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## **From designing to implementing mathematical tasks: Investigating the changes in the nature of the T-shirt task**

Claire Vaugelade Berg<sup>1</sup>

### ***Introduction***

From looking at research literature it is possible to see that research on design, implementation and analysis of mathematical tasks is an actual theme: there is a special issue of the Journal of Mathematics Teacher Education (2007) with Anne Watson, John Mason and Orit Zaslavsky as editors (Watson and Mason, 2007), a book published by Clarke, Grevholm and Millman (2009) concerning “Tasks in primary mathematics teacher education” and under ICME 11 in Mexico (2008) the title of one of the Topic Study Groups was “Research and development in task design and analysis”. In addition several substantial research projects conducted in the United States focus on this issue. For example the QUASAR project (Quantitative Understanding: Amplifying Student Achievement and Reasoning), involving a group of researchers (Stein, Smith, Henningsen & Silver, 2000), aimed at improving mathematics instruction for students by emphasising thinking, reasoning, problem solving and the communication of mathematical ideas. One of the central aspects of their research was to focus on the use of instructional tasks in project classroom and they proposed the elaboration of “the mathematical tasks framework” where the kinds of thinking needed to solve tasks were referred to as “cognitive demands”. They reported on observations concerning the change of cognitive demands during a lesson where “a task that starts out challenging ... might not induce the high-level thinking and reasoning that was intended as the students actually go about working on it” (Stein et al., 2009, p.xviii). This aspect is also address by Artigue (1994) arguing that it might be tempting to implement too quickly development products arising from research into products for teaching. She characterises the processes related to the transmission of products from didactic engineering in terms of distortions and she emphasises the distinction between the activities of conducting research and of engaging in teaching. My aim, in this article, is to follow Artigue’s argumentation and to investigate, trace and characterise the distortions of a specific mathematical task (the T-shirt task) from its design by a group of didacticians at University of Adger (UiA) to its implementation by two different teachers. This research is situated in a larger research project conducted at (UiA), the *Teaching Better Mathematics* project (TBM).

The structure of the article is as follows: First I present central aspects of the TBM project and emphasise the theoretical constructs of didactical aim and pedagogical means. I also introduce the methodological approach adopted in the project. Then I turn to an example and explain how the T-shirt task was designed by didacticians at UiA and how it was implemented by a teacher from primary school and by a teacher from lower secondary school. Finally, I discuss the results and present implications for further collaboration between didacticians and researchers.

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## ***Central aspects of the TBM project***

### **Co-learning agreement with teachers**

The aims of the TBM project are reflected in the title: *Teaching Better Mathematics*. First it promotes to develop better understanding and competency in mathematics for pupils in schools (Better Mathematics), and second to explore and develop better teaching approaches (Teaching Better) as a means to achieve the first aim. The nature of the project is developmental research and we collaborate with in-service teachers from 4 kindergarten, 6 primary and lower secondary schools and 3 upper secondary schools. Our collaboration with teachers is organised around workshops, approximately 4 – 5 per year, and school visits during which a didactician get the opportunity to observe the nature of the impact the project had on the participating schools. In the project we see teachers and didacticians as working together as co-learners (Wagner, 1997). This implies that both teachers and didacticians are engaged in action and reflection, and by working together, each has the opportunity to develop further understandings of the world of the other and of his/her own world. In addition, we are all, teachers and researchers from the university, engaged in researching and developing our own practice and this is the reason why I use the term “didacticians” for the group of researchers at UiA, since we consider all participants are researchers (Berg, in press). Thereby through our collaboration with teachers we, as didacticians, might learn about the teachers’ teaching practice in schools and, at the same time, about our own research practice. Central to the project activity is the design of mathematical tasks, by the didacticians at the university, as a means for engaging collaboratively with the teachers in mathematics. This engagement takes place between teachers and didacticians during the workshops regularly organised at UiA, and between teachers and pupils in the classrooms during their teaching practice. Teachers often take mathematical tasks which were presented during the workshops and adapt them to their own teaching practice (Berg, 2010).

### **Theoretical basis of the TBM project**

The theoretical basis of the TBM project is elaborated from two fundamental ideas: community of practice as developed by Wenger (1998) and the idea of inquiry (Jaworski, 2010). By using the notion of *community of practice* I can refer to the activities in which we, teachers and didacticians, are engaged, and are mainly related to learning, teaching and didacting. In addition, the idea of *inquiry* enable us to consider a *community of inquiry* within which we use inquiry as a tool in all aspects of our practice and aim at developing “inquiry as a way of being” in practice (Jaworski, 2004). The idea of inquiry refers to asking questions and recognising problems, seeking for answers and solutions, and at the same time wondering, exploring and investigating the activity we are engaged into while looking critically at what we do and what we find. In the TBM project inquiry is addressed at three different levels: at the first level, inquiry in mathematical tasks in relation to pupils’ mathematical learning in classrooms, at the second level, inquiry in the developmental process of planning for the classroom and exploring ways of developing better learning environments for pupils in mathematics, and at the third level, inquiry in the research process of systematically exploring the developmental processes involved in the two previous levels (Jaworski, 2007). The first level refers to the collaboration in classrooms between a teacher and his/her pupils, the second and the third levels address the collaboration between teachers and didacticians/researchers.

### Theoretical basis of the research

My aim with this article is to conceptualise the collaboration between didacticians at the university and the teachers working in schools in terms of Activity Theory (Engeström, 1999). Central to this approach is the idea of *activity*, a term which has a precise meaning. According to Leont'ev

... in a society, humans do not simply find external conditions to which they must adapt their activity. Rather these social conditions bear with them the motives and goals of their activity, its means and modes. In a word, society produces the activity of the individuals it forms. (Leont'ev, 1979, pp. 47-48)

Thereby the key idea is that human activity is motivated by the sociocultural and historical processes of society and comprises mediated goal-directed actions. Furthermore, Leont'ev proposes a three-level explanation of the idea of activity: First human activity is always stimulated by a motive. Second, human activity is rooted in actions which enable the subject to realise her activity through achieving the goal of each action. Finally, each action is realised through operations which are dependant of the conditions associated with the action. In the TBM project, our activity, as didacticians, is to work collaboratively with teachers on developing mathematics and the teaching of mathematics in order to learn more about the role played by our community of inquiry and inquiry processes both in relation to teachers' teaching practice and to our own research practice. Concerning our actions and goals, the design of mathematical tasks for workshops is one of the actions our group is engaged with. As a consequence, the workshops conducted by the didacticians from UiA are understood as one of the outcomes of our activity system at UiA. Similarly, I consider the different schools where the teachers are working as activity systems where the teachers' teaching practice is one of the outcomes of their activity system. There is no space here to go into details concerning Activity Theory (see Roth & Lee, 2007; Virkkunen & Kuutti, 2000) but I will concentrate on the processes behind the design of a particular task by the didacticians and the implementation of this task by two mathematics teachers, one from primary and one from lower secondary school.

However, I consider that Activity Theory addresses "activity" *in general terms* and as a means to point to the specificity of our activity systems, which is addressing the collaboration between didacticians and teachers with focus on mathematical learning and teaching, I propose to introduce the ideas of *didactical aim* and *pedagogical means* in order to articulate the goal of our actions in a more precise way. Didactical aim refers to "the choice of a particular area or knowledge target within a subject-matter" (Berg, 2009, p.100), while pedagogical means refers to a task "to use in order to address the chosen didactical aim" (p.100). For example, a didactical aim could be "to investigate Pythagoras theorem" and it is possible to find many different tasks used as pedagogical means to achieve this didactical aim. Furthermore, I consider that "...by presenting a particular task within a specific social setting, a didactician creates a *mathematical environment* whose characteristics depends *both* on the mathematical task and on the social setting." (Berg, 2009, p.103).

In this article I consider three different mathematical environments: the first one refers to the workshop during which the T-shirt task was presented to the teachers. Here the social setting refers to the group of didacticians working collaboratively together with the teachers while engaging in the T-shirt task. The second and the third mathematical environments refer to the way the task has been implemented in the teaching practice of each of the two teachers. In that case the social setting refers to the teacher together with his/her pupils working on the T-shirt task. In each of these mathematical environments, I explain what the didactical aim and the chosen pedagogical means are and I follow the processes behind the design of the task and its implementation in terms of change and modification in the didactical aim and pedagogical means. I argue that the introduction of these theoretical constructs enables me to develop

central concepts of Activity Theory further and to articulate the collaboration between the teachers and ourselves in a more accurate and focused way. In this article I consider the processes behind the design and implementation of the T-shirt task (Figure 1). The T-shirt task was previously introduced during a seminar at UiA concerning theoretical perspectives in mathematics teaching and learning through an article concerning socio-mathematical norms (Tatsis & Koleza, 2008).

The T-shirt task was designed as an imaginary phone call where one person had to explain to another the design of a logo to be reproduced on a T-shirt (Figure 1). In this context the nature of the questions the other person may ask, as a means to reproduce the logo of the T-shirt in an accurate way, was important. The team of didacticians at UiA had decided to present the T-shirt task as a means to engage and explore what communication in mathematics might mean.

T-skjorte oppgaven  
Mål: Matematisk kommunikasjon, bruk av spørsmål, terminologi og begreper

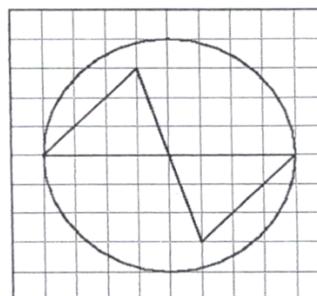


Figure 1: The T-shirt task

## Methodology

The methodological approach adopted in the TBM project is developmental research. According to Goodchild (2008), developmental research is characterised by a cycle between a *development cycle* and a *research cycle*. The research cycle refers to a cycle between global theories and local theories and, in the TBM project, global theory refers to community of practice (Wenger, 1998) and co-learning agreement (Wagner, 1997), while local theory refers to community of inquiry (Jaworski, 2007). Furthermore, a development cycle consists of a cyclical process between *thought experiment* and *practical experiment*. In other words, the notion of thought experiment refers to the preparation of the workshops where we collaborate with teachers, while practical experiment refers to the actual realisation of these. Feedback from participants informs the next step of thought experiment. In the previous section, I argued for introducing Activity Theory as a means to articulate the collaboration between the teachers and our group of didacticians. Thereby, in this article, the local theory refers to Activity Theory with the ideas of didactical aim and pedagogical means as a further elaboration of the theoretical framework. I consider that this theoretical approach allows for a better understanding of what thought experiment (preparation of the workshops or of teaching period) and practical experiment (realisation of the workshops or of the teaching period) mean in the context of this research.

## The research setting

In this article I report episodes taken from a meeting in November 2008 at UiA during which didacticians were engaged in preparing for the next workshop and discussing a specific task (the T-shirt), from the presentation of the task during the workshop, and from interviews with the two teachers before the implementation of the task in December 2008 and May 2009. Within the TBM project we collected data consisting of video recording of all workshops we organised with the teachers. Furthermore all classroom observations and interviews with teachers are either video recorded or audio recorded. In addition, we keep field notes and e-mail correspondence as part of our data collection. In the following sections I present the first,

the second and the third mathematical environments and trace the way the T-shirt task has been modified and adapted by the teachers using the central ideas of didactical aim and pedagogical means.

### **The first mathematical environment: preparation and realisation of the workshop in December 2008**

The theme of the workshop in December 2008 was “Communication in mathematics”. This theme has been chosen among several suggestions sent to us by the teachers. Before the workshop we had several meetings where we prepared for the workshop and discussed how to address this theme. During one of the first meetings, in November 2008, we agreed on the fact that it was important to contextualise the discussion around the idea of communication in mathematics by relating it to a specific task. In addition one of the didactician emphasised that:

”...in communicating mathematics, questions are a far more effective way of communicating than telling. In order to make sense of mathematical knowledge, pupils need to take the responsibility for exploring which means questioning the teacher, questioning others. The fundamental aspect about communication is *questioning*” (Didacticain 1, TBM meeting 261108)

Thereby we decided that the idea of questioning was crucial to communication in mathematics and we see both issues as deeply rooted in our inquiry-based approach to mathematics and mathematics teaching (Berg, in press; Jaworski, 2006; Wells, 1999). I consider these meetings, while preparing for the workshop, as part of our “thought experiment” (Gravemeijer, 1994) since we were envisaging possible ways of teachers’ engagement. Looking at these preliminary meetings it is possible to identify both our didactical aim and pedagogical means: Communication in mathematics was the chosen theme for the next workshop and, among several tasks, we choose the T-shirt task (see Figure 1) since we considered that it had the potential to stimulate the participants in engaging in reflecting about the issue of “questioning”. During our discussion we mentioned the fact that one of the possible elaborations of this task could be to introduce a coordinate system instead for the grid on which the logo is drawn (see Figure 1). These ideas were presented to the teachers during the plenary session in the workshop from December 2008 where the theme was Communication in mathematics and the title of the workshop was “To ask good questions in mathematics”. In addition, we initiated a discussion related to the meaning of inquiry in mathematics and to the importance of inquiry as an approach to mathematics and to teaching mathematics. The T-shirt task was introduced as a context for addressing the following questions: How can we ask “good” questions? Can we, as teachers, learn how to formulate questions which stimulate students? After the plenary session, we all divided in different groups, each one consisting of teachers from the same level (primary, lower secondary or upper secondary), and one of us, didacticians. Looking at the preparation and realisation of the workshop where the T-shirt task was introduced it is possible to extract the main aspects of this social setting using the constructs of didactical aim and pedagogical means where “communication in mathematics” was the didactical aim and the T-shirt task was chosen as the pedagogical means. The main elements from the first mathematical environment are summarised in Table 1.

<b>Implementing the T-shirt task during the workshop</b>	<b>Mathematical task: Didactical aim</b>	<b>Mathematical task: Pedagogical means</b>
<b>Social setting: Didacticians and teachers</b> Workshop, December 2008	Communication in mathematics	The T-shirt task

Table 1: Central aspects of the first mathematical environment

In the previous section I explained the nature of the first mathematical environment where the didacticians chose to focus on “communication in mathematics” as the didactical aim for the next workshop. In the next section I present the results of the analysis of the way the T-shirt task was implemented by two teachers and thereby I offer a characterisation of the second and the third mathematical environments by explaining their didactical aims and pedagogical means.

### **The second and the third mathematical environments: implementation in primary and lower secondary school**

As mentioned before, the rationale for investigating the implementation of the T-shirt task is that shortly after the workshop a teacher from primary school invited me to come and observe her teaching since she wanted to implement the T-shirt task in her class. The same happened during spring 2009 with a teacher from lower secondary school. The first teacher (Kari) is teaching in primary school, grade 6 (age 10 to 11), while the second teacher (Rikard) is teaching in lower secondary school, grade 8 (age 13 to 14). In addition to classroom observations I asked the teachers if it would be possible to interview them both before and after their teaching period. My aim was to investigate the reasons why they found this particular task interesting and worthwhile to implement in their respective classes. In addition I wanted to follow in which ways they modified and adapted it.

#### ***Following Kari in her class***

As mentioned I had the possibility to interview Kari before observing her teaching period. My aim was to ask her the reasons why she selected the T-shirt task as an interesting task for her class. Furthermore I was interested in the way she had modified and adapted the task to her pupils:

”Yes, it [the task] captured me, and then, when I started to think that it could be about coordinate system, then, then I thought that this is a task I will use.... I relate it [the task] to my teaching and to what I do on that grade.... Pupils will need to use their mathematical language, they can talk about circles, triangles, and several concepts I would like them to have.”

It seems that Kari became interested in the T-shirt task when she realised that it could be related to the learning of coordinate system. Furthermore she explained that this was the focus of her teaching on that grade and she considered this task as a good opportunity for her pupils to develop their understanding of the use of coordinate system further. In addition it seems that she saw the opportunity for pupils to engage with the task while using accurate mathematical terminology, like “circles” and “triangles”. Even though Kari recognised the importance of mathematical communication and the use of accurate terms, my interpretation of her reflections, as presented during the interview before class, is that the main focus or didactical aim for her teaching period was on the use of coordinate system. One important aspect here is the introduction of the idea of “coordinate system”. Looking back to the way the T-shirt task was introduced during the workshop (Figure 1), the logo of the T-shirt was drawn on a grid, not on a coordinate system. Thereby, by removing the grid and introducing a

coordinate system, Kari was able to relate the task to her teaching. During the classroom observation, I had the opportunity to follow how Kari organised her teaching lesson by first offering a repetition of the main aspects concerning coordinate system (for example, what does “origin” mean, how to write the coordinates of a point, what does the first number represent, the abscissa, and what does the second number represent, the ordinate). Then she introduced a task consisting of several logos, starting with a logo with only straight lines and located in positive y-values, and finally ending with the same logo as the T-shirt task. The pupils were sitting in pairs and the challenge consisted of describing to each other the logo, which was drawn on a coordinate system, and using only the coordinates of the different points. Elsewhere I address in more detail the elaboration, realisation, and the challenges Kari met during her teaching period (Berg, 2010, in preparation). The main aspects of Kari’s teaching period are summarised in Table 2.

<b>Implementing the T-shirt task in grade 6</b>	<b>Mathematical task: Didactical aim</b>	<b>Mathematical task: Pedagogical means</b>
<b>Social setting: Kari and her pupils (grade 6)</b> Teaching period, December 2008	Coordinate system	The T-shirt task (communication)

Table 2: Central aspects of the second mathematical environment

### ***Following Rikard in his class***

As mentioned previously, I was also invited in May 2009 by Rikard as he wanted to implement the T-shirt task in his class. Similarly to Kari’s observation, I asked Rikard the possibility to interview him before observing his teaching. Again my aim was to follow the processes behind his interest for the T-shirt task and to trace the way he modified and adapted it to his class. During the interview before his teaching period Rikard explained the rationale for choosing this task:

”From the curriculum, there are first of all two aspects which I would like to have as goals for my teaching, it is the use of coordinate system, and the second is the introduction of functions... And you can say, what I want to emphasise is communication, I would like the pupils to have an understanding of how one communicates in mathematics.”

Again it seems that Rikard became interested in the T-shirt task as he saw the possibility to relate it to the curriculum and more specifically to the use of coordinate system. In addition the curriculum for grade 8 introduces the notion of “function” and links it to the use of coordinate system. Thereby, similarly to Kari’s arguments, the first aspect Rikard emphasised was the opportunity to develop pupils’ understanding of the notion of “coordinate system” further and to establish a link to “function”. At the same time, he seemed to recognise the importance of how one communicates in mathematics and therefore the T-shirt task would be suitable for implementation in grade 8. Here again, Rikard modified the T-shirt task by introducing a coordinate system instead for the grid from the original presentation of the task. By following Rikard in his class I was able to observe the way he introduced the task to his pupils. First of all, he presented a repetition of the main elements of a coordinate system, emphasising the fact that when writing the coordinates of different points, the first value corresponds to the x-coordinate (abscissa), while the second value corresponds to the y-coordinate (ordinate). Then Rikard organised his lesson as follows: first he introduced the logo from the T-shirt task *without* any coordinate system or grid behind it. He asked two pupils to come in the front of the class and one of them had to describe the logo to the other.

The rest of the class was following the discussion and Rikard asked them to be sensitive to the terms the two pupils used in their description of the logo. In the second phase, Rikard introduced the logo of the T-shirt task *with* a coordinate system behind it and chose two other pupils for describing the logo. According to Rikard, the aim of organising the teaching period in that way was to emphasise the usefulness of a coordinate system when describing a logo or a figure. From Rikard's explanation, it seems that even though the main focus during his teaching period was on the usefulness and advantages of using a coordinate system, he also emphasised the use of accurate mathematical terms during the description of the logos. Elsewhere I address in more detail the elaboration, realisation, and the challenges Rikard met during his teaching period (Berg, 2010, in preparation). The main aspects of Rikard's teaching period are summarised in Table 3.

<b>Implementing the T-shirt task in grade 8</b>	<b>Mathematical task: Didactical aim</b>	<b>Mathematical task: Pedagogical means</b>
<b>Social setting: Rikard and his pupils (grade 8)</b> Teaching period, May 2009	Coordinate system	The T-shirt task (communication)

Table 3: Central aspects of the third mathematical environment

In the previous section I described and analysed the way the T-shirt task was implemented both in primary and in lower secondary school, and identifying in each cases the didactical aims and pedagogical means. In the next section I discuss the findings and propose implications for further collaboration between didacticicians and researchers.

### ***Discussion and conclusion***

From the analysis of Kari's and Rikard's teaching session, as presented above, it seems that they both decided to implement the T-shirt task in their own teaching practice since they saw the possibility to address the use of coordinate system as a topic which is relevant both in grade 6 and 8. Thereby the rationale for choosing this particular task is rooted in the role played by the curriculum in the organisation of the teachers' teaching practice. Using terminology from Activity Theory and referring to the teachers' activity system, it is possible to consider the curriculum as one of the rules the teachers follow while preparing for their practice. Results from the analysis of the implementation of the T-shirt task both in Kari's and in Rikard's teaching practice show that both of them chose "coordinate system" as the didactical aim for their lesson and the T-shirt task as chosen as a pedagogical means for achieving this aim. In order to address the use of coordinate system, the teachers modified and adapted the task in the following way: in Kari's class, the task consisted of several logos, all of them drawn on a coordinate system and thereby offering the possibility to identify each point through its coordinates. She modified and adapted the T-shirt task by designing several logos where the first one consisted of straight lines only and where it was drawn in the positive y-values. Finally she presented the same logo as in the T-shirt task by the end of her lesson. The issue of communication in mathematics was addressed through the challenges Kari met during the lesson (Berg, 2010): pupils were sitting in pairs and the first one tried to give a description of the logo to the other but some of the pupils used gestures (pointing to the figure) in order to help their friend in drawing the logo.

Looking at Rikard's class, even though his didactical aim was the use and advantages of introducing a coordinate system, it seems that he also tried to emphasise communication in mathematics as he organised the class as follows: two pupils were responsible for reproducing

the logo (one is describing the other is drawing the logo) while the other pupils were asked to observe which mathematical terms the two pupils used in describing the logo. Thereby my interpretation of classroom observations is that there was more emphasise on communication in mathematics in Rikard's class than in Kari's class. Comparing the three mathematical environments in terms of didactical aim and pedagogical means I argue that it is possible to observe an inversion between the first environment, during which the T-shirt task was introduced during the workshop in December 2008, and the second and third environments, during which the T-shirt was implemented in Kari's and Rikard's class. Looking back to the way the T-shirt task was designed and its implementation both in primary and lower secondary school, it is possible to observe that from a focus on communication in mathematics, in the first environment, the task has been modified and adapted in order to focus on the use of coordinate system. This inversion is illustrated in Table 4 where the main aspects of the three mathematical environments are summarised.

Comparing the implementation of the T-shirt	Mathematical task: Didactical aim	Mathematical task: Pedagogical means
<b>First mathematical environment:</b> Didacticians and teachers Workshop, December 2008	Communication mathematics	The T-shirt task (Coordinate system)
<b>Second and third mathematical environment:</b> Kari's and Rikard's teaching period	Coordinate system	The T-shirt task (communication)

Table 4: Inversion of didactical aim and pedagogical means between the first and the two others mathematical environments

I argue that by following this research approach I am in a position to establish a link between theory, here using Activity Theory which has been developed further with the ideas of didactical aim and pedagogical means, and the teachers' teaching practice. This approach allows me to study and analyze the one of the outcomes from the didacticians' activity system (here the workshop during which the T-shirt task was presented to the teachers) and to follow the processes behind its implementation in the teachers' activity system (here the teaching period of the two teachers). By developing awareness of these processes, I consider that we, as researchers, get insights into the way teachers prepare their teaching and more generally "by working together, each might learn something about the world of the other" (Wagner, 1997, p.16). I consider that the recognition of the importance of the rules, using an Activity Theory terminology, within the teachers' activity system is of crucial importance while engaging in collaboration with teachers.

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