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INQUIRY BASED MATHEMATICS EDUCATION (IBME) AND ITS REFLECTION BY PRIMARY SCHOOL TEACHERS

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Abstract

In the paper we present selected outcomes of a research into possible acceptance of inquiry based mathematics education as a method used by primary school teachers. We suggest some objective as well as subjective reasons for explaining its so far low level of usage and aim at identifying obstacles, which prevent the enquiry based techniques in the primary school educational environment.

1. Introduction and theoretical basis

In the discussion on possible system changes in teaching mathematics and (not only) mathematical education of primary school teachers there is among others one imperative: the need for quality of professional competencies of the teacher. It has been shown in everyday practice that the quality of mathematical teaching depends to a great extent on the didactic competence in the subject as the "core" of professional competencies of teachers, which makes teachers different from (and impossible to substitute by) other professionals. This includes especially the knowledge of the teaching content and various ways of its didactic processing *(Helus, 2001)*, knowledge of the curriculum and ability to apply this knowledge in teaching and also the competence to react and respond to students' performance in class in a qualified way, and the ability to makes use of this in teaching *(Tichá, 2012)*.

There are many challenges which suppose developed professional competence of the teacher and at the same time aim at their further development. Inquiry based education is one of these. However, as *Hošpesová (2014)*,

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points out, in the Czech environment, this concept is sometimes understood in a rather vague or even naive way. The words "inquiry based" often have (especially for the non-teaching public) incorrect connotations as they imply idea of passing latest findings of science to elementary school pupils, which – naturally – seems to be impossible in mathematics. Thus by inquiry based mathematics education we understand teaching inspired by research and inquiry techniques as a "purposive process of stating problems, critical experimenting, judging alternatives, planning, study and verification, making conclusions, searching for information, making models of studied events, discussion with others and forming coherent argumentation" *(Linn, Davis, Bell, 2004, p. 15)*, i.e. teaching containing activities focused on study and discovery. For more details on this method see *Stuchlíková (2010)*, *Dostál (2013)*, in Czech primary school education context *Hošpesová (2014)*, which both include relevant foreign sources.

In our paper we follow in the study done in papers *Fleková and Novák (2013)* and *Nováková (2013)* and include several findings from a questionnaire research into opinions of primary school teachers on possibilities of using inquiry based education at primary schools.

2. An example of inquiry based education in the elementary school context

In order for the respondents to recall the concept of the inquiry based education (IBE or IBME further on), we included the following example in the questionnaire: working out the number of vertices (v), sides (s) and edges (h) using models of solids which was meant to result in finding out the Euler's theorem $v + s = h + 2$ (for details see *Fleková, Novák 2013).*

This tasks assumes the common knowledge of pupils at the end of their elementary education – basic solids (convex polyhedrons), naming the polyhedrons, concepts of vertex, side and edge.

Stages of discovery:

(1) *Setting the task for students:* Create models of tetrahedron, cube, regular square pyramid, regular five-sided pyramid, and hexagonal prism. Look for the relation between number of sides edges and vertices in each polyhedron.
(2) *Experiment realization and its recording (pupils do themselves based on teacher instructions):* Write the number of vertices (v), sides (s) and edges (h) of each polyhedron in a table and try to find out the relation between v, s and h.
(3) *Inquiry – discovery (with teacher's help):* From the data in the table we have found out that

- The greatest number for all solids is the number of edges. Furthermore, it is obvious that
- If we make the sum of two smaller numbers on each row (in all cases $v + s$), we get a number which is only slightly different from h, the number of edges. How slightly? Is the difference the same for each row?
- After a closer look we find out that there holds $v + s = h + 2$.

(4) *Hypothesis formulated – by pupils or with teacher's help:* In an arbitrary convex polyhedron with v vertices, s sides and h edges there holds $v + s = h + 2$ or $v - h + s = 2$.

(5) *Hypothesis verification:* Make models of some other solids such as cuboid or octahedron and verify the hypothesis: does the above assumption hold for these solids as well?

number of	tetrahedron	cube	regular square pyramid	regular five-sided pyramid	hexagonal prism
vertices (v)	4	8	5	6	12
sides (s)	4	6	5	6	8
$v + s$	8	14	10	12	20
edges (h)	6	12	8	10	18

Table 1: *Number of vertices, sides and edges of convex polyhedrons*

3. Objective and method

We wanted to find out whether teachers know the idea of inquiry based education and whether they (based on their own pedagogical experience) regard it as suitable for teaching mathematics at elementary school. We also wanted to find out topics which have the greatest potential for using IBME (and in which year can these be taught) and what obstacles prevent IBME from being used.

Our research was conducted in a group of 72 respondents, which included both experienced teachers of faculty primary schools at which students of the attended form of study do their teaching practice (16) and students of 3^{rd}–5^{th} year of the combined form of study who were mostly teachers actively teaching at schools yet who at the same time were receiving or expanding their primary school teaching qualification during their lifelong learning (56).

The following two research tools were used:

(1) Our own questionnaire which consisted of 20 closed-ended or semi-closed-ended questions: 8 questions focused on personal characteristics of respondents, further questions aimed at establishing respondent's knowledge of IBE, their to-date experience with this teaching method and obstacles which prevent teachers from its wider application in teaching. As for advantages of questionnaire research are concerned, it has been often suggested that *(Chráska, 2007)* it enables the carrier to gather great amount of data in a short time period. On the other hand, the possibility of including personal opinions of the respondents is limited. In order to minimize this handicap, we included the semi-closed-ended questions. We also supplemented the research with

(2) Interviews of selected respondents (students of the 4^{th} or 5^{th} year of study).

We are fully aware that the relevance of our findings is limited due to our choice of the method and sample of respondents. Yet even in spite of these drawbacks we believe that it gives useful feedback and is a good tool which can be considered in the professional training of teachers.

4. Selected findings

From the answers there follows that vast majority of the teachers is not familiar with the concept of IBE yet would like to learn it. This is the answer given by 84% of the respondents. At the same time the knowledge of IBE is considerably higher for teachers of the faculty schools (56%). This can be justified by the fact that such teachers usually learned about the method during the optional courses they had taken.

The method was mentioned as suitable for primary mathematical education by 87% of teachers, more than half (53%) would use it when working with talented pupils. However, the answers might be influenced by equalling the method with the demonstrative example which was included in the questionnaire. Respondents also gave their reasons for implementing IBE. Most often: it increases motivation of pupils to learn mathematics, makes pupils be interested in the subject matter, may help in better understanding of the subject matter, pupils "absorb" knowledge better, pupils' knowledge is more durable.

Among the main reasons against IBE there were: the fact that it is time-consuming both in class and in teacher preparations (67%), the fact that prior to using it suitable conditions and tools must be created (47%). Respondents also are not convinced that the IBE teaching is more efficient and gives better results than the usual frontal teaching.

We were also interested in how often would respondents include IBE in their teaching if they had this opportunity. Vast majority of respondents (91%) would include it scarcely, only in some special classes when teaching certain suitable topics.

Topics suggested by teachers for the potential use of IBE in teaching include most often the triangle inequality, the correspondence between area and circumference of planar geometric objects such as square; puzzles, numerical quizzes, etc.

The decision to include IBE in teaching depends mainly on the possibility to use sufficient amount of specific topics and ideas (the answer given by 87% respondents). The answer "depends on my own mathematical knowledge and didactic competencies" was chosen by 9% of respondents only.

The follow-up interviews of selected respondents clearly indicate interest in the inquiry based education which is seen as important motivational tool especially when working with talented pupils. However, the respondents warn that application of the method assumes developed pupils' competence to solve problems as well as competence to work such as to perform measurements, search for data and interpret data. This to some extent means that the method is not suitable for the very young pupils.

Topics suitable for IBE were discussed in the interviews as well. Only at the intuitive level, without previous verification, the following topics were suggested: properties of arithmetical operations (commutativity, associativity, existence of the neutral element), relations or rather regularities in number or image series, sorting geometrical shapes according to their properties. As one of the teachers frankly pointed out, "anything can be used, it all depends on the teacher".

5. Final remarks

We do not hold findings of our research for surprising. Yet even though it would be incorrect to state firm conclusions, we believe that certain points may be deduced:

- Inquiry based education as one of current constructivist directions is neither sufficiently known nor used in the primary school education environment. However, when acquainted with it (usually in some optional courses in the lifelong learning), teachers welcome it and try using it in their teaching. Our findings correlate with findings from Slovakia *(Pavlovičová, 2014)*.
- Obviously, the reasons limiting or preventing the use of IBE are seen as "outer", "objective" ones by the teachers; this mostly includes great time-consumption preventing "teaching the subject matter", insufficient amount of didactic materials, etc. while low level of

didactic competence or didactic quality of the teaching content are marginal.

- We were alarmed to have found out that the respondents had no chance to learn about IBE in detail. If one agrees that IBE should be included in teacher training, one must look for suitable ways of implementing it in teaching. One of the attitudes, which is based on students' own experience with inquiry based activities and their reflection has been mentioned by *Hošpesová (2014)*.
- In our research we have not reflected one of the important factors of potential application of IBE – what the attitudes of pupils are? We believe that on the pupils' side there sometimes exists insufficient motivation or problematic background of necessary mathematical knowledge and skills. Yet also here the role of the teacher is the key one. As *Dostál (2013)* points out, pupils who cannot proceed when solving problems and as a result are at a loss after a few unsuccessful attempts, must be helped by the teacher by questions, assistance or advice so that they are able to construct their own authentic image of the world, built on their own experience.

References

[1] J. Dostál, *Badatelsky orientovaná výuka jako trend soudobého vzdělávání*, 2013 [online]. [cited 2014-05-17]. Available from: `http://www.pdf.upol.cz/fileadmin/user_upload/PdF/e-pedagogium /2013/epedagogium_3-2013.pdf`

[2] A. Fleková, B. Novák, *Inguiry-based mathematics education – a challenge and a chance*, In: Usta ad Albim BOHEMICA, UJEP Ústí n.L., XIII (3), 2013, pp. 35–42. ISSN 1802-825X.

[3] Z. Helus, *Čtyři teze k tématu "změna školy"*, Pedagogika, 51 (1), 2001, 25-41.

[4] A. Hošpesová, *Badatelsky orientovaná výuka matematiky na 1. stupni ZŠ a příprava učitelů*, In: Acta Univ. Palack. Olomucensis, Fac. Paed., Mathematica VIII – 2014, Matematika 6. M, Uhlířová. (ed.) Olomouc: Vydavatelství UP 2014, pp. 8-14. ISBN 978-80-244-4062-0.

[5] M. Chráska, *Metody pedagogického výzkumu. Základy kvantitativního výzkumu*, Praha: Grada Publishing, a.s. 2007. ISBN978-80-247-1369-4.

[6] M. C. Linn, E. A. Davis, P. Bell (Eds.), *Internet environments for science education*, Mahwah: Lawrence Erlbaum Associates Publishers. 2004 [online]. [cited 2014-03-15]. Available from: `http://f3.tiera.ru/1/genesis/645-649/649000/e3914554 debcad2 ca0810 c46716 a87a4`.

[7] E. Nováková, *Od rutinního počítání k objevování*, In: Moderní trendy ve vyučování matematiky a přírodovědných předmřtů. 1^{st}*ed.* Brno: Masarykova Univerzita, 2013. ISBN 978-80-210-6724-0, s. 36-43. 2013, Brno.

[8] G. Pavlovičová, S. Čeretková, *Zvyšovanie matematických kompetencií učiteľov z praxe a v pregraduálnej príprave učiteľov primárneho vzdelávania*, In: Acta Univ. Palack. Olomucensis, Fac. Paed., Mathematica VIII – 2014, Matematika 6, M. Uhlířová (ed.) Olomouc: Vydavatelství UP 2014, pp. 188-192. ISBN 978-80-244-4062-0.

[9] I. Stuchlíková, *O badatelsky orientovaném vyučování*, In: M. Papáček (ed.), *Didaktika biologie v České republice 2010 a badatelsky orientované vyučování, DiBi 2010. Sborník příspěvků semináře, 25. a 26. března 2010*, Jihočeská univerzita, České Budějovice, 2010. ISBN 978-80-7394-210-6.

[10] M. Tichá, *Rozvíjení profesních kompetencí učitelů*, In: Specifika matematické edukace v prostředí primární školy, Acta Univ. Palack. Olomucensis, Fac. Paed., Mathematica VII – 2012, Matematika 5, M. Uhlířová (ed.), Olomouc: Vydavatelství UP 2012, pp. 25 - 29. ISSN 0862-9765, ISBN 978-80-244-3048-5.

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