

## INFLUENCE OF STUDENTS' BIOLOGICAL KNOWLEDGE IN SOLVING COMPLEX COGNITIVE TASKS

*Valerija Begić<sup>1</sup>, Marijana Bastić<sup>2</sup>, Ines Radanović<sup>3</sup>*

<sup>1</sup> Sesvetski Kraljevec Primary school, Školska 10, 10 000 Zagreb ([valerija1.begic@gmail.com](mailto:valerija1.begic@gmail.com));

<sup>2</sup> Rudeš Primary school, Jablanska 51, 10 000 Zagreb;

<sup>3</sup> Department of Biology, Faculty of Science, University of Zagreb, Rooseveltov trg 6, 10 000 Zagreb, Croatia

### ABSTRACT

The aim of this study was to determine the conceptual understanding of Biology curriculum content on a sample of written tests designed for the County and State level Biology competitions for 7th grade students in the school year 2014/15. The sample consisted of 148 best solved tests, i.e. tests with 75% success rates, plus 11 tests from the state level. Written tests contained tasks designed in accordance with the recommendations for Biology test building. Data was analyzed (SPSS 17) with respect to defined learning outcomes in accordance with macro conceptual framework of Biology, quality assessment tasks, influence of the tasks on the level of discrimination, compliance with the 7th grade prescribed Biology curriculum, how it relates to everyday life, general culture, and content of other natural science subjects. The results showed no significant difference in performance with regard to gender, and that students are most successful in solving tasks of cognitive level 1 regardless of task difficulty level. Success rate in problem solving decreases with higher cognitive level tasks and higher levels of difficulty. According to the metric analysis, 65% of the tasks are of the adequate difficulty level and 57% are discriminatory. The result analysis shows that the level assessment and the task difficulty level are greatly influenced by the experience of the test compilers.

**Keywords:** cognitive levels, quality of the question, 7th grade Biology curriculum, students' competition, Science curriculum

### INTRODUCTION

Science, including Biology as an important indicator for school system evaluation, should develop students' competences, especially conceptual understanding as one of its important elements (Garašić et al., 2013). The development of methodology for Biology lessons, with an accent on the development of conceptual understanding as an important students' competence during their schooling (Lukša et al., 2013), has motivated the authors of written tests in all of the categories of the students' Biology competition to consolidate criteria for creating tests and constructing written assignments for competitions, but also to be used in tests during the school year (Radanović et al., 2013). According to Radanović et al. (2010), Croatian Biology teachers have conventionally accepted division into three cognitive levels according to Crooks (1988). The base is represented by the literary understanding (Radanović et al., 2010), which means that the student, thanks to his/her memory and language competences, will be able to retell certain information, and by doing so he/she does not necessarily reach a higher level of understanding of the concept, including conclusion, reproduction and explanations conducted during teaching or read in literature sources. That base is connected with the existing knowledge by conceptual connections, creating networked and lasting knowledge (Roberts and Johnson, 2015). The third cognitive level focuses on the ability to solve problems by integrating higher cognitive levels of Bloom's taxonomy (Anderson et al., 2001) with the analytical work mode (Crowe et al., 2008), and by doing so it is necessary to integrate the knowledge and application of critical thinking (Quitadamo et al., 2008). The

realization of the goals must be examined by questions formed in such a way to check the starting concept, as well as its defined educational outcome, which significantly contributes to the quality and meaningfulness of Biology tests (Radanović et al., 2013). When designing tests (Radanović et al., 2013), it is important to adjust the levels of achievement, as well as task difficulty with the evaluating system, to adjust the type of questions to the curriculum being tested, and to check the knowledge of basic biological concepts. For tests that check higher levels of knowledge, it is desirable to integrally connect the concepts within the Biology curriculum for a certain grade, but also in relation to previous grades, because biological concepts grow spirally during one's schooling.

The aim of this study was to examine the conceptual understanding of Biology teaching content of 7th graders on a sample of written tests from the Croatian County Biology competition, and a sample of written assignments from the State competition. Based on the basic goal, specific objectives were derived: 1) to compare the performance of students by gender; 2) to determine the outcomes that were examined in relation to the representation of biological macro concepts; 3) to analyze the credibility of task difficulty evaluation in relation to actual percentage of solved tasks; 4) to determine the effect that the measured task difficulty within a certain cognitive level had on percentage of solved tasks on both levels of competition; 5) to analyze the impact of students' biological knowledge on selected issues that check conceptual understanding and problem solving, and credibility of the question as a tool to identify particularly successful students.

## METHODS

The study was conducted on a sample of 7th graders' written tests from County and State level competitions that were conducted in the school year 2014/2015. The sample consisted of the 148 (10%) best written tests from County competitions, which means the tests that were at least 75% solved and 11 assignments from the State competition held in the same year.

According to the method of expert test quality assessment (Radanović et al., 2010), adapted for use in teaching, quality assessment questions used two criteria: assessment of scientific literacy, and the impact of question on the answer, both with the corresponding sub-criteria in the form of five-parted Likert scales. The analysis of question quality is determined by individual assessment, and joint assessment based on the arithmetic mean, by conciliating until consensus. The methodology used in determining the accuracy and the level of understanding expressed in students' answers to individual open-ended questions of higher cognitive level was the one by Radanović et al. (2010), adapted with certain questions. Difficulty index ( $p$ ), discrimination index ( $D$ ), and the variance of a binary variable ( $V$ ) (Hopkins, 1998) were determined by psychometric analysis. The representation of macro concepts and associated outcomes was determined according to the macro conceptual frame which was created by Radanović et al. (2015) for the purpose of making the Examination catalogue for State graduation exam in Biology.

The Kolmogorov-Smirnov Z-test, with the help of SPSS 17 software package, was used for the comparison of test completion by gender. The methodology that classifies students in 10 success ranks, according to the total success percentage in the entire written test

(Lukša et al., 2016), adjusted with the point value as the more precise determinant of student success, was used to compare solved tests according to cognitive levels.

## RESULTS

In the 10% of the best participants of the County competition there were 91 girls (61.5%) and 57 boys (38.5%). The proportion of boys and girls at the National competition was the equal, five female students (45.5%) and six male students (54.5%) participated. Based on the Kolmogorov-Smirnov Z test, it was found that in dealing with written assignments at the County competition ( $Z = 1.008$ ;  $p = 0.262$ ), as well as at the State competition ( $Z = 0.771$ ;  $p = 0.593$ ;  $M_f = 34.18 \pm 2.09$ ;  $M_w = 28.08 \pm 5.91$ ), with regard to gender ( $M_f = 63.18 \pm 10.97$ ;  $M_w = 66.46 \pm 10.93$ ), there were no significant differences in performance according to gender.

With regard to performance ranks based on the points gained at the state level of the competition, we can observe that the most successful students of rank VIII (71 - 80% points scored) solved 25% to 40% more of the test in comparison to students which successfully solved only a part of the test. This does not necessarily mean that they successfully addressed all parts of the test, because the in the assignment D2\_2S students with lower success rate (61% to 70%) achieved a higher middle point value, while the most successful were the students who scored a total of 51% to 60% points (Figure 6). The methodology that classifies students in 10 success ranks, according to the total success percentage in the entire written test (Lukša et al., 2016), adjusted with the point value as the more precise determinant of student success, was used for comparison of test solving by cognitive levels.

By comparing the students' results in solving the tasks of varying difficulty in a written form at the County competition, and by assessing the difficulty of these assignments, some deviations were observed. Teachers tend to assess easier assignments well, while they perform 50% worse while assessing the ones that are medium or hard in difficulty. Psychometric analysis of the results (Table 5) achieved in a written test at the County competition, which is a relevant indicator because of its size, showed that 15 assignments had an appropriate difficulty index ( $p$ ) (65%), and according to the variance of binary variable, 14 assignments (61%) had an adequate sensitivity, and thirteen assignments had variance in the range from 0.20 to 0.24, meaning that the assignments were of appropriate difficulty. Almost half of the assignments in the written part of the County competition test had something to do with the students' everyday lives, while the correlation with other Science subjects is somewhat weaker (39%).

The percentage of completion, and the test's sensitivity in dividing successful and less successful students, depending on the assessed difficulty and cognitive level of the assignment, were analyzed based on chosen examples from the State competition (Image 10-14). Assignment 8 (multiple combinations) tests the students' understanding of breathing process of fish, and it poorly separates the students who were successful in the entire written assignment, because 45% to 80% of students in all ranks of performance manage to solve it. Assignment 11 (multiple combinations) questions the conceptual understanding of the mitosis process, and it poorly separates the most successful students

altogether, because 30% of the weakest IV rank students managed to solve it, the ones who scored 31% - 40% points.

Assignment 12 (multiple combinations) checks the understanding of concepts of diffusion and osmosis in case of fish in changed living conditions. Exactly 18,92% of the students solved it, and the gained data says that students found the assignment difficult, although it was assessed as being of middle difficulty. However, this assignment successfully separates the students that scored better in the whole written assignment. Assignment 16 (alternative choice) examines the understanding of shark body adaptations according to their lifestyle. This assignment has a series of alternative choice questions and it poorly separates the students who scored better in the whole written assignment, because only 40% to 20% less students of all ranks (in relation to the most successful students) solved it, apart from the ones of the weakest, IV rank, where no student solved this assignment.

Assignment 21 consists of five multiple choice questions and it is assessed as an assignment of the third cognitive level, therefore difficult, and it examines the understanding of the process of aerobic and anaerobic respiration of yeast. The assignment precisely separates the students who are the most successful in the entire written assignment, but its discrimination index ( $D = 0.9$ ) is low, because some students who managed to solve only 60% to 80% of the whole assignment also managed to solve it.

Based on the middle point value of County level competition tests (Figures 13 - 15), most students achieve more than a half of necessary points per assignment in easy and mid-difficult assignments that check reproductive knowledge and literary understanding. In easy and mid-difficult assignments that check conceptual understanding and the use of knowledge, it is visible that students score more than a half of needed points per assignment, while they score a bit less in difficult assignments, and the ones that require problem solving. National competition (Figures 16 - 17) proved that the students are less successful in solving the problems of higher cognitive level.

## DISCUSSION AND CONCLUSIONS

Slightly larger number of girls who participated in the County competition can be explained by their greater interest for the Biology contents dealing with the phenomena of the living world, which is also consistent with the conclusion devised by Garašić (2012), which states that girls consider school subjects of Nature and Biology more usable and easier than the boys. The share of the investigated cognitive levels of knowledge in a written assignment on the State competition shows a slight discrepancy with the recommendations in favour of problem assignments, which is acceptable, considering that the tests on national level are prepared for the best students.

First level assignments are not required if the test preparations ensure that the assignments of higher cognitive levels also contain the verification of key information related to a certain concept that is being checked. It is more important that the higher level assignment, apart from solving the problem, also checks the integration of knowledge and critical thinking skills, as indicated by the Hoskinson et al. (2013), and strictly follows the form. In cases like this, it is always better to integrate more solutions to one

assignment, if that can enable a better check of the conceptual understanding and problem solving abilities.

The results have shown deviations from the estimated assignment difficulty, in such a way that the students found assignments more difficult than the estimation, as determined by Lukša et al. (2014). This happens because teachers tend to expect better test results for questions they consider important for the profession. Teachers estimate easy assignments well, while they have considerably less certainty in estimating mid-difficult and difficult ones. Teachers' methods play a great part in assessing the assignment difficulty, because they act according to their classroom experience, or based on the experience of analyzing written tests. Therefore it is extremely important to encourage teachers to analyze the results of their written tests in detail. Insufficient experience in solving higher cognitive level assignments, and overcrowded curriculum that negatively affects the quality of teachers' support of students' conceptual understanding, with still quite dominant traditional teaching, or, sometimes, just formal implementation of active forms of learning, is reflected in successful students' reduced capacity, as the ones participating in the Biology competition and solving cognitive level III assignments. DeHaan (2009) and Maskiewicz et al. (2012) confirmed the fact that the curriculum which entices problem solving in class and is used within formative grading frame had the potential for development of complex problem solving in students.

Students were less successful in solving the higher cognitive level assignments, with only 10% of cognitive level III assignments solved, and 40% of cognitive level II assignments solved. Those assignments are solved only by the most successful students and are a great tool for separating them from other students, which is the main goal of a competition knowledge test. Considering the fact that the assignments that check fact-oriented reproduction (Bannister, 2002) were solved only in 60%, we can conclude that students have problems in choosing which facts to memorize in order to create a quality basis for conceptual understanding.

The multiple combinations assignments and alternative choice questions proved to be a bad basis for distinguishing successful from less successful students. In contrast, well designed multiple choice assignments with a good conceptual basis successfully separated the most successful students, although they can (in some small percentage) be solved by other successful students. Because of this phenomenon, the discrimination index for such assignments can have a low value, which suggests that the assignment needs to be modified or excluded (Hopkins, 1998), and in such cases, a professional qualitative analysis, along with psychometric analysis, is necessary. It is common for quality assignments of higher cognitive levels, particularly level III assignments, which have been evaluated as important for Biology and for the application of biological knowledge in everyday life, to have weaker psychometric properties. Considering that it is not expected for all the students to solve these assignments, but only those who are most successful, the final say in deciding if the assignment needs to be revised, or if it is effective in written evaluation, must be given by the science, in this case Biology.

The results support the conclusion brought by Domazet (2009) - that the motivation for students to develop biological competences rests on a specific problem solving approach, where the aspirations of individuals (students) for direct participation in the learning

process, the understanding of the material environment, and the desire for entertainment as an important motivational factor in primary school must be met. All of these should also be encouraged at Biology competitions.

The majority of assignments within the *Organization of the living world* macro concept confirm the teaching emphasis set by the National curriculum (MZOS, 2006), and the absence of assignments from the *Life Science* macro concept, as well as the weaker conceptual understanding of biological processes, points to the need for experiential learning and discovery learning, as well as the introduction of exploratory learning into Biology lessons. A proactive approach, i.e. independent initiative taking during solving written assignments in Biology competitions, and the construction and detection of relations in the learned contents, are all desired results or learning achievements. Therefore, future research should compare and investigate the extent to which biological learning and teaching modes affect the quality of students' knowledge in Biology competitions.

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