Using Concept Cartoons to investigate future teachers' knowledge – new findings and results

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In the study presented here we address the issue of how to use Concept Cartoons for investigating future primary school teachers' mathematics content knowledge. We focus on various types of composition of Concept Cartoons, and on advantages and disadvantages associated with using these types of Concept Cartoons for diagnostic purposes.

Keywords: Concept Cartoons, future teachers' knowledge, mathematics content.

INTRODUCTION

The findings presented here continuously extend our contribution from last CERME conference (Samková & Hošpesová, 2015). The referred study belongs to a three-year project focusing on opportunities to influence professional competences of future primary school teachers through experienced *inquiry based mathematics education*. Within this project we aim to implement inquiry based methods into a set of university mathematics courses for future primary school teachers, and observe what impact the implementation has on students' knowledge and beliefs. As one of the diagnostics tools in this project we use an educational tool called *Concept Cartoons*.

In the previous contribution (Samková & Hošpesová, 2015) we introduced Concept Cartoons in their diagnostics role. We showed that suitably chosen Concept Cartoons allow us to distinguish between subject matter knowledge and pedagogical content knowledge in the sense of Shulman (1986), and also between procedural and conceptual knowledge in the sense of Baroody, Feil and Johnson (2007).

In this particular study we concentrate more deeply on relation between the composition of a given Concept Cartoon and its suitability for investigating teachers' knowledge. Our research question is: What attributes of Concept Cartoons allow us to use them for investigating future teachers' mathematics subject knowledge?

THEORETICAL BACKGROUND OF THE RESEARCH

Teachers and their knowledge

Teachers and their knowledge needed for proper conduct of teaching are the focus of many educational researches. In this contribution we shall pay attention to areas related to Shulman's *knowledge base for teaching* (1986, 1987), and Rowland's *knowledge quartet* (Rowland, Turner, Thwaites, & Huckstep, 2009).

From Shulman's concept we focus on categories called *subject matter content knowledge* (SMK) and *pedagogical content knowledge* (PCK). The category of SMK can be understood as “knowledge for oneself”, i.e. knowledge that the teacher can use during his/her own learning of a given topic. The category of PCK can be understood as “knowledge for helping others”, i.e. knowledge that the teacher can use during teaching a given topic to someone else. In general, SMK and PCK are unequal but not disjunctive.

According to Grossman (1990), PCK consists of four components: *conceptions of purposes for teaching subject matter*, *curricular knowledge*, *knowledge of pupils' understanding*, and *knowledge of instructional strategies*. Our study relates to the last two. Knowledge of pupils' understanding refers to knowledge of pupils' conceptions and misconceptions related to a given topic, and to extend and limits of pupils' understanding of this topic. Knowledge of instructional strategies refers to strategies and representations needed for teaching a given topic.

Rowland's concept of *knowledge quartet* relates specifically to knowledge needed for teaching mathematics at primary school level. It consists of 20 categories grouped to four dimensions: *foundation*, *transformation*, *connection*, and *contingency*. The *foundation* dimension refers to teacher's theoretical background and beliefs, *transformation* to knowledge-in-action with central focus on representations (analogies, examples, explanations, etc.), *connection* to ways the teacher achieves coherence within and between lessons, and *contingency* to teacher's responses to unpredictable events in the classroom. Our study relates to all of these dimensions.

Rowland et al. (2009) also specify how knowledge quartet relates to SMK and PCK: foundation knowledge includes most of SMK, transformation knowledge belongs mostly to PCK, connection and contingency knowledges both combine SMK and PCK.

Concept Cartoons

In the research referred here we study a primary-school educational tool called *Concept Cartoons* (Naylor & Keogh, 2013). Each Concept Cartoon is a picture showing a situation well known to pupils from school or everyday reality, and a group of children in a bubble-dialog. The texts in bubbles present alternative viewpoints on the situation or alternative solutions to a problem arising from the situation (see Fig. 1).

Originally, Concept Cartoons were created as a classroom tool oriented on pupils, their goal was to support teaching and learning in science classroom by generating discussion, stimulating investigation, and promoting learners' involvement and motivation. Later the tool also expanded to mathematics (Dabell, Keogh, & Naylor, 2008). When working with Concept Cartoons, the pupils have to choose all children in the picture that are right, and justify their choice.

According to research conducted by authors of Concept Cartoons (Naylor, Keogh, & Downing, 2007), the lack of agreement amongst the children pictured in the Concept Cartoon encourages pupils to join the discourse with their own opinions, and such discourse can take a form of sustainable and purposeful argumentation.

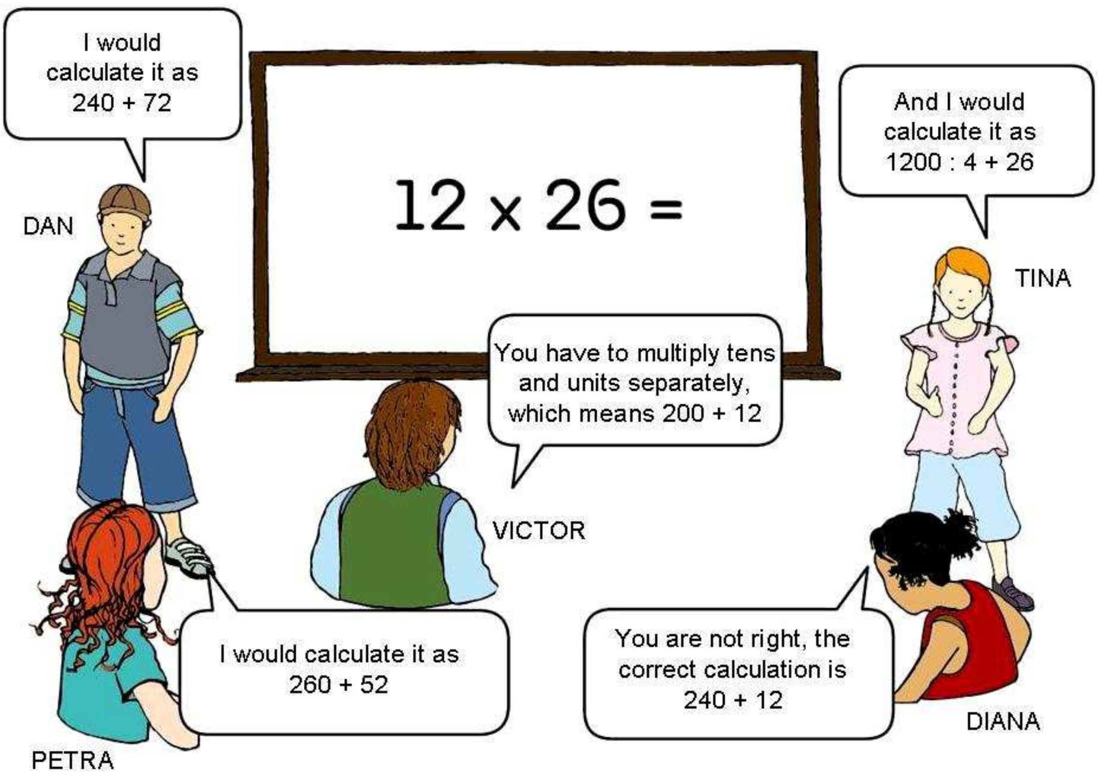

Figure 1: Concept Cartoon on multiplication; template with empty bubbles and empty board taken from (Dabell, Keogh, & Naylor, 2008), names of children added

In our project, we aspire to use Concept Cartoons as a diagnostic instrument for investigating various aspects of future primary school teachers' mathematics content knowledge. We understand each Concept Cartoon as a model of a classroom situation, and observe how the future teachers respond to such a situation. The situation modelled by the Concept Cartoon is predictable for an experienced teacher but may be unpredictable for an inexperienced future teacher. That means that from future teachers' training perspective, Concept Cartoons may be considered as models of contingent situations in the sense of Rowland's knowledge quartet, i.e. as models of situations where both SMK and PCK come into play. This attribute of Concept Cartoons shall ensure that data collected with Concept Cartoons might refer to both SMK and PCK.

We also need to be sure that Concept Cartoons allow us to collect enough data. For this purpose we shall supplement Concept Cartoons by a set of investigative questions, and we hope that the above mentioned way how Concept Cartoons encouraged pupils to present their own opinions during science lessons will also work in the case of future teachers during mathematics lessons. Hopefully the lack of agreement amongst the pictured children shall lead future teachers to responsiveness towards Concept Cartoons on mathematics topics, and towards willingness to contribute to the discussion pictured in them.

But still we are aware that Concept Cartoons were originally created for a different purpose, so that it is important to verify whether and what Concept Cartoons are suitable for the knowledge diagnostics.

DESIGN OF THE STUDY

Participants

Participants of the research were 129 university students, future primary school teachers, in full-time or distance form of study. In our country, primary school teachers are not math specialists, they teach all primary school subjects.

Course of the research

The research was conducted in two separate stages.

The first stage

For the first stage of the research we selected four Concept Cartoons from the original set created by Dabell, Keogh, and Naylor (2008). We picked out Concept Cartoons that differed in several factors:

- type of the pictured situation
    - classroom event;
    - everyday event;
- type of the text in bubbles
    - proposal of a result;
    - proposal of a procedure and a result;
    - advice to a pupil who made a mistake;
- number of bubbles with correct alternatives.

These Concept Cartoons were assigned to students on a worksheet with four common questions:

1) Which child do you strongly agree with?
2) Which child do you strongly disagree with?
3) Decide which ideas are right and which are wrong. Give reasons for your decision.
4) Try to discover the cause of the mistakes, and advise the children how to correct them.

Students worked on worksheets individually, approximately 80 minutes.

Data from worksheets were processed qualitatively, using open coding (Miles & Huberman, 1994). We focused on displays of SMK and PCK related to provision and recognition of right and wrong answers, to recognition of procedures used by pictured children, and to identification of the causes of mistakes. Detailed description of analysis of data connected with two Concept Cartoons that proved to be suitable for investigating SMK and PCK, and particular results belonging to data from 64 future primary school teachers in full-time form of study were reported in (Samková & Hošpesová, 2015).

The second stage

Based on findings from the first stage, we created 22 own Concept Cartoons, and used them in the second stage. 11 of them were modifications of original Concept Cartoons (just some texts in bubbles were adjusted to suit better our purpose), 11 were brand new (new pictured situation, new perspectives in bubbles). For some of these Concept Cartoons we also established new types of the text in bubbles:

- proposal of a procedure;
- proposal of a statement (e.g. a rule);
- opinion on the validity of a statement;
- opinion on the number of solutions;
- reference to an absent schema.

When creating the new Concept Cartoons, we put into bubbles various more or less usual pupils' conceptions or misconceptions, descriptions of various ways of solving (correct, incorrect), or intentionally prepared authentically looking misconceptions (for a sample of such a misconception see Samková & Tichá, 2015). We searched for inspiration in our own teaching experience and in teaching experience of our colleagues (e.g. Tichá & Hošpesová, 2010), in results of educational research (e.g. Ryan & Williams, 2011; Bana, Farrell, & McIntosh, 1995), in books and textbooks (Ashlock, 2002, 2010). The process of creation of one of the Concept Cartoons is described in detail in (Samková, Tichá, & Hošpesová, 2015).

These Concept Cartoons were assigned to various groups of participants.

Data from both stages of study were again processed qualitatively. In this time, we focused on displays of SMK and PCK described above but this time in relation to composition of given Concept Cartoons. We also monitored the amount of relevant data obtained from participants to various compositions of Concept Cartoons.

FINDINGS

For better comprehensibility of this section we shall illustrate the reported findings by means of a set of Concept Cartoons that are all based on common strategies for mental multiplication of integers. Such topic belongs to primary school curriculum, where we can find recommended strategies as rearranging numbers (e.g. counting 2 x 5 instead of 5 x 2), rearranging operations (e.g. counting 14 x (2 x 5) instead of (14 x 2) x 5), using repeated operations (e.g. counting 120 : 8 as 120 : 2 : 2 : 2), adjustment (e.g. counting 18 x 6 as (18 x 5) + (18 x 1), or counting 18 x 9 as (18 x 10) – (18 x 1)), using inverse relationships (e.g. calculating 12 x 25 as 12 x (100 : 4) = (12 x 100) : 4 or as 12 : 4 x 100), etc. For a detailed overview see e.g. (DfE, 2010).

Bubbles with just results

One of the studied types of Concept Cartoons contained bubbles proposing various results (solutions) of a pictured task. If the task was in a form of a calculation (e.g. as in Fig. 2, except Petra's bubble), then the respondents too often tended just to compare the correct result of the calculation with numbers in bubbles, and did not seek procedures hidden behind the incorrect results. Even though all four questions were assigned with the Concept Cartoon. These Concept Cartoons often emerged as not enough thought-provoking, providing little data, and thus not suitable for diagnosis.

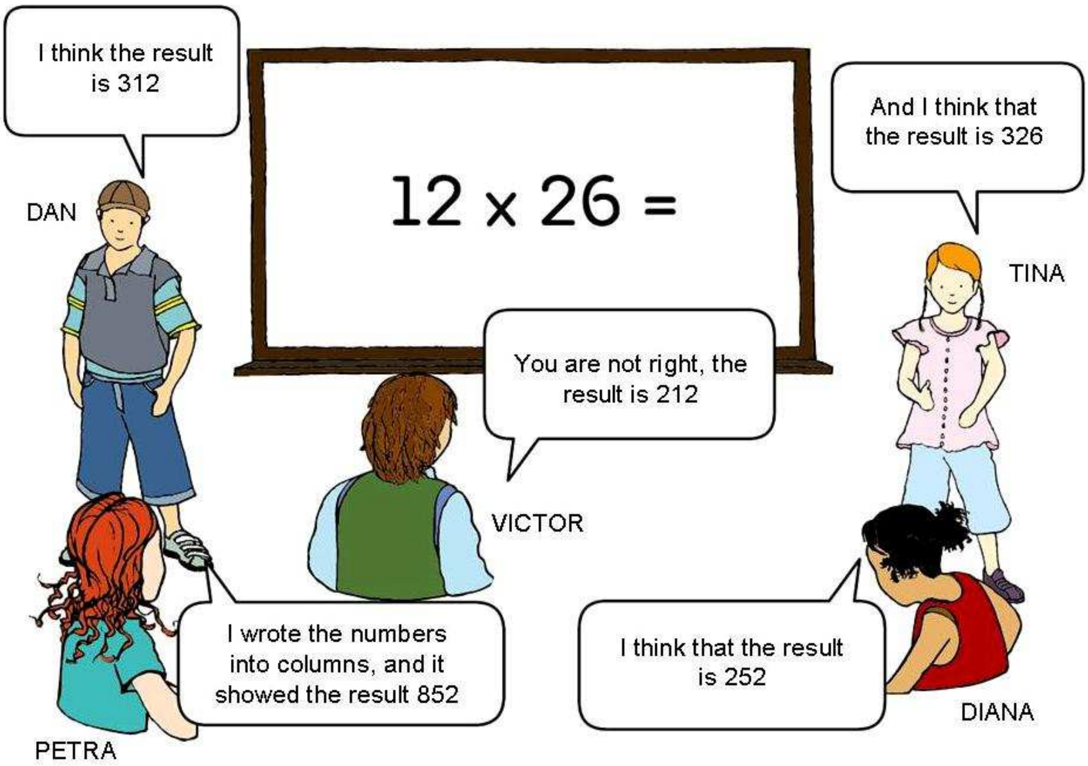

Figure 2: Concept Cartoon with results in bubbles; template with empty bubbles and empty board taken from (Dabell, Keogh, & Naylor, 2008), names of children added

Among Concept Cartoons in our research we found just one exception – a Concept Cartoon containing various results to a calculation 5904 + 5106, where all proposed results were composed only from digits 1 and 0. This unusual composition of numbers attracted respondents' attention, it showed as very thought-provoking, and we got a lot of relevant data (for more details see Samková & Hošpesová, 2015).

In Concept Cartoons containing bubbles with results we also used tasks in the form of a word problem. In case when the word problem is rather difficult to solve (e.g. unequal partition problem with compared quantities unknown), the Concept Cartoon is suitable for investigating respondents' knowledge of solving strategies as well as their grasping of a situation: the respondents who tend to avoid solving the difficult word problem, try to verify all offered alternatives instead, and this activity can reveal the level of their grasping of the situation (for more details see Samková & Tichá, 2015).

Bubbles with reference to an absent schema

As diagnostically valuable appeared bubbles introducing a result and referring to an absent schema leading to this result (e.g. Petra in Fig. 2). These bubbles were often though-provoking, respondents made attempts to find out what schema the child was talking about, they often proposed their own schemas that could lead to the result. In this case the Concept Cartoons played a similar diagnostic and developmental role as problem posing (namely as posing problems corresponding to a given calculation, see Tichá & Hošpesová, 2010).

Bubbles with procedures / with procedures and results

Another of the studied types of Concept Cartoons contained bubbles proposing various solution procedures of the pictured task, either with a result or without it (Fig. 1). With this type of bubble content, respondents can comment described results and procedures, look for errors in procedures leading to incorrect results (and also in procedures leading to correct results). This kind of Concept Cartoons proved to be thought-provoking for respondents. Unlike the previous case with just results, now a lot of concrete facts is offered to the respondents to judge and discuss, so that the respondents' responses provide a lot of relevant data on various dimensions of knowledge:

S11: Dan decomposed 26 as 20+6, and then added 12x20 to 12x6. His procedure is similar to "column" multiplication.

Petra: the same as Dan, she just multiplied 26 by 10+2.

S19: I agree with Dan and Petra. And also with Victor – but he should not use the formulation "have to", better would be "may".

Victor: his procedure is not the only one that is right. But he is right. 10x20=200, 2x6=12. Transparently and quickly solved! Correct.

For the diagnostic purposes, it showed profitable to include into one of the bubbles a procedure that is "clever" (unusual, tricky, advantageously using a certain attribute or relation) – e.g. as in Eve's bubble in Fig. 3. Such bubble allows to reveal good knowledge when a respondent is able to decode the background of the procedure (S4 below), and also poor knowledge when the respondent offers inappropriate explanation and/or blames the child to count randomly (S15 below):

S4: 12x100=1200, 100:4=**25**, **1** is missing to **26**, 1x12=12

300+12=312

S15: Eve replaced 26 by 00, and got 1200. Then she divided 1200 by number of digits (4). In the end she added those 26 that had been previously replaced by zero.

The result is correct, but with different numbers the rule (the procedure) does not hold. A coincidence.

To investigate knowledge more intensively, we may include into one of the bubbles a procedure that is “clever” but contains a mistake in the last step, e.g. as in David’s bubble in (Samková & Hošpesová, 2015), or in Tina’s bubble in Fig. 1. But we must be careful with including this kind of bubbles – when a “clever” procedure is hard to decode, then the same procedure with a mistake might be undecodable. It happened in our research with Tina’s bubble in Fig. 1: only 1 of 34 respondents was able to find the background of Tina’s procedure, the others left her bubble without any comments or with responses like “I do not know what she is doing”. To clarify the situation (both to researchers and to respondents), we assigned the respondents a supplementary Concept Cartoon with Tina’s and Eve’s bubbles together (Fig. 3). The presence of the correct version helped several students to decode the Tina’s procedure as well.

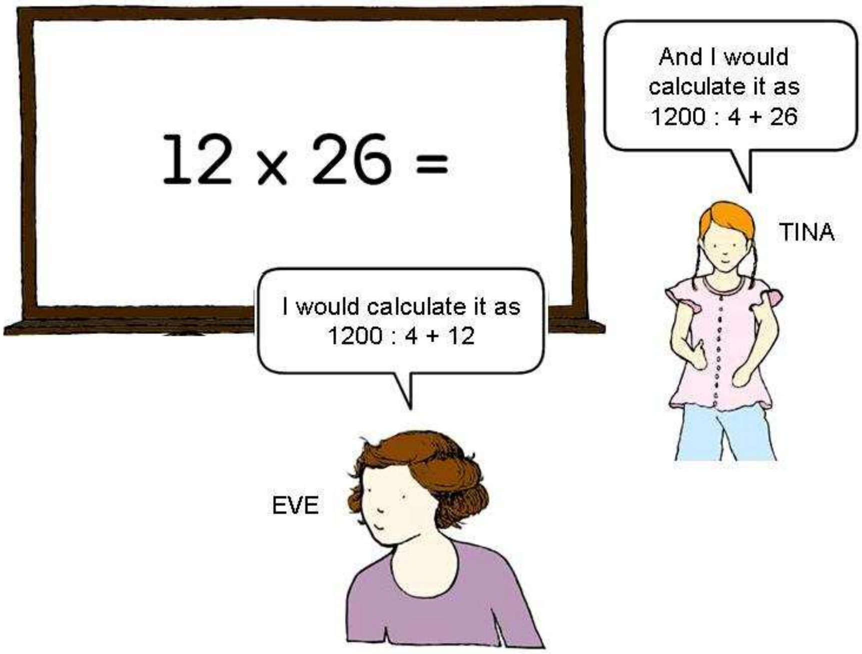

Figure 3: A supplementary Concept Cartoon to Fig. 1

“Clever” procedures (with or without mistakes) appear in classroom only rarely but they always announce a pupil that is thoughtful enough to produce an unusual idea, or courageous enough to try an unusual procedure that might be profitable. Even if being rare, we consider such moments as very important steps in the pupil’s learning process, and the teacher should be prepared for them.

CONCLUSIONS

In this study we focused more deeply on an educational tool called Concept Cartoons, and on its possible usage in diagnosing mathematics content knowledge of future primary school teachers. We conducted a large survey with more than 100 participants, and tested with them more than 20 different Concept Cartoons. During data analysis we observed what attributes of Concept Cartoons allow to collect enough data that are suitable for the diagnosis. Many of the original Concept Cartoons appeared to be unsuitable for these purposes, so that we prepared and tested also our own Concept Cartoons.

Findings show that the decisive attribute is the form of the texts in bubbles. The greatest amount of relevant data we got while using Concept Cartoons containing procedures in their bubbles. This type of bubble content was thought-provoking, and provided a lot of data on both SMK and PCK aspects related to provision and recognition of right and wrong answers, to recognition of procedures used by pictured children, and to identification of the causes of mistakes.

Concept Cartoons with just results in their bubbles appeared often as unsuitable, especially when the task was in the form of a calculation. In these cases the respondents tended to compare the results in bubbles with the correct result, and did not attempt to seek procedures hidden behind the results. Such Concept Cartoons provided little relevant data. Nonetheless, it was possible to take advantage of this type of Concept Cartoons in diagnosing – we used them for investigating just SMK, or took them as a basis for a new Concept Cartoon with a special bubble(s). The special bubbles contained unusually looking numbers that attracted respondents' attention, or referred to an absent schema to provoke respondents to pose their own schemas.

We also introduced special bubbles with a "clever" procedure, and with a "clever" procedure containing a mistake. In this case the difficulty of the bubbles must be determined carefully to optimize cases when the respondents are not able to decode the procedure and thus the bubble provides little relevant data.

Our research confirmed that Concept Cartoons are able to encourage future teachers to present their opinions on mathematical topics and display their mathematics content knowledge through this activity, and established a typology of Concept Cartoons suitable for such purposes.

NOTES

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