The van Hiele Geometry Test at Czech Secondary School

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Abstract. This paper focused on the results of the pilot study based on van Hiele theory of geometric thinking. This study was realised at three types of Czech secondary schools. Adapted Usiskin test was used and testing was performed with electronic voting equipment Interwrite. Results were evaluated by standard statistic procedures. Main points of view were ability to classify student into van Hiele levels and differences between types of schools and genders.

Introduction
Theory [Van Hiele, 1986] describes the model of geometric thinking with three main attributes: the existence of levels, properties of the levels and the movement from one level to the next level. According to theory, there are five levels of geometric understanding which are labelled as Level 1: recognition (visualization), Level 2: analysis, Level 3: order (abstraction), Level 4: deduction and Level 5: rigor. The ability of the van Hiele model to describe and predict the performance of students in secondary school geometry was tested in the USA [Usiskin, 1982]. Van Hiele Geometry test clearly distributed students according to the level they achieved, except Level 5.

Our research
The main target of the pilot study was to verify the validity of the Usiskin’s van Hiele geometry test in the Czech mathematics education. This goal was already mentioned in the author’s previous article [Vojkuvkova, 2012]. Obtained data were further statistically processed from other points of view — differences between types of school and between gender and comparison with American results.

Methods
Method of testing: Van Hiele geometry test adapted by Usiskin (except Level 5) and translated into the Czech language was used. This test contained five questions for each of the four levels (Level 1...Level 4) of geometric thinking. Respondents had a printed form of the test, but they answered by electronic voting equipment Interwrite PRS (Figure 1).

Methods of data analysis: descriptive statistics, comparing binomial distributions, effect-size value.


Figure 1. Interwrite PRS.
Results

Criterion “3 from 5” was used, it means “level is achieved if and only if 3 or more than 3 out of 5 questions are answered correctly”. The same criterion was used by Usiskin.

Percentage of students who achieved different level

There are results of level N in binary variable – 0 means that a level was not achieved, 1 means that a level was achieved. In general, 96.7 % of students achieved Level 1, 86.5 % achieved Level 2, 39.1 % achieved Level 3 and 8.8 % achieved Level 4. The table shows percentage of students who achieved particular levels and confidence interval for binomial distribution (left, right) at 0.05 significant level.

Table 1. Summary results.

<table>
<thead>
<tr>
<th>Level</th>
<th>Percentage</th>
<th>Left</th>
<th>Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>0.97</td>
<td>0.94</td>
<td>0.99</td>
</tr>
<tr>
<td>Level 2</td>
<td>0.87</td>
<td>0.82</td>
<td>0.91</td>
</tr>
<tr>
<td>Level 3</td>
<td>0.39</td>
<td>0.33</td>
<td>0.46</td>
</tr>
<tr>
<td>Level 4</td>
<td>0.09</td>
<td>0.05</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Comparison of groups

The analysis of differences was performed by comparing two proportions (two binomial distributions) and effect size as the absolute value of difference between percentages – see Figure 2.

Comparison of gender

There are statistically significant differences between male and female at Levels 1, 3 and 4, but effect size is bigger than 10 % only at Level 3 – see Figure 3.

Comparison of schools

Detailed analysis [Haviger, Vojkuvkova, 2013] shows bigger differences among three types of schools – see Figure 4. The lowest results had students of business school. Students of technical school achieved quiet good results at Level 1 and Level 2. The best results at Level 3 and Level 4 were obtained by students of general school (“gymnasium”).

Comparison with Usiskin’s results

Usiskin’s results are not completely transferable to Czech environment or comparable with Czech results due to differences between curricula. American study had ten times more respondents, test was performed before and after the one-year course of plane geometry with other standard tests together. However, the ability to classify students into van Hiele levels is similar. Czech students had worse results essentially only at the last level, notably in question 24 (Czech version) = question 19 (Usiskin’s version) – see Figure 5.

Figure 2. Summary results.
Discussion

The use of Interwrite equipment was very effective in terms of testing and data processing. Error rate was low, as shown by previous researches at the University of Hradec Kralove.

There are several problematic questions, especially at higher levels. Translation into Czech is not entirely clear due to fundamental differences between language at Levels (according van Hiele) and correct mathematical expression. This issue will be discussed in a separate article. Despite these possible difficulties, our study showed that the theory is testable in the Czech school system. The results correspond to Usiskin’s study.
Conclusion

There are other research areas in the Czech Republic, particularly possible differences before/after completing explanation of plane geometry and comparison with results of other mathematics tests or school marks. Van Hiele theory can help improve geometric thinking in Czech school system (curricula, textbooks etc.).

Van Hiele Levels could exist in other parts of mathematics [De Villiers, 2010], authors intend to verify existence of them in calculus and to perform test in basic courses at the University of Hradec Kralove.

References