# Towards a multimedia tool for numeracy education

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## Summary

Recent research is aimed at getting a better grip on the thinking of individuals in numeracy situations. To reach this goal an instrument is developed that can be used by teachers, researchers, developers of instructional material to analyze the thinking and acting of individuals in numeracy situation.
The research and the development of the instrument have also led to a series of design principles for a set of learning tools. This follow up in actual learning tools is motivated by the idea that "*research must be closely linked with practice in a field where development and improvement in practice have priority status*"(FitzSimons et al., 2003, p.117).
The learning tools are designed in a way that they are closely connected with the thinking of individuals in numeracy situations. The assumption is that this close relation will reinforce the transfer of concepts and skills from the learning tool to actual numeracy situations.
In this paper we describe the exploratory research that was done on the thinking of individuals in numeracy situations. The research how the thinking of individuals in numeracy situations can be visualized and the development of the learning tools are still in progress. In this paper the results achieved thus far will be presented.

## Introduction

In the Netherlands the achievements on arithmetic and mathematics of many students in the basic streams of pre-vocational (age 14-16) and vocational education (age 16-19) are unsatisfactory. These achievements are measured with pen-and-paper tests, sometimes with computer aided tests. Most of these students in the basic stream have a long history of being diagnosed as deficient and subsequently remediated with pen-and-paper drill materials until they show some progress on the test or until the school year ends.
In some schools it was noticed that in the basic stream of pre-vocational education the scores of the students on this kind of written tests at the end of the second year were roughly the same as the scores at the end of the third year and are roughly the same as the scores at the end of the fourth year on the same tests. The mathematics courses and the remediation do not seem to yield much added value. We have found in schools the same situation as John Gillespie found in schools in England and Wales: *"One response was to provide "stand-alone" maths techniques courses often outside specific vocational contexts. But many students saw such courses as not relevant to their main courses, and there was little evidence of their being able to transfer skills from them to their vocational work".* (Gillespie, 2000, p.55)
We observed that in the mathematics classroom motivation problems outweigh any development of numerical skills and knowledge. Zevenbergen (2000) reports similar experiences: "*For many of the students for whom school mathematics has been a disempowering experience, a broader conceptualisation of mathematics may offer different experiences than the current regimes of school mathematics that are on offer in contemporary institutions. This may be particularly the case for those students undertaking vocational oriented courses where it is common for students to have low levels of numeracy and have been alienated from the formal schooling process*." (Zevenbergen, 2000, p.222)
Also we found by many students a fair amount of math anxiety (Tobias, 1994)

To solve this problem there are two contesting views in the Netherlands. One view states that more time must be spent on training the students rigorously in basic literacy and arithmetic in combination with practical vocational education, is the most sensible way to proceed.
The other view claims that a paradigm shift to project based authentic learning will bring an end to the problems of motivation and will create an environment for the successful achieving of numeracy knowledge and skills. However in this approach we hardly find any explicit definitions of numeracy nor good images how that would look like in classrooms.
A fruitful discussion about the fundamentals of numeracy (or mathematics or arithmetic) within the education for these students is overshadowed by the fight of the ideologies behind these two points of view. The discussions between the supporters of the different views are quite fierce and emotional. These kinds of discussions are reported from other countries as well, for instances Australia (Zevenbergen, 2004) (FitzSimons, 2002) and the USA (Wilson, 2003), sometimes referred to as the "Math War".
Within the context of this paper we made the choice to first investigate more closely and in depth what individuals do and think when they are coping (or not coping) with numeracy situations. This has lead to the research question for the ongoing study: "How can the thinking of individuals in numeracy situations be visualized?" In the next sections this research question is elaborated upon.

## Definitions of numeracy

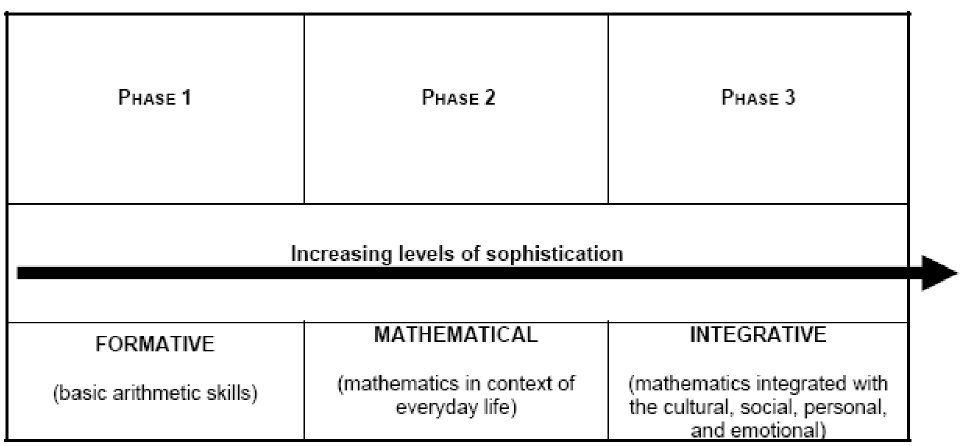
Before elaborating on the research question, we first go more into the definition of numeracy used in this study. The definition of numeracy we use in this study is the most wide spread definition in the Netherlands:
*"Gecijferdheid is de combinatie van kennis, vaardigheden en persoonlijke kwaliteiten die een individu nodig heeft om adequaat en autonoom om te gaan met de kwantitatieve kant van de wereld om ons heen".* (www.gecijferdheid.nl, 2007) (Wiki-NL, Gecijferdheid, 2007):
This translates to:
*"Numeracy is a combination of knowledge skills and personal qualities, which an individual needs to adequately and autonomously deal with the quantitative side of the world around us."*
The various elements of this definition can be clarified in the following sense:
* *combination of knowledge, skills and personal qualities*
This shows that numeracy in our opinion not only encompasses knowledge and skills, but also personal qualities like: self-confidence, perseverance, curiosity, a lack of fear for the quantitative, assertiveness, et cetera. The combination of knowledge, skills and personal qualities in the Netherlands quite often is referred to as the definition of "competence". In that sense it is quite different from for instance a definition of competence as "*the ability to do a particular activity to a prescribed standard* " (Working Group on Vocational Qualifications ,1986). The emphasis on the combination of attributes is also in line with the definition of numeracy situations by Gall (2000), who states that numerate behaviour is also enabled by dispositional elements as prior beliefs, attitudes and habits.

* *to deal with*
This verb comes closest to the meaning of "omgaan met" in the Dutch definition.
In our definition the focus is on identifying, interpreting, acting upon, communicating about situations. In this sense it is close to the operational definition used by the Adult Literacy and Life skills Survey (ALL). There the verb "to manage" is used (Gall et al., 1999), (Groenestijn, 2000).
* *adequately*

This adjective is essential in the definition, because the knowledge, skills and personal qualities must be effective, in the sense that they contribute to perform better in numeracy situations.
* *autonomously*
This adjective is also essential, because individuals must rely on strategies that are at his own disposal to deal with numeracy situations.
“Avoiding strategies” are among the most used strategies of many individuals to cope with quantitative situations. These strategies are excluded from the study.
* *quantitative side of the world around us.*
The quantitative side of the world around us has many appearances. It shows up in artefacts and devices (meters, gauges, clocks, numbers, symbols), in constructions (measurements, angles, spatial attributes) and in texts (numbers, symbols, diagrams, maps, graphs, formulas).

When individuals have to deal with those appearances of the quantitative side of the world, we call that numeracy situations.
In some sense our definition of numeracy is close to the idea of Wedege (2001) of a “*math containing everyday competence*”.
In the organising framework of Maquire and O’Donoghue (2002, 2003)) this definition fits in the integrative phase of the development of the conceptualisation of numeracy.

**Adult Numeracy Concept Continuum of Development**




**A continuum of development of the concept of numeracy showing increased level of sophistication from left to right (from Maguire & O’Donoghue, 2002)**

In the categories used by Jablonka (2003) our definition fits the category “Mathematical literacy for evaluating mathematics”, which aims at interpreting information presented in a numerate way (Hoogland & Jablonka, 2003).
The elaboration above was meant to clearly lay out the definition of numeracy used in this study and subsequently what we mean by numeracy situations, as they are a central issue in the principal research question of this study.

## Research question

This study focuses on the following research question: “How can the thinking of individuals in numeracy situations be visualized?”

How thinking can be visualized will be addressed in the section on methodology.
The idea of numeracy situations directly stems from the definition of numeracy worked out in the previous section. We especially want to study individuals in situations where they are confronted with the quantitative side of the world around us, as it shows up in artefacts and devices, in constructions and in texts.
We investigated students in the basic streams of pre-vocational and vocational courses. We did not study the students in the mathematics lessons. We studied them at work in authentic situations where they had to perform authentic vocational tasks. Only these settings we considered to fall within the definition of numeracy situations (Hoogland, 2005).
With the knowledge gained from this investigation we started to develop a set of design principles for constructing learning tools.

**Methodology**

The broad research idea of the current study is to validate an instrument for looking at individuals at work in numeracy situations and acquire valid conclusions about their thinking and acting. In this paper we limit ourselves to the results and conclusions that were relevant for developing some design principles for constructing learning tools.
The research was conducted as follows. We focused on students in the age group of 14-16 in the basic stream of (pre-)vocational education. The students were working on meaningful tasks in an authentic learning situation. For example: they were constructing a bicycle trailer for a surfboard, they were constructing garden lights for a company, they were constructing spotlights for the school, they were making garbage bins for the school shop, they were producing tomato soup for the school lunch, they were making a rectangular flower bed, et cetera.
After finishing or almost finishing their products, they were asked to come and tell something about the way they manufactured the product. The product was always at hand. This interview was videotaped and analyzed.
In analyzing the tapes we noticed a remarkable difference between "*interviewing* a student about the product and their way of working" and "*letting them tell* about their product and way of working".
In the first case these students tend to give very short answers, preferably yes or no. And in many instances noticeable from the hesitations they try to give "the right answers": i.e. answers given in a questioning way, accompanied by a questioning look.
In the second way the students seem to get a bit into a flow and talk most of the time with enthusiasm about their product and their way of working. The role of the interviewer was just giving some non-interventional incentives to talk on.
We learned in our research that this second way more clearly reveals how the students are thinking numerately and provided the best opportunity to get answers to our research question. So first those video clips were selected where the students were speaking freely and proudly about their way of working. To analyze these video clips an instrument was used to focus the observer on different aspects of the videotaped sessions.
The first version of the instrument consists of several observation categories. These categories deal with the mathematical concepts or ideas used by the students, as expressed in
1. the mathematical language used
2. the technical language used
3. the everyday language used
4. the gestures made during their talk.

The methodology is a variation on Stimulated Recall. Stimulated recall is used by different researchers in the field of mathematics education (Zevenbergen, 2000, 2004), (Lyle, 2003) and was used extensively in learning second language research (Gass, 2000). This kind of retrospective reporting is used to explore learners' thought processes (or strategies) at the time of an activity or task.

**Results**

We limit ourselves to the results that were relevant to come to the design principles for the learning tools. We found as main results:
1. When the artefact or device is at hand the students show significantly more usage of mathematical concepts in language than when the artefact is not at hand.
2. When the artefact or device is at hand the students show significantly more usage of mathematical concepts in gestures than when the artefact or device is not at hand.
3. The students use everyday language to describe mathematical concepts. They use quite of a lot of non-distinct descriptions: "what-d'you-call-it", "something-like-this". This non-distinct descriptions prevail heavily over the use of mathematical language that could be relevant in the situation.
4. Relevant technical language is used quite regularly, much more regular than the use of relevant mathematical language.

Some examples:
A student has constructed a window casing and is telling about it. Somewhere in the casing an angle of 45 degrees was necessary. He uses technical construction words as "overlengte" (overlength), "schrijfhaak" (setsquare) , "afschrijven" (line out) without hesitation. When it comes to creating the angle of 45 degrees the language becomes much less defined and the number of supporting gestures rises.
Interviewer*: How about those 45 degrees?*
Student*: It is something like this (gestures), it then goes like that (gestures), then there is an angle with your setsquare, you can shift it a bit and then it is exactly 45 degrees.*
Nevertheless it is from the video clip clear that the student knows what he is doing and knows how to construct the right angle.

A student has constructed a plan for a L-shaped flowerbed with outside measures of 150 x 150 cm and a width of 60 cm. He shows an ingenious way of constructing the plan, which is also very effective as a working plan for the real constructing.
Interviewer: *How long are now those inside measures?*
Obviously the inside measures are 90 x 90 cm. The student also used this in his construction.
Student: *I do not know, I am not much a numbers man.*

A student has constructed with his team a pyramid shaped garden lamp. The top of the lamp consists of a triangle that bends into two sides of the pyramid and a triangle that makes the lampshade complete. The student shows with bending a triangular piece of paper that the last triangle always fits. This showing reveals his mathematical thinking. The language supporting the demonstration is very nondescript.
Student: *It always fits, a small one, a pointed one, it just fits, also a (mumbling), it just fits, the other just bends.*

## Conclusions

From the results we draw the following conclusions.
- Students show a much sophisticated mathematical competence when they have an artefact or device at hand than when the product is not available.
- Students use gestures to support their mathematical reasoning.

These two conclusions are very important in combination. Without the artefact or device there is hardly any possibility to gesture, and for these students that means that their ways of showing the numeracy thinking are very limited. These conclusions offer also a possible explanation why these students score so poorly on written tests. Showing their numeracy thinking only in writing is for these students a very limiting setting.
- Students use a very limited mathematical vocabulary.
- Students use regularly technical language.

These two conclusions indicate that the relevant technical language is meaningful for the students; it is internalized. There seems to be hardly any mathematical language internalized by these students. Language does not seem to be the key tool to show their numeracy thinking.

## Towards a multimedia tool for numeracy

Based on the research described we are in the process of developing web based multimedia learning tools which deal with the basics in arithmetic and some mathematical concepts like area and volume, percentage and ratio's, interpreting and deciding, division and dividing. The design principles for the learning tools were derived from this research.
The design principles are:
- Every problem posed must be directly related to a real situation, presented in a picture or video clip. No situations or contexts are presented that only are presented in text.
- Necessary information on the situation is presented in written and spoken text (voice-over)
- Every question posed on the situation must be imaginable for the student as a real and relevant question.
- Answering the posed question demands some numerate action.
- The built up is in the complexity of the situations and not in the complexity of the mathematical concepts.

On the basis of these design principles in the spring of 2007 the tools were developed. First tryouts were conducted with three groups of students. The results are under investigation.

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