

## THE NATIONAL ASSESSMENT OF MATHEMATICS IN HIGH SCHOOLS IN ITALY WITH SLOVENE AS THE LANGUAGE OF INSTRUCTION

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**Povzetek/Abstract** In the following paper, we analyzed the question types in the INVALSI national mathematics assessments in Italian high schools with Slovene as the language of instruction. Through a statistical analysis, we found that closed-type questions were more frequent than open-type questions. A greater presence of closed-type questions could lead to the issue of guessing and cheating. Moreover, a greater quantity of closed-type questions could lead to a partial evaluation of knowledge, since procedures and other mathematical competences are not considered. In our research, we also considered the topics of the questions that were presented in national assessments.

### Nacionalni preizkus znanja iz matematike na višjih šolah s slovenskim učnim jezikom v Italiji

V prispevku predstavljamo tipologijo vprašanj v vsedržavnem preverjanju znanja iz matematike INVALSI. S pomočjo statistične analize lahko ugotovimo, da so vprašanja zaprtega tipa pogostejša od vprašanj odprtega tipa. Prisotnost večjega števila vprašanj zaprtega tipa lahko privede do problema ugibanja in prepisovanja. Poleg tega pa lahko večje število vprašanj zaprtega tipa privede to nepopolnega preverjanja znanja, saj se pri teh vprašanjih ne oceni postopkov in drugih matematičnih kompetenc.

## Introduction

National assessments have the purpose of evaluating learning outcomes, which are based on criteria and expectations set by various national education authorities (Benavot & Tanner, 2008). These assessments should describe the level of achievement and competences of the education system in its totality, or a specific part of it, such as 11-year-old pupils (Kellaghan & Greaney, 2001). National assessments also play an important role in providing national policymakers with objective information about the status of the education system (Benavot & Tanner, 2008). Since they are typically subject-oriented (mathematics, language, science etc.), and since they evaluate a particular grade level, they are an important diagnostic tool, used to identify which areas in the school systems need more attention (*ibid.*).

Discussions regarding standardized tests have long been part of the overall concern in relation to their ambiguity and validity (Powell & Gillespie, 1990). Despite this, the spread and growth of such tests has not diminished in recent years. On the contrary, such tests are still very much in use, and the growing concern is that they are no longer a true representation of a student's knowledge, but focus instead only on the techniques needed to pass the tests. In fact, as Roberts (2006) suggests, learning has been focused on the assessments themselves, on "passing tests", as it were.

Assessments are usually divided into two main categories: formative and summative (Garrison & Ehringhaus, 2010). Summative assessments are periodic tests of student knowledge. Their aim is to measure students' knowledge and acquisition of standard curricular content. They are also tools to evaluate the effectiveness of curricula and school programs (Leung, Leung & Zuo, 2014). Examples of such summative assessments, as Garrison & Ehringhaus (2010) explain, include state assessments, end-of-unit or chapter tests, semester exams and other types of tests. According to the authors, this kind of assessment is helpful for the school and teacher, specifically when they need to make instructional adjustments and interventions.

Formative assessments, on the other hand, can be used in classroom practice as a tool to understand how to adjust both teaching and learning. This kind of assessment can be formal or informal; in both, it is nevertheless important that the teacher give students feedback that shows the presence of a 'gap' between the level of the assessed work and the required standard (Taras, 2005).

The Italian national examination of knowledge, INVALSI, is a summative assessment. Since 2010, grade 10 students in Italian high schools are supposed to take an examination in both mathematics and the Italian language (Italian is replaced by Slovene in schools with Slovene as the language of instruction). The questions in these assessments can be either open- or closed-type. There are several reasons for preferring one type to the other: for example, closed-type questions are easier to grade; on the other hand, open-type questions do evaluate students' knowledge and abilities in a more complete way. When students answer closed-type questions, there is a greater chance of guessing, since in the INVALSI examinations, there are no penalties for answering a question incorrectly.

In order to establish which question type (open- or closed-type) was more frequent in the INVALSI assessment of knowledge of mathematics over the last 8 years, we decided to conduct a study based on seven INVALSI mathematics assessments for grade 10 students in Italian high schools. We were additionally interested in finding out which mathematical topic was more common in the INVALSI national assessments of mathematical competence. In particular, we wanted to understand whether there had been a shift in interest over the last three years from more theoretical topics (functions, equations, radicals etc.), to more applied topics (statistics, data representation, modeling with linear functions etc.). If some mathematical topics were being neglected by the national assessment of knowledge, the issue could emerge of more marginal students' knowledge of certain mathematical content, which could lead to mathematical illiteracy and to the impossibility of a deeper understanding of mathematical topics. In fact, teachers that base their programs on assessment of knowledge could omit some of the more theoretical content and concentrate only on those mathematical topics that are somehow "hot" and statistically more common in the examinations.

## **Theoretical Framework**

### *Which evaluation?*

In education, evaluation is necessary in order to gauge what students understand and what they can do (Kartianom & Mardapi, 2017). National evaluations are done to measure the level of knowledge and competence of students, as well as to diagnose the status of the school system (Bansilal, 2017; Kartianom & Mardapi, 2017), and the national competences and achievements in specific subjects (Sulistyaningsih & Sugiman, 2016). National assessments, which are equal for the whole population, guarantee objective information about student knowledge (Cankar, 2008).

Assessment practices are rapidly transforming, since today we use more open-ended problems, hands-on problems, essays and information technology (such as computer simulations of real-world problems) (Linn, Baker & Dunbar, 1991; Stecher et al., 1998). On the other hand, some national assessments also include closed-type questions, such as multiple-choice questions, as can be seen in the INVALSI examination (Quadro di Riferimento, 2017).

The INVALSI assessments in mathematics do not take into account open-ended problems, or essays. There are no hands-on problems that might be evaluated just by solving the INVALSI assessment of knowledge. Hence, if we compare the structure of the INVALSI examinations with the ideas present in Linn, Baker & Dunbar (1991) and in Stecher et al. (1998), we could conclude that the INVALSI national assessments do not evaluate students' abilities, knowledge and competences in the ways described by the authors, since they diagnose only the student's ability to solve a certain type of problem.

As stated by Cankar (2008), some national examinations assess only the cognitive achievements of students, and only in specific subjects. In the case of the Italian assessment, the INVALSI examinations evaluate only student knowledge of mathematics and languages.

Nevertheless, national assessments of mathematics might help teachers and educators to modify, and hence improve, their teaching (Felda, 2018). Moreover, national assessments are useful in identifying the strong and weak points of teaching mathematics, and they help to monitor the developing factors in education, such as lesson programs, textbooks and teachers' learning and training (Magajna & Žakelj, 2011; Žakelj, Ivanuš Grmek, Cankar, 2012).

Parveva, De Coster & Noorani (2009) stated that national assessments can be divided into three groups:

- in the first group we consider all the national assessments that have the goal of grading students' knowledge: the results of national assessments also have an impact on the grades of individual students. This kind of assessment also has an impact on the future choices of students, determining, for example, which school a student can attend;
- in the second group, there are national assessments that are done mainly to assess the school system and identify reforms regarding schooling;

- in the third group, we consider those assessments which are a supplement to teaching processes. Based on the results of the examinations, educators and schools can identify their weak points and teaching needs, while seeking improvements. In this category, we could place the national assessments in Italy.

Some authors are concerned by the fact that students who are not motivated perform worse in national and international assessments than those who are motivated (O'Neil Jr., Sugrue & Baker, 2010). In this respect, Cankar (2008) states that national assessments may seem to many a waste of time, since they are “not for a grade”. In Italy, the national assessment of knowledge does contribute partly to the final grade in grade 9 (INVALSI, 2010), but with the new school reform, the INVALSI examinations have only a diagnostic function and not a grading one (Studenti, 2019a, 2019b). In grades 10 and 13, the INVALSI examinations are obligatory, but they do not influence the final grading of the student (Studenti, 2019; Studentville, 2019). Considering these affirmations and the conclusions of Cankar (2008), we can observe that many students are demotivated while sitting the INVALSI assessment tests, which is congruent with what was stated by the Italian educator Daniele Novara (Repubblica, 2018).

### *Open- and closed-type questions*

Stankous (2016) points out that the issue of measuring student performance has often been at the center of several debates. In order to evaluate students' knowledge, teachers can prepare tests with different typologies of questions: open (constructed-response) and closed (selected-response) questions.

In open questions, students must construct their own responses, organizing and applying their knowledge (Powell & Gillespie, 1990). Preparing such questions is easy, while grading them seems to be much more difficult, since clear criteria and scoring tables are difficult to prepare (*ibid.*). In these types of questions, there is less chance of students answering by guessing. In closed questions, on the other hand, students need to select the answers among various alternatives. Grading such questions is much easier and faster, but their preparation is time consuming. Guessing in closed-type questions is also an important issue (Klůfa, 2015). Students, who face a multiple-choice question with 4 options, have a 25% chance of guessing the correct answer. If there is no penalty for a wrong answer, students are more likely to guess a correct answer, in order to collect more points (Espinosa & Gardeazabal, 2010).

National assessments can have both open- and closed-type questions. Scoring assessments with multiple-choice questions is cheaper than those with judgement-based tasks, but the gains to student learning are greater (Wiggins, 1990). Similarly, Stankous (2016) has shown that constructive-response tests do more to encourage student learning than multiple-choice tests. The author affirms that open-type tests are more reliable and valid than closed-type tests and that student success cannot be measured by multiple-choice tests alone. In her research, the author found that many teachers want their students to recognize questions and question types, memorizing the correct answers, so that they can “meet certain educational performance standards” (ibid., p. 315), forgetting this information when the tests are over. Conversely, Roberts (2006) thinks that multiple-choice tests could be used to enhance the learning process. On the other hand, students might leave the multiple-choice testing having assimilated false or incorrect knowledge, (Roediger III & Marsh, 2005).

We would like to present an example of the application of concerns voiced by Stankous (2016) about mere memorization, an example taken from the INVALSI examinations.

**Example 1: Example of a multiple-choice question form the INVALSI examinations.**

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*School year 2010–11*

Term                      it's the same:

- A.
- B.
- C.
- D.

*School year 2011–12*

Term                      it's the same:

- A.
- B.
- C.
- D.

*School year 2014–15*

Term                      it's the same:

- A.
  - B.
  - C.
  - D.
- 

In Example 1, we note that the structure (or the “Question type”, Stankous, 2016) is similar, and the answers are constructed on the same basis; the numbers involved are also often repeated. Students could just “recall” the answer form previous exercises and “drills”, forgetting how to get to the correct answer.

### *Topics in Mathematics Assessment*

Mathematics literacy is defined by the OECD (2018, p. 51) as follows: “an individual’s capacity to formulate, employ and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognise the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens”.

Following this basic concept, there are four categories of mathematical knowledge and the mathematics program that are assessed in the PISA and PISA-D. These are (OECD, 2018):

- change and relationships;
- space and shape;
- quantity;
- uncertainty and data.

The OECD document (ibid.) states that the proposed problems should be challenging and based on real situations. The categorization of the content into the four presented categories is important for the development and selection of items, but some problems might be transversal and would thus fit into more than one category: for example “space and shape”, “change and relationships” and even “quantity”. The interdisciplinarity of the proposed problems is also important, in order to underline the coherence of mathematics as a discipline (ibid.).

### *The situation in Italy: the national INVALSI examinations*

Italian schooling comprises five school levels: kindergarten, primary school (five years, from level 1 to 5), middle school (three years, from level 6 to level 8), high school (five years, from level 9 to level 14), and university. After the third year of middle school, students are supposed to pass a state exam, in order to proceed to a high school; after the fifth year of high school, students must sit the “*Esame di stato*” (State Exam) to get their diploma.

The National System for Evaluation (*Sistema Nazionale di Valutazione*) works inside the National Institute for the Educational Evaluation of Instruction and Training (INVALSI). The INVALSI also works under the supervision of the Ministry for

Education, University and Research (*Ministero dell'Istruzione, Università e Ricerca, MIUR*); its aim is to investigate and periodically assess student knowledge on the whole Italian national territory, as proposed in the decree D.Lgs. n. 286/2004. In the directive of the MIUR 76/2009, INVALSI must assess the level of knowledge among primary school pupils, as well as middle school and high school students. Student knowledge is measured through standardized tests of Italian language and mathematics (Martignone, 2016; Quadro di Riferimento, 2017). As written in the Quadro di Riferimento (2017), these tests are currently applied in the second and fifth years of primary school (levels 2 and 5), the third year of middle school (level 8) and the second and fifth years of high school (level 10 and 13). INVALSI prepares the examinations considering the curricula for primary and secondary schooling, i.e. “*Indicazioni Nazionali per il curricolo della scuola dell’infanzia e del primo ciclo di istruzione*” and the “*Indicazioni Nazionali e Linee guida per le scuole secondarie di secondo grado*” (Martignone, 2016; Quadro di Riferimento, 2017).

The decree MIUR-MEF n. 211 from the 7<sup>th</sup> October 2010 and the directive MIUR n. 57 from 15<sup>th</sup> July 2010 are the two documents that regulate the curricula in Italian high schools. In these documents it is stated that students, at the end of five years’ schooling, should know the basic concepts and methods used in mathematics, not only from a theoretical point of view, but also to model and describe various phenomena from the real world. It also stresses that students should be able to use logical and coherent argumentation and apply mathematical concepts in everyday life. In these documents it is also stated that, while formulating problems for students in high schools, it is important to show them the connections between theoretical knowledge and other sciences (economics, sociology, technology, physics, biology, etc.) or the real world. The documents invite teachers to show students how to use formal language and how to prove theorems, how to analyze data and predict the evolution of phenomena, use mathematical knowledge in other sciences, introduce new concepts using elements from the history of mathematics, history of science, technology and cultural development.

During the second year of high school, students at all Italian high schools are required to write a national assessment of Italian language and mathematics. However, these standardized tests:

- cannot evaluate students’ metacognitive or non-cognitive achievements, such as that embodied in “the students develop a positive attitude toward mathematics” (Quadro di Riferimento, 2017);
- cannot evaluate students’ ability to argue, prove or solve certain problems (that would require more time or a greater number of steps), formulate



hypotheses, or model real-world situations and analyze them from a mathematical point of view (Quadro di Riferimento, 2017);

- are objective; hence, they do not take into account the affective and conative aspects, which are also important in evaluating student work and assessing competence (Quadro di Riferimento, 2017).

Until the school year 2017-18, the INVALSI examinations for schools with Slovene as language of instruction were printed. Every year, the printed dossier had a variable number of questions, which were divided into different items (Quadro di Riferimento, 2017). Questions in the INVALSI examinations, as expressed in the Quadro di Riferimento (2017), can be

- closed: multiple choice questions, where there are four alternatives (only one answer is correct); true-false questions, composed of several sub-questions (see Example 2);
- short, open questions: these require a simple, rapid open answer, such as the result of a computation, or some graphic answers (see Example 3);
- open: these require simple argumentation or short computations;
- *cloze*: the student is required to complete a sentence, computation or expression.

**Example 2: Example of a multiple-choice question from the INVALSI examination for the school year 2017–18.**

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<b>The result</b>	<b>is the same:</b>
A. <input type="checkbox"/>	
B. <input type="checkbox"/>	
C. <input type="checkbox"/>	
D. <input type="checkbox"/>	

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**Example 3: Example of a short answer question from the INVALSI examination for the school year 2017–18.**

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The equation is given		, with unknown in real number .
The equation solution is , if .....		

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Students were allowed to use their calculators during the tests, but not devices that could connect to the internet, wireless or Bluetooth. They could also use compasses, rulers and goniometers.

In the Quadro di Riferimento (2017) it is also stated that simple language must be used in writing the problems proposed to the students; no dialectal or regional expressions are used, and the testers try to avoid useless technological jargon. Pictures are used only when particularly explicative; the data provided in the problems are mainly taken from real data and statistics. Questions are also equally distributed among the various topics.

The proposed problems have two dimensions: the cognitive dimension and the topic dimension. Topics are divided into four categories: numbers, geometry, algebra and data analysis (and probability). The cognitive dimension is divided into three categories:

- knowing: the student understands the facts, concepts and procedures;
- applying: the student should know how to apply their knowledge and acquired concepts to solve problems and answer questions;
- reasoning: the student solves problems related to complex and unfamiliar contexts.

## **Empirical Research**

### *Aim of the Research*

The aim of the present research is to analyze several INVALSI examinations in mathematics in the Slovene language, in order to understand the typology of their questions and the mathematics field to which each question is related. This research could have practical applications: teachers and students could be informed of the mathematical topics that are more common on the INVALSI examinations and the question types. On the other hand, this research could show which knowledge and competence in mathematics Italy requires from its students.

We wanted to investigate whether there have been changes in the types of questions and the interest field from 2011 to 2017. And, if so, what these differences were. Our research questions were the following:

- Is there a prevalent typology for questions on the INVALSI examinations? Are there more closed-type questions (e.g. true-false questions or multiple-choice questions) or open-type questions (e.g. short answer questions)?

- Is there any mathematical topic that appears more often in the INVALSI examinations than others? And if so, has there been any change in the topics of interest over the years?
- Have theoretical fields, such as functions, set theory and logic, become gradually less common on the INVALSI mathematics examinations?

## Methodology

### *Research method*

In the research, we used the descriptive statistical method and the non-experimental method for causal analysis. We decided to use these methods, because they are best suited to answer the research questions.

### *Statistical sample*

In the research we considered seven INVALSI mathematics examinations for the second year of high schools with Slovene as the language of instruction, i.e. all the examinations from the school year 2010–11 to the school year 2016–17. We omitted from our sample the INVALSI examination from the school year 2017–18 because it was almost identical to the one from 2013–14. The samples cannot be found online, since they are prepared *ad hoc* for schools with Slovene as the language of instruction; the samples in Italian can be found on the website [https://www.engheben.it/prof/materiali/invalsi/seconda\\_superiore\\_matematica.htm](https://www.engheben.it/prof/materiali/invalsi/seconda_superiore_matematica.htm). These versions are similar to those in Slovene.

### *Analysis of the Data*

We first looked at the types of questions appearing on the various INVALSI examinations. Next, we sought to identify the mathematical topic to which the question referred, in order to understand which topic is the most popular. The collected data was analyzed using the descriptive statistical method, expressing frequency of appearance. All data was analyzed with the help of the statistical software *Jamovi*.

## Results and Discussion

### *The Typology of the Exercises*

In Table we present the typology of the various questions on the INVALSI examinations from the school year 2010–11 to the year 2016–17. In the table we present the number of questions (and sub-questions) for each type: multiple-choice, true-false, long answer questions (a procedure is evaluated and scored), fill-in the blank, short answers (only a numerical answer is required, no procedure is evaluated), connect the terms, and the total number of questions on the examination. In brackets, we give the percentage of that type for that year's examination.

**Table 1: Typology of exercises in various school years.**

School year	Multiple-choice	True-false	Long answer	Fill-in the blank/complete	Short answer	Multiple-choice and discussion	Connect	Total
2010–11	23 (56.1%)	3 (7.3%)	3 (7.3%)	1 (2.4%)	11 (26.8%)	0 (0.0%)	0 (0.0%)	41 (100.0%)
2011–12	21 (46.7%)	4 (8.9%)	2 (4.4%)	4 (8.9%)	11 (24.4%)	3 (6.7%)	0 (0.0%)	45 (100.0%)
2012–13	28 (63.6%)	2 (4.6%)	0 (0.0%)	1 (2.3%)	11 (25.0%)	2 (4.6%)	0 (0.0%)	44 (100.0%)
2013–14	13 (34.2%)	6 (15.8%)	0 (0.0%)	2 (5.3%)	16 (42.1%)	1 (2.6%)	0 (0.0%)	38 (100.0%)
2014–15	18 (42.9%)	4 (9.5%)	0 (0.0%)	2 (4.8%)	16 (38.1%)	2 (4.8%)	0 (0.0%)	42 (100.0%)
2015–16	17 (42.5%)	3 (7.5%)	0 (0.0%)	3 (7.5%)	15 (37.5%)	2 (5.0%)	0 (0.0%)	40 (100.0%)
2016–17	14 (35.0%)	6 (15.0%)	2 (5.0%)	4 (10.0%)	13 (32.5%)	0 (0.0%)	1 (2.5%)	40 (100.0%)
Total	134 (46.2%)	28 (9.7%)	7 (2.4%)	17 (5.9%)	93 (32.1%)	10 (3.4%)	1 (0.3%)	290 (100.0%)

From Table 1, we can see that the most frequent type of question on the INVALSI mathematics examinations for the second year of high school is the multiple-choice question (46.2%). The second most frequent type is the short answers (32.1%), followed by true-false questions (9.7%). In the last three years, there has not been any significant increase in the frequency of multiple-choice questions, or true-false ones, but it is still clear that the most frequent type of question is the multiple-choice; it is also the most frequent in each school year examination, with the only

exception being the school year 2013–14, when short answer questions were the most frequent.

In order to understand which type of question was the most frequent, we grouped multiple-choice, true-false and connect in the category “closed-type questions”, and long answer, short answer, fill-in the blank, and “multiple-choice and discussion” in the category “open-type questions”. These results are shown in Table 2. From the analysis, we see that closed-type questions (56.2%) are more frequent than open-type ones (43.8%). In particular, in the school years 2010–11 and 2012–13, closed-type questions were significantly more frequent than open-type ones, whereas on the other examinations, the frequency was slightly higher. No significant increase in the frequency of closed-type questions can be seen in the last three years. Every year, the number of closed questions was greater than or equal to those of the open-type.

**Table 2: Open- and closed-type questions on the examinations.**

School year	Closed-type questions	Open-type questions	Total
2010–11	26 (63.4%)	15 (36.6%)	41 (100.0%)
2011–12	25 (55.6%)	20 (44.4%)	45 (100.0%)
2012–13	30 (68.2%)	14 (31.8%)	44 (100.0%)
2013–14	19 (50.0%)	19 (50.0%)	38 (100.0%)
2014–15	22 (52.4%)	20 (47.6%)	42 (100.0%)
2015–16	20 (50.0%)	20 (50.0%)	40 (100.0%)
2016–17	21 (52.5%)	19 (47.5%)	40 (100.0%)
Total	163 (56.2%)	127 (43.8%)	290 (100.0%)

As presented, closed-type questions are easier to correct, but they have several limitations. A unavoidable limitation of multiple-choice questions is that it is possible for students to guess the correct answer (Burton, 2001). Furthermore, closed-type questions cannot completely evaluate students’ knowledge and abilities.

### *The Mathematical Topics*

We first sought to understand which mathematical topics are covered by the national INVALSI examination; we therefore analyzed the content of each question and sub-question. From the content of such questions, we decided to distinguish among the following topics:

- statistics: sampling, data organization, data representation (tables, graphs, etc.), relative and absolute frequency, percentage frequency, means, standard deviation, variance;
- probability: definition of classical probability, events, disjoint events, dependent and independent events, computation of probability of elementary events, *a priori* and *a posteriori* probability, binomial tree;
- geometry: principal geometrical shapes and objects, definitions, relations between geometrical objects, congruence, parallelism, perpendicularity, geometrical constructions, segments, distance in the plane, measuring with the ruler, angles (internal, external, vertically opposite angles, supplementary, complementary, explementary, etc.), measuring with the goniometer, translations, rotations, symmetries, similarity, Pythagorean theorem, Euclid's theorem and equivalency, Thales' theorem and similarities, perimeters and areas of plane shapes (square, rectangle, triangle, parallelogram, circle, trapezoid, etc.);
- arithmetic: natural numbers, integers, rational and real numbers, operations between numbers, properties of the operations, representations of numbers on the number line, fractions, proportions and applications, powers and their properties, square roots and cube roots, decimal and scientific notation, rounding and positions, numerical expressions, symbolic expressions;
- approximation: approximation of real and rational numbers, operations with approximated numbers, working with big or small numbers, scientific notation;
- diagrams: line diagrams, histograms, bar diagrams, pie charts, representation of numbers, reading diagrams, interpretation of a diagram;
- Solid geometry: solids (cube, parallelepiped, cone, sphere, cylinder, pyramid, prism, etc.), volume and surface area, diagonals and sections;
- analytic geometry: coordinate plane, points and coordinates of points, distance between points, areas of shapes in the coordinate plane, triangles in the coordinate plane;

- algebra: unknowns, polynomials, factorization of polynomials and binomials, equations, equalities, inequations and inequalities, squares and square roots of expressions;
- percentages: interpretation of percentages, discounts and marketing, application of percentages;
- functions: definition of functions, plots of functions, roots of functions, modeling with functions, domain and codomain of functions, polynomial and rational functions, parabola and hyperbola;
- linear functions: definition of linear function, plot of linear functions in the coordinate plane, lines, intersection of lines, parallel lines and perpendicular lines, slopes and lines through two points, equation of a line in the coordinate plane, modeling with the linear function, increasing rate;
- logic: propositions, logical connectives, negations, conjunctions, disjunctions, implications and equivalences;
- set theory: sets, elements, operations with sets (union, intersection, etc.), complementary set, power set, cardinality of a finite set.

Our findings are shown in Table 3. In the last column we presented the relative frequency percentage of the topic among all 290 questions analyzed.

**Table 3: Content of INVALSI examinations.**

	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17	Total
Statistics	3	1	4	6	6	6	2	27 (9.3%)
Probability	1	3	2	2	6	2	5	21 (7.2%)
Geometry	6	4	7	8	5	6	6	42 (14.5%)
Arithmetic	13	8	9	6	3	5	6	51 (17.6%)
Approximation	3	0	1	0	0	1	0	5 (1.7%)
Diagrams	6	2	2	3	2	3	4	22 (7.6%)
Solid geometry	2	2	3	0	2	1	2	12 (4.1%)
Analytic geometry	2	1	0	1	1	0	0	5 (1.7%)
Algebra	2	3	1	4	5	3	2	20 (6.9%)
Percentages	1	8	6	3	4	4	2	28 (9.7%)
Functions	1	5	2	0	0	1	0	9 (3.1%)
Linear functions	1	7	7	4	8	6	11	44 (15.2%)
Logic	0	1	0	0	0	0	0	1 (0.4%)
Set theory	0	0	0	1	0	2	0	3 (1.0%)
Total	41	45	44	38	42	40	40	290 (100.0%)

From

Table we can conclude that the most frequent topic is “Arithmetic” (17.6%), followed by “Linear functions” (15.2%) and “Geometry” (14.5%). It is also possible to see that the number of exercises on the topic “Linear functions” grew and almost doubled in the school year 2016-17. In the last three years, only one question was related to functions in general terms, while “Linear functions” has become a more popular topic. Considering merely linear functions and problems from linear modeling, it is therefore possible to conclude that interest has shifted from a more “theoretical” analysis of functions, to a more “concrete” and “explicative” one, in the last three years.

As explained in the Quadro di Riferimento (2017), some questions could cover more than one mathematical topic. For example, while working with a certain statistical problem, a knowledge of percentages was required. Plotting a line in the coordinate plane also requires a knowledge of analytic geometry itself. Since many questions could have been included in two or more categories at the same time (for example, in the category “Linear functions” and “Algebra”), we decided to include a given question in the category that was most indicative of that problem.

In Example 4, a question taken from the INVALSI examination for 2012–13 focuses on areas and sides of squares. In order to solve this mathematical problem, the student needs to understand percentages as well as geometry; this question could thus be considered both a geometry problem and a percentages problem. Since the question is about “squares”, it seems more natural to consider it as a “geometry-related” topic.

**Example 4: Example of an interdisciplinary question.**

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A square is given with the side  $a$ .

- a. If the side is  $2a$ , a new square emerges with the side  $2a$ . Which of the following expressions represents the length of  $2a$ ?
    - A.  $a$
    - B.  $2a$
    - C.  $4a$
    - D.  $8a$
  
  - b. By how many per cent is the surface of the square with the side  $2a$  larger than the surface of the square with side  $a$ ?
    - A.  $200\%$
    - B.  $300\%$
    - C.  $400\%$
    - D.  $800\%$
-



In order to limit the number of mathematical topics, we decided to group together those categories with similar mathematical content. We decided to distinguish the following macro-categories:

- data representation, data analysis and uncertainty (DRDAU): we joined the topics “Statistics”, “Probability” and “Diagrams”;
- geometry: we joined the topics “Geometry” and “Solid geometry”;
- linear functions: we grouped the topics “Analytic geometry”, “Linear functions” and “Functions”;
- logic and set theory (LST): this combines the topics “Logic” and “Set theory”;
- algebra: comprising only the topic “Algebra”;
- numbers and quantities (NQ): we joined the topics “Arithmetic”, “Approximation” and “Percentage”.

Table represents a graphic illustration of the questions divided into the macro-categories that we proposed. Each column gives the percentage of questions in a category with respect to the total number of questions in that year. In contrast, the last column gives the percentage of the category’s question among the 290 total questions that we analyzed.

**Table 4: Macro-categories in the INVALSI examinations.**

	2010–11	2011–12	2012–13	2013–14	2014–15	2015–16	2016–17	Total
DRDAU	10 (24.4%)	6 (13.3%)	8 (18.2%)	11 (29.0%)	14 (33.3%)	11 (27.5%)	11 (27.5%)	71 (24.5%)
Geometry	8 (19.5%)	6 (13.3%)	10 (22.7%)	8 (21.1%)	7 (16.7%)	7 (17.5%)	8 (20.0%)	54 (18.6%)
NQ	17 (41.5%)	16 (35.6%)	16 (36.4%)	9 (23.7%)	7 (16.7%)	10 (25.0%)	8 (20.0%)	83 (28.6%)
Linear functions	4 (9.8%)	13 (28.9%)	9 (20.5%)	5 (13.2%)	9 (21.4%)	7 (17.5%)	11 (27.5%)	58 (20.0%)
Algebra	2 (4.9%)	3 (6.7%)	1 (2.3%)	4 (10.5%)	5 (11.9%)	3 (7.5%)	2 (5.0%)	20 (6.9%)
LST	0 (0.0%)	1 (2.2%)	0 (0.0%)	1 (2.6%)	0 (0.0%)	2 (5.0%)	0 (0.0%)	4 (1.4%)
Total	41 (100.0%)	45 (100.0%)	44 (100.0%)	38 (100.0%)	42 (100.0%)	40 (100.0%)	40 (100.0%)	290 (100.0%)

From Table we can see that problems in the category “Numbers and quantities” are the most frequent (28.6%). The second most frequent macro-category is “Data representation, data analysis and uncertainty” (24.5%); the third most frequent problems are from the macro-category “Linear functions” (20.0%). The least frequent, and almost neglected in every year’s examination, is “Logic and set theory” (1.4%).

## Conclusions

In the paper we analyzed seven INVALSI examinations for mathematics in the second year of high schools with Slovene as their language of instruction. We analyzed the questions from two perspectives:

- the typology of the questions: in particular, we sought to understand which question type (open-type and closed-type) was more frequent;
- the content of the questions: we sought to understand which mathematical topic was the most frequent on the INVALSI examinations.

From the analyzed data, it is evident that many closed-type questions, i.e. multiple-choice questions, true-false questions, or connect questions occur more frequently. Among the closed-type questions, multiple-choice questions are the most popular and represent 46.2% of the total questions. This answers our first research question: closed-type questions are the most frequent on INVALSI mathematics assessments.

Using mainly closed-type questions on an examination could lead to an emerging issue with guessing, (Haladyna, Downing & Rodriguez, 2002; Lau, Lau, Hong & Usop, 2011). Instead of evaluating procedures and the deeper knowledge that students have achieved, these national assessments are evaluating mainly the numerical result. Students who answer multiple-choice questions have a 25% chance of guessing the correct answer rather than showing their actual work and ability (Lau et al., 2011). Hence, it could be argued that guessing lowers the assessment’s reliability (Burton, 2001).

We have shown that the most frequent mathematical topic present in the seven analyzed INVALSI assessments is “Number and quantities” (28.6%). We noted that in the last three years, the assessed topics favoured more “applied” mathematical fields, such as “Linear functions” and “Data representation, data analysis and uncertainty”.

Our work points to the emergence of a critical situation, in that there are very few questions concerning mathematical logic and set theory. Teaching and learning only those topics that are the most frequent in national assessments, could lead to mathematical illiteracy and to the impossibility of understanding deeper mathematical topics. For example, very few questions on the INVALSI examinations focused on the general concept of function (i.e. not specifically on linear functions); therefore, it could happen that teachers just bypass this topic, centering their lessons more on linear functions than on functions in general. No question on injective, surjective or bijective functions was found in our analysis.

There is no reported evidence that the INVALSI assessments do influence the teaching of certain mathematical topics or dictate which topics should be studied in class. Limiting questions to a few topics, such as linear functions, arithmetic and data analysis, could lead to a more marginal knowledge of other topics, such as functions, logic, set theory and algebra.

More research should be carried out to understand whether national assessments regulate and direct modern tendencies in the learning and teaching of mathematics.

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