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WHY DO CHILDREN DIFFER IN MATHEMATICAL COMPETENCIES? THE EXPERIENCE OF A STANDARDIZED TEST IN THE PRIMARY SCHOOL OF CANTON TICINO, SWITZERLAND.

Abstract:

Standardized tests are, as it is well known, a highly controversial and widely debated topic. On the one side they are considered a relatively objective tool for measuring student achievement that consumes little class time and produces useful information on which teachers, school administrators and policy makers can rely in order to assess and improve their classes or schools (Crescentini and Zanolla, 2013). On the other side, according to some authors, they only reveal students' knowledge during the very short timeframe in which the tests are administered (Boaler, 2003), the results are influenced by factors such as anxiety or time pressure (Buck, Ritter, Jenson & Rose, 2010) and reflect the inequities that already exist within schools and end up advantaging the students from higher socioeconomic statuses (Vigdor and Clotfelter 2003; Alon, 2010).
Despite all the criticism, a recent project aimed at producing and administering a standardized test to evaluate mathematical competencies in the fourth class of primary school in Ticino, an Italian-speaking region of Switzerland, has brought some interesting findings about the pupils' weaknesses and strengths and the overall school system. The paper is aimed at presenting this test, which has involved almost 3,000 pupils, and at examining the main determinants of the results obtained by the pupils. The analysis of the impact of environmental, school, class, teacher, individual and household factors reveals that children's scores differ considerably in relation to the district where the school is located (in Ticino there are 9 districts, each of which is a geographical area with its own inspector who is responsible for the quality of teaching), the family socioeconomic status, the nationality and the age of the pupil and the Math's grade given by the teacher. While factors such as the school's size, the urban/rural location of the community, the attendance of a multi-class, the teacher's and the pupil's gender exert a significant effect only on a part of the competencies that have been considered, class size, seems to be overall irrelevant.

Keywords:

standardized test, determinants of learning, evaluation of competencies, primary school

JEL Classification: I24, I29

1. Introduction

Standardized tests area highly controversial and widely debated topic. On the one side they are considered a relatively objective tool for measuring student achievement that consumes little class time and produces useful information on which teachers, school administrators and policy makers can rely in order to assess and improve their classes or schools (Crescentini and Zanolla, 2013). On the other hand, according to some authors, tests only reveal students' knowledge during the very short timeframe in which they are administered (Boaler, 2003); test results are influenced by factors such as anxiety or time pressure (Buck, Ritter, Jenson & Rose, 2010) and reflect the inequities that already exist within schools and tests end up advantaging the students from higher socioeconomic statuses (Vigdor and Clotfelter 2003; Alon, 2010).

Despite all the criticism, a recent project aimed at producing and administering a standardized test to evaluate mathematical competencies in the fourth year of primary school in Switzerland's Italian speaking Canton of Ticino has delivered some interesting findings about the pupils' weaknesses and strengths and the overall school system. The paper is aimed at presenting this test, which has involved almost 3,000 pupils, and at examining the main determinants of the results obtained by the pupils.

2. The elaboration of a standardized test in Mathematics in Canton Ticino[1]

In 2010, the Center for Innovation and Research on Education System of the University of Applied Sciences and Arts of Southern Switzerland was given the task to assess the competencies in mathematics of the students at the end of the primary school by Ticino's Directorate of primary education. This assessment has two main aims: on the one hand, it has to provide information about the system's performance and any gaps it may have; on the other hand, it has to provide feedback to each teacher about his or her students' needs, so that the teacher can make adjustments if needed.

Much of the efforts were spent on developing a set of more than 300 items concerning 6 domains of mathematics competency and for this purpose a team of primary and lower secondary school teachers, discipline experts and teachers of didactics of mathematics was set up. The 6 dimensions (table 1) cover only part of the math curriculum in schools because the financial resources did not allow testing the whole program. This means that other dimensions had to be excluded from the test. The main selection criterion is that the different domains must be relevant in the specific school year considered.

Table 1: Selected dimensions and areas

Dimensions	Areas
AR – Data and relations	SRD – Knowing, recognizing and describing
GM – Dimensions and measures	EA – Executing and use
GEO – Geometry	EA – Executing and use
GEO – Geometry	SRD – Knowing, recognizing and describing
NC– Numbers and calculating	AG – Arguing and Justifying
NC – Numbers and calculating	EA – Executing and use

[1] A detailed description of the standardized test and of the procedure of the item selection can be found in the paper Crescentini, A. & Zanolla, G. (2014): The Evaluation of Mathematical Competency: Elaboration of a Standardized Test in Ticino (Southern Switzerland) Original Research Article Procedia - Social and Behavioral Sciences, Volume 112, pp. 180-189. This paragraph constitutes a short resume of this paper.

In order to analyse the quality of the items on the basis of the item response theory (Lord, 1980), they were distributed over 10 booklets. Every pupil of a sample corresponding to half of the students attending the 4th year of primary school in Ticino (i.e. 1,683 pupils) was given two booklets with 60 items each, one week apart from one another.

Using the software ConQuest we analyzed how different item response models (one-dimensional and multidimensional Rasch model) fitted the data, then we compared the one-dimensional model “Mathematics” with a multidimensional model, as well as with a one-dimensional model with domains. In the end we opted for fitting the data to a one-dimensional model and defining the domains at a later stage. This choice is based on the assumption that one latent construct “Mathematics” exists and can be divided into different domains that are highly correlated.

After choosing the model, we assessed the item quality looking at the items which fitted the model better.

The best fitting 120 items (20 for each domain) were chosen to assess the whole population of students in the selected dimension. Two different booklets were prepared, each one containing three domains to be tested. In the booklets the items were ordered from the least to the most difficult.

Ticino’s entire population of students attending the fourth year of primary school amounted to 2935 children, including 2203 (75.1%) with Swiss citizenship only, 93 (3.2%) with a second passport in addition to the Swiss, 295 (10.0 %) with solely Italian citizenship or with a second non-Swiss passport in addition to their Italian passport and 317 (10.9%) from a country which is neither Switzerland nor Italy (of which 161, i.e. half of the, come from non-EU countries). There were 1517 (51.7%) boys and 1418 (48.3%) girls. The research involved 186 classes in public schools, including 68 multi-age classes. Out of the 2935 students, 619 (21.1%) attend a multi- age class, i.e. a class in which there are students of different ages, a typical condition in small communities.

Each teacher received a report on his or her own class with the explanation of the process followed and the description of the results. The report gives every teacher the opportunity to compare his or her class average performance score in each dimension with the average performance score of both the whole population and the population of his or her district. The scale corresponding to each domain is given by the sum of the related items weighted by the difficulty coefficient resulting from the analysis of the first test administration.

3. The determinants of the results in the test

To determine which factors affect the students’ performance in the test, we considered five types of variables concerning the social setting, the school, the class, the student and the test administration mode (by the teacher or another external specially-appointed person) (Table 2). For the sake of brevity, we will discuss here only the findings which were considered most significant. In addition to the six dimensions already mentioned, "General Mathematics" was included, which consists of the average scores of all six dimensions.

Table 2:

Type	Variable
Environment	District Level of urbanization of the municipality
School	Size of the school
Class	Class size Multi-aged class Teacher's gender Teacher's experience Full or part-time teacher Ethnical composition of the classroom
Pupil	Gender Nationality Age Grade in Mathematics Socio-cultural background
Test administrator	Teacher or other external person

3.1 The school district

The primary school in Ticino is organized on a geographical basis. There are 9 districts (called "*circondari*") and each district has an inspector, who is responsible for the quality of teaching. Larger schools have a school manager in charge of coordinating all the activities of the school. The nine inspectors are coordinated by a director of the infant and primary school.

When it comes to compare the performance of students, variance analysis reveals significant differences across the nine districts. In the case of "General Mathematics", the highest average score was recorded in district 8 and district 2 (over 52), followed by district 7 (over 50). The lowest scores were observed instead in district 1 (43.0) and district 3 (47.3). Districts 4, 5 and 6 had intermediate scores (Table 3).

Table 3: Average scores in the 9 districts.

District	Data and relations – Knowing, recognizing and describing	Geometry – Knowing, recognizing and describing	Geometry – Executing and use	Numbers and calculating – Arguing and Justifying	Numbers and calculating – Executing and use	Dimensions and measures – Executing and use	General Mathematics
1	64.08	45.76	40.32	36.51	44.79	38.44	43.04
2	69.44	58.34	53.73	44.81	50.75	47.36	52.58
3	64.29	49.10	48.91	39.22	48.76	42.01	47.27
4	66.69	50.43	48.18	41.11	47.96	44.98	48.31
5	69.00	51.99	47.06	40.14	48.92	42.93	48.06
6	66.61	49.49	46.93	42.66	53.20	42.84	48.59
7	68.75	50.94	50.44	41.91	52.58	47.45	50.39
8	69.33	55.79	52.14	43.73	53.37	49.66	52.60
9	66.53	51.19	49.04	39.91	51.27	44.07	48.68

3.2 Age of the students

In any class there might be students who are one or more years older than the majority of their classmates: that may be due to their late entry to school or to the fact they had to repeat a school year, one or more times. The latter case is rather uncommon in Ticino's primary school: even looking at the 2nd grade, which is the most selective year, the percentage of students who repeated the grade in the period between school year 2002/2003 and 2011/2012 never exceeded 2.8 % (Rigoni, 2013). Whatever the reason for lagging behind their peers, older students were often found to come from disadvantaged social groups and/ or have experienced migration (UNESCO, 2006; UNESCO, 2007), which may also negatively impact school achievement. Older students pose a challenge for teachers because they have different needs: demotivation, for instance, may be common among students who repeat a school year.

86.5 % of the students we surveyed were born in 2002 and 12.4 % in 2001.

A negative and significant correlation was found to exist between the student performance in the different domains of mathematics and the age of the student. With increasing age (often coupled with a history of changes of residence and school, migration from other countries or school failure) students get significantly lower scores in all domains (Table 4).

Table 4: Correlation between the average scores in the six domains of mathematics and the age of the student attending the fifth year of primary school (5th grade).

		Data and relations – Knowing, recognizing and describing	Geometry – Knowing, recognizing and describing	Geometry – Executing and use	Numbers and calculating – Arguing and Justifying	Numbers and calculating – Executing and use	Dimensions and measures – Executing and use	General Mathematics
Age of the student	Pearson correlation coefficient	-.198**	-.151**	-.153**	-.143**	-.148**	. -.145**	-.182**

**Significant at 0.01

3.3 Student nationalities and ethnic composition of the class

The presence of a high number of children of immigrant parents and belonging to minority ethnic groups in a school is sometimes viewed with suspicion by local families, who fear that such situation might adversely affect their children's learning. In the 1950s, for example, the term "White Flight" was used in the United States to describe the large-scale migration of white students from the public schools in the metropolitan areas to the schools in the suburbs to avoid studying together with black students who were more socially disadvantaged. In fact, several American and European sociological studies have shown that a negative correlation exists between the concentration of immigrants in a school and students' academic performance (Felouzis, 2003; Porter and Hao, 2004; Fekjaer and Birkelund, 2007; Szulkin and Jonsson, 2007). Furthermore, it seems that the influence of the peer group rises with increasing age of the students, to become very significant - for instance - at the time of choosing a secondary school (Van Ewijk and Sleedgers, 2010; Veerman, van de Werhorst and Dronkers, 2013).

The reason why migration has a negative impact on school performance has been explained in three main ways, which have to do with inequality in educational opportunities, characteristics of the school setting and residential segregation. Let us briefly go through them.

Some authors argue that unequal opportunities in education arise from microinteractions. Generally speaking - probably due to a "floor effect" and to the influence of reference groups - migrant parents tend to set less ambitious educational goals for their children and as a result the presence of a high number of migrant students in a school allegedly discourage educational achievement (Porters and Zhou, 1993; Porters and Rumbaut, 2001). However, the socio-economic characteristics of individual students can off-set the impact of their migrant background (Evans, Oates and Schwab, 1992; Dietz, 2002; Cebolla-Boado and Garrido and Medina, 2010).

As for the school setting, schools with a high concentration of migrants tend to be located in deprived neighbourhoods with a weaker cultural background: that can be detrimental for their quality performance. Furthermore, teachers in these schools might be induced to “level down” their teaching to accommodate the needs of less proficient children, thus creating a less stimulating learning environment (Duru Bellat and Mingat, 1997).

The issue of residential segregation stems from the fact that migrant families tend to be concentrated in low-income residential areas, home to disadvantaged families. The over-representation of families from a disadvantaged background might explain why the students attending the schools in such areas have a poorer academic performance (Cebolla-Boado and Garrido Medin, 2010).

Out of the 186 classes surveyed in our study, 173 (93.0 %) were composed primarily of Swiss students (i.e. students holding exclusively Swiss citizenship or else Swiss and another citizenship), 4 classes (2.2 %) had Swiss and foreign students in equal numbers; in 9 classes (4.8 %) foreign students prevailed (Italian or any other citizen nationality)[2]. The analysis of variance shows no significant difference in the scores in the six math domains for the three types of class. It must be emphasized, however, that the majority of classes consisted predominantly of Swiss students and only a few classes (13) had a prevalent non-Swiss student population: given this imbalance we deemed it inappropriate to indulge in the search for explanations.

Looking at the origin of students, it can be noted that in all math domains Swiss students (i.e. students holding Swiss citizenship only; N 2287) scored significantly higher than Italians (i.e. students holding Italian citizenship only or else Italian citizenship in addition to another citizenship other than the Swiss; N 295) and other foreign students (N 324). The difference between Swiss and Italian students is irrelevant only in the "Numbers and calculating; Arguing and justifying" domain (Table 5). Instead, no significant difference in performance was found between Italians and other foreigners in any domain of the test. It seems, therefore, that the students’ migration background (and probably the associated social background) has a stronger detrimental influence on performance than linguistic competence. This may be due to the fact that even students who presumably do not speak Italian at home possessed appropriate language skills to complete the exercises of the test, or else to the fact

[2] Please note that approximation is used here: class composition data do not refer to the entire class, but only to the students who completed the test in any given class.

that mathematical competence is not strongly impacted by language skills. Another factor that might influence performance is the date of arrival of the student in Switzerland: this issue however could not be further investigated.

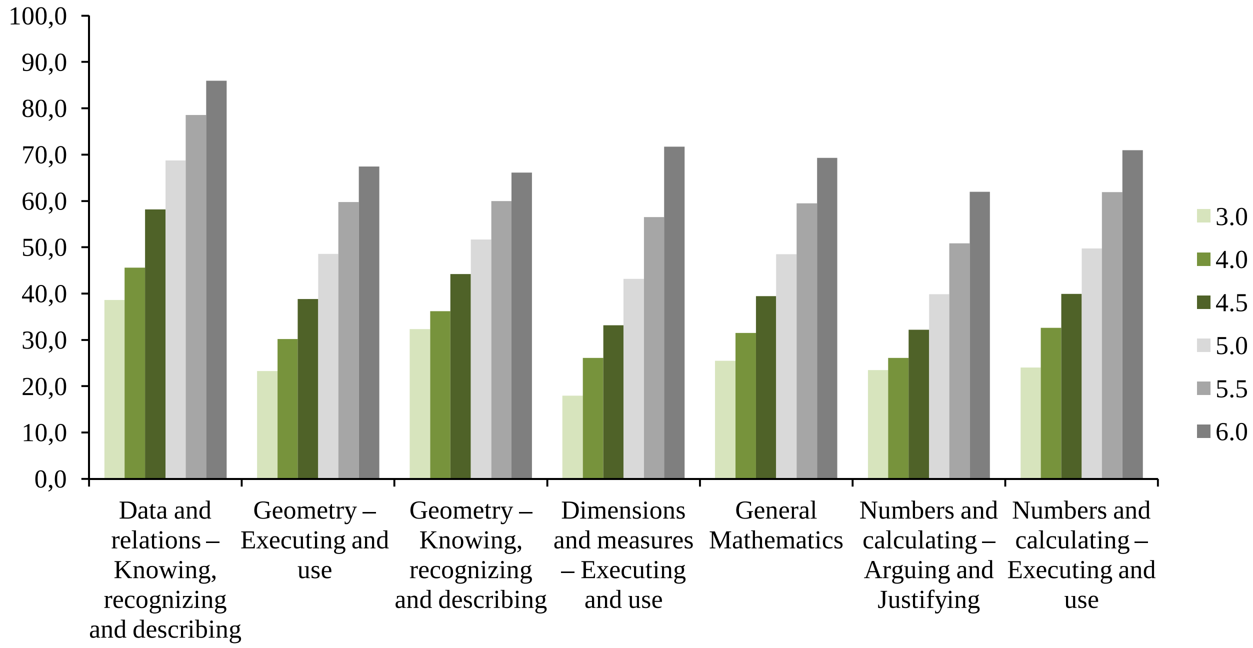
Table 5: Relationship between the average scores in the six domains of mathematics and student nationality.

Nationality	Data and relations – Knowing, recognizing and describing	Geometry – Knowing, recognizing and describing	Geometry – Executing and use	Numbers and calculating – Arguing and Justifying	Numbers and calculating – Executing and use	Dimensions and measures – Executing and use	General Mathematics
Swiss	68.60	52.33	49.70	41.85	51.00	45.67	49.86
Italian	63.74	49.50	46.03	39.63	47.67	41.47	46.47
Other	60.93	47.09	43.51	37.74	47.21	40.76	44.75

3.4 The link between school marks and test results

The GAGI database reveals that only 1% of the students who took the test got mark 3 at the end of the school year (which indicates failure in Ticino), while more than one-third got mark 5 or higher. A closer look at the mark in math at the end of the year and at the results of the standardized tests reveals that in all domains of mathematics better marks at the end of the year are linked to significantly higher scores in the test (Figure 1). The Pearson correlation coefficient between scores in "General Mathematics" and school marks was no less than 0.63. Although the test covers only a part of the math syllabus of the previous year, consistency was found between teacher-made assessments and test results.

Figure 1: Relationship between scores in the tests and the mark awarded to the student at the end of 5th grade (percentages, N=2855).



3.5 The student's social background

In his well-known work on educational inequality, Boudon (1974) distinguished between primary and secondary effects. While primary effects are expressed via the association between the students' class backgrounds and their actual levels of academic performance, secondary effects stem from the influence of the social background on educational choices. In this paper we will focus on the primary effects of educational inequality, although, in general, both primary and secondary effects are very relevant when it comes to investigate the students' individual education paths and outcomes.

Children from better-off families receive more intellectual stimulation and motivation from their parents, develop better language and cognitive skills thanks to their parents' reading habits and mode of verbal interaction with the child (De Graaf et al., 2000) and receive more support for school work (Breen et al., 2009). An analysis of the 2009 PISA data revealed that nearly 40 % of the students in their fourth year of middle school in Ticino resorted to private lessons between the third and fourth year of middle school and a large part of them had already used private tutoring during primary school (Zanolla, 2013a). In many cases, the decision to hire a private tutor does not stem from the need to provide educational support to a child with a poor school performance but mainly from the desire to further improve a child's already good performance (Zanolla, 2013b). This decision seems to be in keeping with a strategy in which parents emphasize the importance of education, consider very important for their children to grow up in a stimulating learning environment and closely monitor their activities (Davies, 2004). It seems that the use of private tutoring is typical of upper-class families, who more than others worry that their children may experience downward social mobility and, consequently, seek to limit that risk by encouraging children to take on more ambitious school projects so that they can maintain their original competitive advantage (Collins, 1979).

The analysis of data from standardized math tests confirms that, in all domains of mathematics, the higher the socio- cultural background of a student is, the better the student's performance will be. The children of fathers who are "white-collar workers with a high level of education" show significantly better results (Table 6). Both in standardized tests and in the assessment by teachers, the children of socially disadvantaged groups get lower scores, although it is difficult to determine which context mostly contributes to such poor performance. For the "General Mathematics" variable, 17.2 % of the students have fathers who are blue-collar low-skilled workers; in the upper end of the score such percentage drops to 8.4 % (Figure 2). Similarly, out of all students who got a mark 4 or less in mathematics at the end of the year, 24.1 % come from a lower social class; such percentage drops to 7.5 % among students who got mark 5 or higher. (Figure 3). Totally different trends are recorded, however, in the case of upper class students from a higher social class. The 4 groups differed in terms of numbers: there were 884 children of highly skilled white-collar workers, 484 children of low-skilled white-collar workers, 460 children of highly skilled blue-collar workers and 248 children of low-skilled blue-collar workers.

Table 6: Relationship between the average scores in the six domains of mathematics and the social origin of the students.

Socio-cultural background	Data and relations – Knowing, recognizing	Geometry – Knowing, recognizing and	Geometry – Executing and use	Numbers and calculating – Arguing	Numbers and calculating –	Dimensions and measures – Executing	General Mathematics

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	and describing	describing		and Justifying	Executing and use	and use	
Highly skilled white-collar workers	71.31	54.56	53.2	45.3	54.05	49.58	53.08
Low-skilled white-collar workers	68.97	52.62	48.38	42.26	49.62	44.09	49.26
Highly skilled blue-collar workers	65.46	49.43	46.49	37.83	47.95	42.4	46.53
Low-skilled blue-collar workers	61.91	49.59	45.97	36.05	45.95	39.86	44.93

Figure 2: The four score levels for the "General mathematics" variable broken down by social origin of the student (percentages, N = 2062).

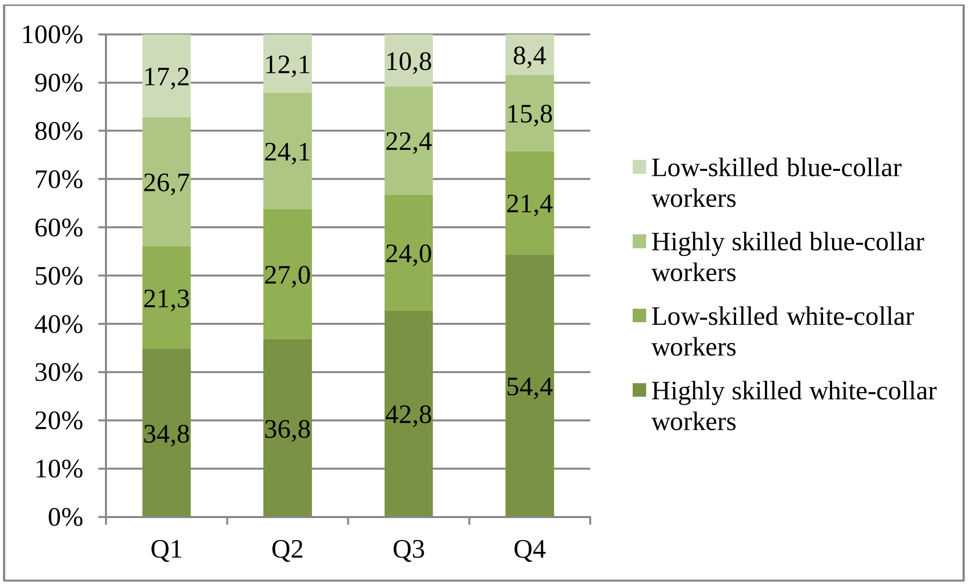
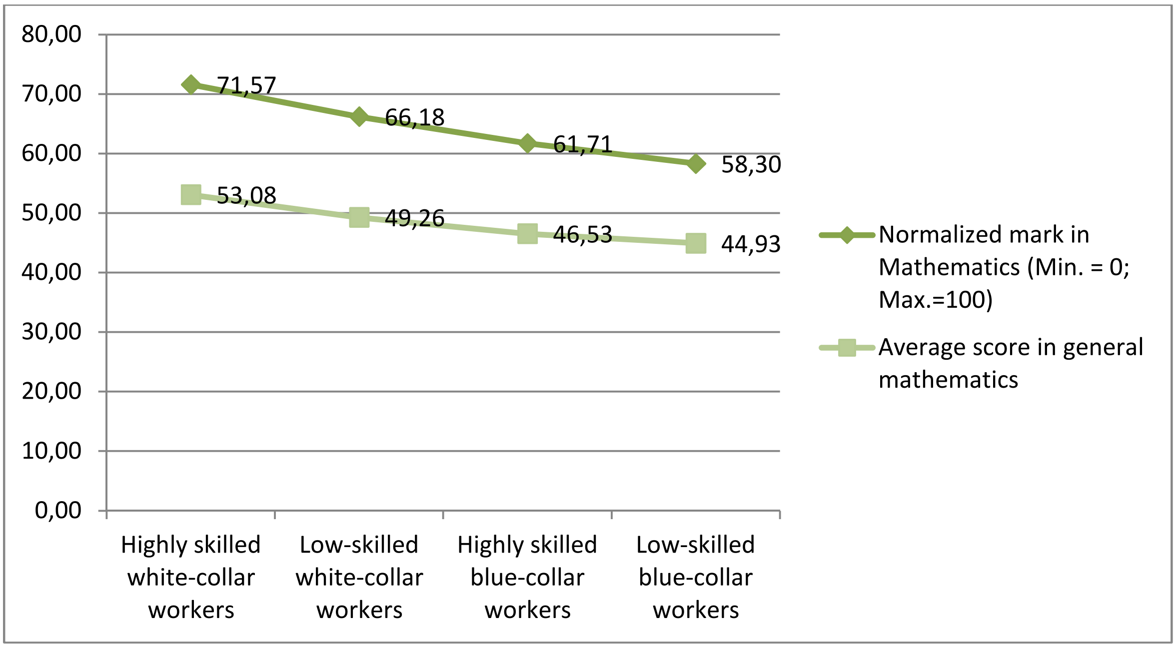


Figure 3: Students grouped by final mark in mathematics at the end of the fifth year of primary school and broken down by social origin (percentages, N = 2033).

Figure 4: Students grouped by final mark in mathematics at the end of the fifth year of primary school and broken down by social origin (percentages, N= 2033).



The final mark in mathematics and the test score grow consistently with each other (Figure 4). For the sake of comparing values, the final marks were normalized: that involved processing original marks between 0 and 6 and calculate them again so that they can be expressed in the 0 to 100 range. Despite many reservations about the comparability of values, we believe this analysis is worthwhile.

3.8 Mode of test administration

Almost 90 % of the students took the test in the presence of their teacher, 10% instead completed it under the supervision of an external person in charge of distributing the booklets. Although the number of students in these two subgroups differed greatly, the variance analysis of the "General Mathematics" scores leads us to conclude that students who completed the tests with their teacher in the classroom got significantly better results (Table 8). "Geometry; executing and use" was the area with the greatest difference between students who took the test in the presence of their teacher and those who were assisted by an external person (average of 49.16 and 43.59 respectively). Some teachers told us that they had helped weaker students by giving them extra time to complete the test, or else by inviting too hasty students to review their answers. That calls for a reflection on the role duly played by the teacher in the classroom, which necessarily influences the students' learning and development.

Table 8: Average scores in general mathematics and mode of test administration.

Mode of test administration	General Mathematics	N	Std. Dev.
Teacher	49.25	2601	17.58
External person	45.99	302	17.32
Total	48.91	2903	17.58

4. Conclusions

This paper presents the case of a standardized mathematics test intended for Canton Ticino's primary schools. After describing the rationale and steps that led to develop the tool, the paper examines the variables that were found to have the greatest impact on the students' performance. Most notably, a high correlation was observed between the socioeconomic status of the students and the scores they obtained in the test: this means that despite efforts aimed at ensuring fairness and equal opportunities, there is still ample room for improvement and action even in the primary school.

Foreign nationality seems to be a hindrance regardless of language skills: Italian students performed similarly to other foreign students and, together with the latter, significantly worse than Swiss students. In addition, female students are to some extent under-represented in the group of the best performers. The test scores proved to be consistent with teacher-made assessments. On the one hand, this fact leads us to conclude that the test is consistent with the work done in class both in terms of contents and arrangement; on the other hand, since a standardized test is expected to provide a more objective evaluation of students' performance than the daily assessment in the classroom, we can assume that in Ticino's primary school assessment practices are very precise and capable of providing an accurate picture of students' achievement.

Finally, results were significantly better when the test was administered by the teacher rather than by an external person. In fact, in many cases teachers admitted that they had intervened to help their students during the test, thereby partly disregarding test protocol instructions. Teachers' interventions involved providing more time, giving specific advice, helping students in difficulty or explaining individual exercises. While being common practice in daily classroom activities, this type of support not only makes it very difficult to assess how much a student's performance was influenced by the teacher but also undermines the test standardization process as a whole. Given the difficulty in ensuring that the teachers follow the instructions also when these differ from their daily classroom practice, we resolved that in the future tests will be administered only by properly trained personnel.

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