... 'transferred', to other contexts". He emphasised the importance of building bridges for transfer between school and out-of-school activities by identifying fruitful overlapping and inter-relations, and by analysing similarities and differences.

Method

The background for the students articles: the Workplace mathematics project

The project was a collaboration among the teachers, the students, the students' parents/guardians, and the researcher. The teachers contacted the researcher because they wanted to do a project that could help their students see the relevance of mathematics. The teachers' idea of visiting parents/guardians' workplaces to document the use of mathematics was embraced by the students, and more than twenty parents/guardians attended an information/kick-off meeting. The parents/guardians were excited by the idea, they expressed a positive attitude towards mathematics, and agreed to be visited and interviewed. The meeting tuned them into the project and was important in order to go beyond Hoyles, Noss, Kent, and Bakker's (2013) finding that visible workplace mathematics tends to be fragmented, routine-based, and mostly simple calculations.

The students were trained to interview, document, and do pre-investigations by the researcher and the teachers. They were encouraged to gather information about the occupation, the particular workplace, and the interviewee's duties, and identify concrete examples of mathematics being used. The students were grouped in pairs and triads, they decided their approach and interview questions, and then they interviewed, observed, and collected documents and photos. One of the teachers or the researcher joined most of the groups. Many of the parents/guardians had prepared information and examples when the students came. In 2017, after working with data handling, collecting supplementary data, and editing articles according to feedback from the teachers, the researcher, and the parents/guardians, the first student articles were published in a national journal for mathematics teaching. The researcher finished the articles, extended some of the examples, and added reflections on links between the students' examples and the competency aims in the national curriculum.

Analytical approach

Evans' (1999) approach to transfer, in terms of similarities and differences, is used as analytical lens to investigate what school mathematics the students were able to identify in the work done by the physiotherapist and the music management duo. The identification of similarities are discussed according to the skills identified by Hoyles et al. (2002) and Wake and Williams (2001), and the identification of differences are discussed according to Wedege (2006). These similarities and differences are used to shed light on a potential transfer of mathematics between school and

workplaces. The examples in this paper are chosen because they are interesting and contain mathematical details that make it possible to identify links to school mathematics.

Description and analysis of workplace examples from students' articles

We now present three examples and discuss the mathematics involved. The first two examples come from a music management duo (Tronstad, Graff, & Herheim, 2017). They work with several artists, and one of their main tasks is to help artists make a living of music. An essential question concerns deciding where artists should sell their music: streaming, CD, or both? Figure 1, made by the researcher based on information collected by the students, shows the sales in Norway for CDs and streaming. In 2011, the graphs intersected, and streamed music generated for the first time more money than CDs. The CD sales continued to drop, but in 2014, there seems to be a trend change.

To make a qualified decision on this requires critical reflections based on mathematical understanding by the music managers. In line with Hoyles et al. (2002) and Wake and Williams' (2001) findings, they have to handle data, understand and interpret a graph, and understand the point of intersection of the two curves in terms of income. They have to predict a trend and make a decision based on past data – typical tasks within predictive modelling. Based on these reflections, they can make knowledge-based decisions of where to sell their artist's music. However, in line with Wedege's (2006) findings on differences between mathematics in school and in workplaces, this workplace example includes disturbing factors and the use of measurement units. Furthermore, it actually requires use of mathematics, and it is a decision that has potentially huge economic consequences.

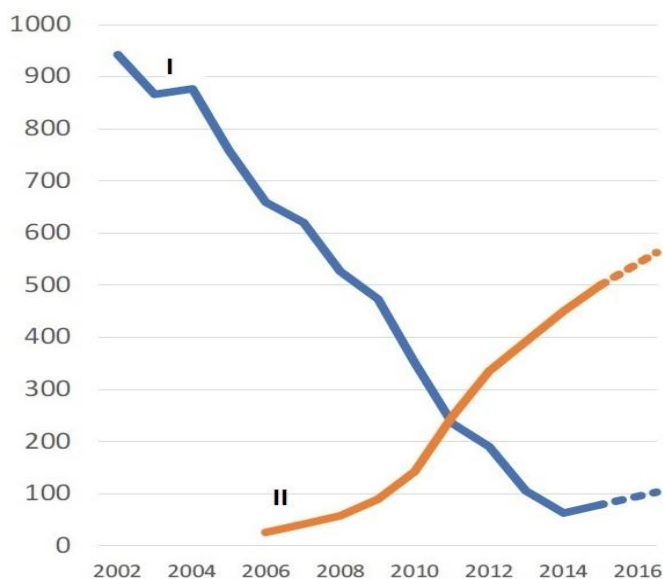


Figure 1: The sales in Norway for CDs (graph I) and streaming (graph II) in million NOK

Another aspect is the income generated from having a song played on the radio. In one of the radio channels in Norway, artists earn 60 NOK/minute. If a song lasts three minutes and 23 seconds, you get the following calculation: $3 \times 60 + (23/60) \times 60 = 203$ NOK. If the song is played 200 times/month, it provides an income of $200 \times 203 = 40600$ NOK. This resembles common calculations in school. However, there are also several differences. The managers have to find many of the numbers themselves, set up an expression including fractions, calculate it correctly in order to know the potential profit, manage different measurement units such as seconds and minutes in the same formula, and deal with practical unit rates such as NOK/minute and times/month. Again, there is an extensive use of measurement units. To summarize, in these two examples, the music managers have to apply all the competences and skills on Hoyles et al. and Wake and Williams' list. In addition, they need to gain an overview of these elements as parts of a complex system where

several factors can influence their decisions such as where to sell the music, marketing, and arranging tours.

The third example comes from a physiotherapist's work with elderly and their walking ability (Berrefjord, Haugland, Nilssen, & Herheim, 2018). When a patient walks across a mat with sensors connected to a computer, a range of functional walking data is registered. The students identified a need for the physiotherapist to integrate mathematics and ICT skills as Hoyles et al. (2002) did. One issue is walking variability, arrhythmic or twitchy walk, and in order to investigate this one needs step times in seconds (see table 1):

Step no.	1	2	3	4	5	6	7	8	9	10	Mean	SD
Left	0,8		0,79		0,8		0,83		0,88		0,82	0,033
Right		0,86		0,82		0,81		0,81		0,77	0,81	0,029

Table 1: Step times

Collecting the ten step times in seconds, five for each foot, makes it possible to calculate the mean values and standard deviations (the physiotherapist and the researcher calculated the standard deviation because this is not part of the students' curriculum):

$$\bar{x} = \frac{0,8 + 0,79 + 0,8 + 0,83 + 0,88}{5} = \frac{4,1}{5} = 0,82$$

$$s = \sqrt{\frac{(x - \bar{x})^2}{5}} = \sqrt{\frac{(0,8 - 0,82)^2 + (0,79 - 0,82)^2 + (0,8 - 0,82)^2 + (0,83 - 0,82)^2 + (0,88 - 0,82)^2}{5}} \\ = \sqrt{0,0011} = 0,033$$

This example shows the need for dealing with decimal numbers, for setting up formulas and calculate correctly, for systematizing and presenting data, and for using statistical concepts such as mean and standard deviation. Standard deviation is frequently used by researchers to quantify the amount of variation of a set of data. Here, it gives the physiotherapist vital information about the extent to which a person's walk is unstable and influences how the physiotherapist should proceed with the physical treatment. Such use of standard deviation exemplifies that mathematics has practical and concrete consequences. The importance of correctly knowing and using mathematics becomes more visible for the students, and can help them find answers to their relevance questions.

Discussion and concluding comments

Building bridges between school mathematics and workplace mathematics, helping students see the relevance of mathematics as something more than just being able to do homework and prepare for tests, is a challenge documented by several researchers (e.g. Alrø et al., 2009; Onion, 2004). Students struggle to see connections between school mathematics and out of school mathematic (Hoyles et al., 2002; Nicol, 2002; Wager, 2012; Williams & Wake, 2007), and they find it difficult to apply mathematics outside school (e.g. English, 2010). Teachers have difficulties answering questions from students on why they "have to learn this" and when they will ever need it (Hernandez-Martinez & Vos, 2018). A possible remedy is to include genuine real life tasks, e.g. tasks situated in workplace contexts, as resources more often in the mathematics curriculum. This is

one way of overcoming the differences between workplace mathematics and school mathematics identified by Wedege (2006).

In contrast to the above-mentioned challenges, the Workplace Mathematics project generated multiple examples of how school mathematics is necessary in several workplaces, e.g. the use of tables, graphs, units, mean values, calculations, and formulas. This is emphasised by the national curriculum as important for developing mathematical competence. Connections between school mathematics and its usefulness in real life were documented, including information about what kind of mathematics was used, where and how it was used, in addition to why it was needed in the workplaces.

By searching for similarities, the students also identified differences between school and workplace mathematics. The workplace tasks were more complex, had numerous units of measurement, there were several potential useful methods and not one definitive answer, and finally yet importantly, doing mathematics wrong could have severe consequences. Although Wedege argued that such differences can create a gap between school and workplace mathematics, they can also help students develop a more flexible, nuanced view on mathematics. Identifying similarities and differences makes it possible to build bridges between school mathematics and workplace mathematics, as Evans (1999) suggested, and through this explicate the relevance of school mathematics.

The parents/guardians took part in a kick-off meeting, they were enthusiastic, and several of them were prepared when the students came. This was important for the documentation of numerous examples on how school mathematics is used in different workplaces. The students experienced that school mathematics was used and had practical consequences. Such outcomes can be used to positively influence students in viewing mathematics as relevant, and this constitutes a valuable contribution to their learning and motivation for school mathematics (Hernandez & Vos, 2018). Including links between school and workplaces in the mathematics curriculum can provide fruitful, joint reference points for students and teachers when doing tasks and make working with mathematics more meaningful. Furthermore, the examples can be used to build bridges between school and workplace mathematics by discussing e.g. the importance of choosing appropriate representations for mathematical concepts in a specific situation and moving flexibly between different representations. We therefore argue that engaging students to identify workplace mathematics is worthwhile. However, further research is needed to find ways to help students “explore how mathematics can be transformed to meet the needs of a range of diverse situations” (Wake, 2013, p. 315).

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