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Mathematics at the enterprise: Industry, university and school working together to facilitate learning

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Based on a pilot study, this paper reflects upon how the industry, university and school can work together to facilitate learning of mathematics. Through a project called MathEUS (Mathematics at the Enterprise, University and School) a modern energy recovery enterprise, Returkraft, the University of Agder and a school collaborated to offer pupils (in 8th and 9th grade) an opportunity to engage with mathematics contextualized at an enterprise. Through comparing the 2015 edition with our re-design in 2016, we discuss the outcome of the project. In particular, we focus on the factors necessary for such a project to succeed. Findings suggest that mathematics contextualized at an enterprise as an isolated event has limited value. Further, findings seem to indicate that working together with the enterprise over time, by including a pre-project, strengthens pupils' experience of mathematics as a relevant subject.

Keywords: Diversity, relevance, authenticity, out-of-school contexts, enterprise.

Introduction

Diversity in mathematics education relates to political, cultural and linguistic aspects. In this paper, the issue of diversity will be addressed in terms of different sites where mathematics education potentially could take place. Meaney and Lange (2013) emphasize the importance of transitions between different contexts and that such transitions “can be a fairly minor issue for learners if they perceive similarities in what knowledge is valued and how learners and others should interact together and with the mathematical content” (p. 169). Throughout the decades, a growing body of research has been carried out, focusing on the learning of mathematics in different contexts (Masinglia, Davidenko, & Prus-Wisniowska, 1996). By linking mathematical tasks to an enterprise, we hope that the pupils experience mathematics as important, also outside the classroom, and in turn this influences their motivation for learning mathematics at school. In Norway, there has been an increased focus on how mathematics could be taught in ways that is perceived by pupils as relevant and more related to their own reality and experiences (Det Kongelige Kunnskapsdepartement, 2011). Diversity in teaching methods and arenas of learning has been important issues in this debate (Norges offentlige utredninger 2015, p. 8). Pupils in Norway are mixed together heterogeneously until grade 10 and with the curriculum focus being academic, offering pupils few perspectives on, for example, vocational and professional practice. In the attempt to diversify such experiences, we found that the processes going on at the energy recovery enterprise, Returkraft, bear the potential of visualizing mathematics at a working place. Further, *Mathematics at the Enterprise, University and School* (MathEUS), in some sense should be regarded as a response to the identified need of moving the teaching of mathematics in a more practical and vocationally-oriented direction. The last two years (2015 and 2016) funding from Regional Research Fund Agder enabled research to be carried out on the

MathEUS project. In this paper, we pose the following research questions: 1) *Which factors are of importance in the collaboration between school and industry for the pupils to experience the mathematics involved as relevant and authentic?* 2) *What might prevent the pupils for experiencing the project as relevant and authentic?* Our discussions focus on the differences in outcome between the first year and the redesigned project run in the second year.

Theoretical background

The idea that learning is *situated* within a certain context and practice was in many ways coined by Lave and Wenger (1991) and in mathematics education, research has shown that the environment in which activities takes place is of great importance for the outcome (Nunes, Schliemann, & Carraher, 1993). In the MathEUS project, mathematics is contextualized and linked to the activities at an energy recovery enterprise, Returkraft. *Situated* in this case alludes both to the physical environment at Returkraft (which surrounded the pupils while they were doing their activities) and to the mathematical content, which was consequently linked to the enterprise. By establishing this link between content and context, it is our aim that the mathematical tasks and activities provided appear more *relevant* and *authentic* to the pupils. When applying the concept of relevance, we draw on the work of Hernandez-Martinez and Vos (submitted) where the main point is that “it involves a judgment of value that is made by a person involved in the activity” (p. 26) and that the “judgment is connected to the motive or object that drives the activity” (p. 26). Nyabanyaba (1999) and Dalby (2014) point to the complexity of the relevance concept in mathematics by listing a number of different ways mathematics could be conceived of “relevant”, depending on contextual, content-related and affective factors. Authentic has to do with the nature of the activity and has several somewhat distinct definitions. In the case of MathEUS, we find the definition from Gulikers, Bastiaens and Martens (2005) to be useful, “An authentic learning environment provides a context that reflects the way knowledge and skills will be used in real life” (p. 509). Here both the contextual aspect and the use value are emphasized, which is fully in line with the purpose of the MathEUS project. To achieve the goal of authentic tasks, considered relevant to the pupils, we aimed also to overcome some of the typical challenges that guided tours of enterprises often entail. Recent research, both national and international, shows that the “classical” excursion day, where pupils use a day to visit an enterprise in terms of a guided tour, is often disconnected to what they normally do at school and leads to some didactical challenges. The pupils easily become passive, engaging in artificial and low-quality tasks (like memorizing and duplicating information posters) due to the lack of preparatory and follow-up work (DeWitt & Storksdieck, 2008; Remmen & Frøyland, 2014).

Methods

In 2015, two schools were participating, each with one secondary class of 9th grade pupils (14-15 years old).

The implementation of the MathEUS project

The schools’ visiting day at Returkraft took place in March on two different days, one day for each class. Before the day of visit, student teachers completing a master degree at the university had designed and prepared mathematical tasks for the pupils. After a guided tour at Returkraft, the student teachers constructed the tasks over a period of two weeks, and during this period staff from Returkraft was available for helping them with information concerning the enterprise. Teachers from the

participating schools were also available for commenting on their suggestions. The premises for these tasks were that they should in some way be linked to the enterprise at Returkraft. These tasks were given to the pupils on their day of visit, and they were given approximately two hours to work with the tasks in groups of four to six pupils. The tasks were solved in a ‘classroom’ at Returkraft. Following an evaluation of MathEUS as it had been carried out in 2015, we decided to make some changes in an attempt to improve the project (see also the section “results and discussion”). We wanted to strengthen the quality of the tasks so that the pupils experience them as more relevant. In addition we wanted the pupils’ experience with Returkraft and the mathematics they engaged with to be more than just an isolated event. Aiming towards this, we invited the class to take part in a pre-project (lasting for six weeks), with a representative for Returkraft coming to their class early in the semester to initiate the following assignment: “How can we improve peoples’ habits, when it comes to sorting their garbage for recycling?” To solve this assignment, the pupils developed questionnaires and went out to different geographical locations to interview people about their sorting habits. Due to the lack of responses during oral interviews the pupils posted the questionnaires on social media, and the number of response escalated rapidly. Their empirical data were treated in spread sheets, resulting in different diagrams, and the results were presented at the university in front of an audience consisting of both the student teachers and employees from Returkraft. In turn, this pre-project served as an important source for the student teachers when they designed the tasks for the pupils. In 2016, one secondary class of 8th grade pupils (13-14 years old) participate in the project.

Methods and data collection

We (the authors of this paper) were responsible for carrying out research and at the same time we planned the implementation of the project together with the participating schools and employees from Returkraft. We also provided the framework conditions for the student teachers’ elaborations of the tasks. The pupils, the student teachers, the teachers (at the participating schools) and the employees at Returkraft all served as informants for our research. In this paper, we mainly focus on data from the pupils. Conducting research at the same time as we are responsible for carrying out the project situates us within the domain of *action research*. Bryman (2012) describes this as “an approach in which the action researcher and client collaborate in the diagnosis of a problem and in the development of a solution based on the diagnosis” (p. 709). We conceive of this definition to be in line with our agenda, where we use data from our experiences to discuss, develop and improve the forthcoming editions of the project.

To measure parts of the outcome of the MathEUS project, we developed a web-based questionnaire which the pupils should answer after the project was carried out. Except from minor changes and some reformulations, we used the same questionnaires both years of research, for the sake of comparison. The questions were mainly statements that the pupils were asked to scale from 1 to 6, based on their “degree of agreement” and in total there was 34 statements to be evaluated. Mainly these statements aimed to inform our research questions mentioned earlier in terms of measuring the pupils’ own experience of their learning outcome, their motivation and beliefs and whether they consider the project meaningful and relevant. In addition, some open ended questions were posed where the pupils had the possibility to comment on these aspects. Since two school classes were involved in 2015, and just one in 2016, the sample size varied and in 2015 there was 44 respondents to the questionnaires, while 23 responded in 2016. But in 2016 we collected some additional data by

including a semi-structured interview with three of the pupils. These pupils were randomly selected among those who volunteered when we visited the class. In this interview, we went deeper into the pupils' own experiences related to the project, and to the content of the tasks and activities provided for them by the student teachers. Both in 2015 and in 2016, interviews involving representatives from the three collaborators (the enterprise, the university and the schools) were conducted, mainly focusing on the outcome of the project. Both years we made observations and voice recorded all the group work sessions at Returkraft. As part of our research, we also conducted interviews with some of the student teachers responsible for designing the tasks.

Results and discussion

Since the scale on our questionnaires ranges from 1 to 6, we sort the results in two halves for the sake of overview. The “low achieving” half ranges from 1 to 3 and the “high achieving” half ranges from 4 to 6. Figure one gives an overview of some of the questions we consider as most significant.

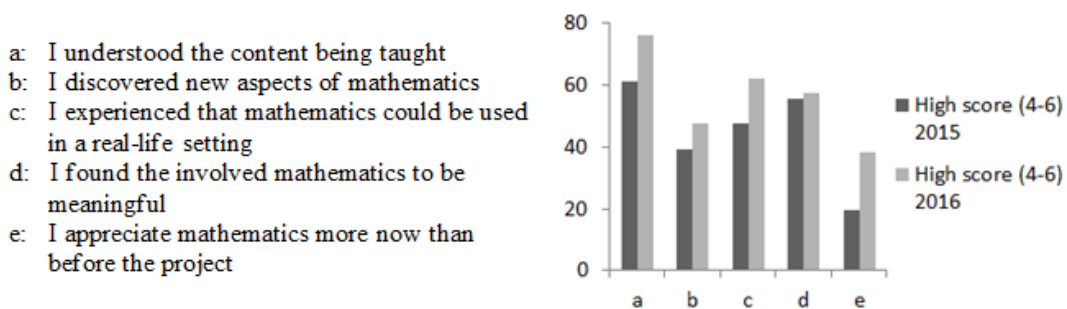


Figure 1: Pupils scaling (in per cent) in 2015 compared to 2016

One can observe from the first columns in the diagrams (1a) that the majority of the pupils both years felt that they understood the mathematics being taught. About half the pupils felt that they discovered new aspects of mathematics in the 2016 edition of MathEUS, a slight improvement compared to 2015 (1b). An improvement related to the experience of mathematics used in a real-life setting is visible (1c), while the experience of mathematics as being meaningful is almost unchanged (1d). Finally, there is a clear improvement on almost 20 per cent related to the appreciation of mathematics as a consequence of the MathEUS project (1e). Since the number of pupils forming the basis of these results is limited and varying one should be careful to draw strong conclusions only from this data set. But since statements in the questionnaires consequently were higher rated in 2016 compared to the year before, a positive trend could be suggested. In addition to the scaling of different statements, there was also a possibility for the pupils to add comments and give some additional justifications for their scaling. In 2015, about half the pupils wrote critical comments, especially related to the question of whether or whether not their expectations had been fulfilled. “I thought they would try to make this fun”, “it was extremely boring, tiring and difficult maths” and “I thought we would learn more. The tasks were just like a typical maths tests”, serve as examples of such comments. Despite that 43 out of 44 pupils in 2015 expressed themselves positively about learning mathematics at a working place, about half of the pupils responded in negative terms related to the question about the fulfilment of expectations, in line with the previous quotations. These comments mainly implied that a negative experience with the content of the tasks. Even though the tasks were designed with the purpose of being relevant, in terms of creating a link between school mathematics and the enterprise, the pupils did not seem to perceive this the same way. Dalby (2014) emphasizes that even though a realistic

context is provided, the impact on pupils can vary since “the context itself is often no more than a metaphor to illustrate an aspect of pure mathematics rather than authentic use of a scenario as a source of mathematics” (p. 90). In the aftermath of MathEUS in 2015, we saw that several of the student-designed tasks could represent examples of contextualized tasks, but with little authenticity.

Task 3 – payments

When the trucks arrive, the garbage is deposited in a big container. We know that each year about 130 000 tons of garbage arrives at Returkraft. Returkraft is paid for receiving our garbage. Juliette works at the counting department. Now you are going to help Juliette with the bill for Lillesand County. The prize is 1750 kroner for 1 ton of garbage.

- a) How much do they have to pay for 2 t (tons) of garbage?
- b) How much do they have to pay for 4 t (tons) of garbage?
- c) What relations do you observe, between the numbers indicating the tons of garbage and the bill that the county receives?

Excerpt 1: Excerpt from task, 2015

The task above serves as an example of a task where the context was reduced to serve only as a metaphor, rather than an authentic use of Returkraft as a source of mathematics.

When revising MathEUS 2015, we wanted to improve especially on two aspects: 1) Make the content of the tasks more relevant and authentic for the pupils and 2) Engage the involved pupils and student teachers earlier in the process, so that the visit to Returkraft became something more than just an isolated event. In this process, we build on DeWitt and Storksdieck’s (2008) “boarder visions on field-trips” (p. 181) and their research-based conclusions that field trips and out-of-school context ought to be embedded in teaching, more holistically. Even though their focus was on natural sciences, we found these ideas to be relevant for mathematics and in the 2016 edition of MathEUS we included a pre-project (as described in the “methods” section). Due to the pre-project, the student teachers designed tasks were also used earlier in the process.

From the web-based questionnaires, illustrated in figure 1, there are some indications that pupils’ experiences in general were more positive in 2016 compared to 2015. Interviews with some of the pupils, also involved statements that could be interpreted as having to do with relevance and authenticity.

Interviewer: Earlier in the interview, you said something about “mathematics in practice”...was this something which characterized the tasks at Returkraft, or did you feel that you just as well could have done this at school?

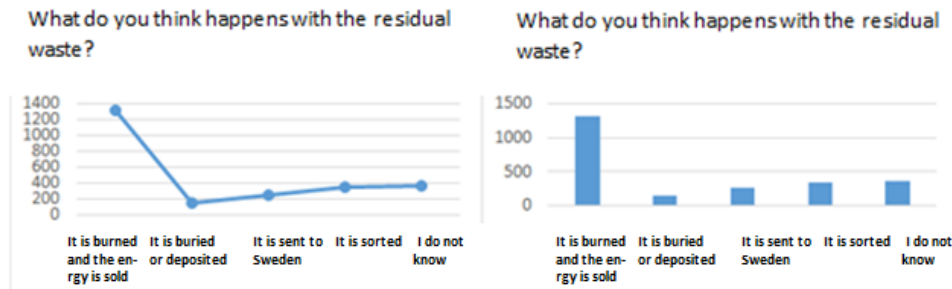
[...]

Pupil: Since we had been to Returkraft and the content was about Returkraft, and the numbers used were the same as we had learned about...the numbers weren’t just made up, in a way.

This pupil emphasizes the experience of working with “real” tasks, in terms of pointing to a close connection between the context and the content of the tasks. Since the student teachers had followed their pre-project and had access to all their results and data, they were also able to build on pupils’ own data from the pre-project when designing the tasks, and in this case provided a more authentic context.

Task 6 - diagrams

This example is from your survey. Discuss what type of diagram you want to use and why:



Excerpt 2: Excerpt from task, 2016

By using numbers from the pupils own pre-project, this task illustrates how one student teacher applied these data to discuss statistical issues. Based on observations from the pupils engaging with this task, we see this as an example of successfully creating a link between the context and the mathematics involved. Pupils judged this as “relevant” since an authentic connection between the mathematics involved and the context is provided in terms of linking the task to something familiar, namely their pre-project.

From this relatively brief analysis, we suggest that pupils’ experience of relevance, and the authenticity of tasks provided in an out-of-school context not only depends on the tasks themselves, but also on the pupils’ possibilities to *relate* to the content. For the context to “reflect the way knowledge and skills will be used in real life” (Gulikers et al., 2015, p. 509) a preparatory phase, where pupils are offered the possibility to become familiar with the context seemed to be advantageous.

Conclusions

Providing out-of-school contexts like excursions and field trips are, unfortunately, often being carried out as isolated, stand-alone events (DeWitt & Storksdieck, 2008; Remmen & Frøyland, 2014). There are few reasons to believe that this is different in mathematics. Our findings tend to show that if mathematics in out-of-school contexts is treated like stand-alone activities, the outcome when it comes to authenticity and pupils’ experiences of relevance is limited. Pupils’ experience of relevance changed in a positive way when a preparatory phase in terms of a pre-project was implemented. Nyabanyaba (1999) argues that pupils and teachers’ conceptions of relevance often differ. In line with this, we suggest that even though mathematics in out-of-school contexts through excursions days at enterprises as stand-alone activities is carried out with good intentions from teachers, such activities ought to be more substantiated in teaching. Authenticity entails reflection on knowledge and how it could be used in real life (Gulikers et al. 2015) and for such a reflection to happen, Meaney and Lange (2013) point to the necessity of being able to make transitions between these different contexts. From our experience a pre-project substantiates the out-of-school context and better prepare the pupils for the subsequent visit to the enterprise. Hence, the connection between the mathematical content and the context provided are perceived by pupils as more relevant. “Making connections between mathematics and life that appear authentic and convincing for students” (Dalby, 2014, p. 91) serves as core criteria in the question of relevance and learning, also when it comes to the subject of mathematics.

Implications and possibilities

From a societal and political perspective, this paper addresses issues concerning the contextual nature of mathematics teaching and learning. One aspect is the pupils' outcome of experiencing mathematics in an out-of-school setting, but in a boarder perspective, MathEUS also contributes to strengthen the bond between school and industry, which according to Sjaastad (2013), is "too weak" (p. 16).

The results and reflections in the wake of the two previous editions of MathEUS serve as a basis for further developing our collaboration strategies. We found that by involving the enterprise at an early stage, pupils to a larger extent were able to make connections between the context and the mathematical content. The pre-project also entailed interdisciplinary activities, where mathematics became an important contributor and ICT was applied by the pupils as a crucial tool in the process of visualizing their findings. The interplay between mathematics and natural sciences in particular played a significant role in the pupils' activities, both during the pre-project and at their visiting day at Returkraft. The topic concerning recycling of garbage also links our project to local and global environmental issues. People's attitudes towards recycling of garbage, were a valuable outcome also for the enterprise, as Returkraft aims to reach out to the public with messages concerning the importance of such issues. These are all, from our point of view, valuable synergistic effects worth looking deeper into. Task-design is a topic of research on its own, and the process of developing tasks and activities within this particular context could also be worth mentioning as potential, forthcoming research.

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