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"YES, I GOT THEM ALL" – SPECIAL EDUCATION STUDENTS' ABILITY TO SOLVE ICT-BASED COMBINATORICS PROBLEMS

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This present study is aimed at revealing special education students' mathematical potential by means of a dynamic ICT-based assessment. The topic of investigation is elementary combinatorics, which is generally not taught in primary special education. Six combinatorics problems on finding all possible combinations of a number of different types of clothing items were presented on screen. Data were collected on students' performance in solving these items. The performances of students in regular education served as a reference. The total sample consisted of 84 students (8- to 13-year-olds) from special education and 76 students (7- to 11-year-olds) from regular education. Their mathematics ability ranged from halfway grade 2 to halfway grade 5. The results showed that special education students are able to solve combinatorics problems equally successful as regular education students.
Special education students, Elementary combinatorics, Dynamic ICT-based assessment, Student performance.

INTRODUCTION

Most research on supporting special education (SE) students in mathematics has focused on the learning and teaching of basic mathematical operations, like addition and subtraction. In general, less attention has been paid to higher order thinking processes that go beyond standard procedural skills. This is not surprising because SE students are often behind in their mathematical development compared to their peers in regular education. Nevertheless, some studies have shown that low achieving students in mathematics may have a higher mathematical potential than assumed. For example, SE students turned out to have proficiency in interpreting tables and constructing graphs (Bottge, Rueda, Serlin, Hung, & Kwon, 2007). Even more unexpected was the observation that SE students can solve combinatorics problems in a systematic way without having worked on combinatorics in school before (Van den Heuvel-Panhuizen & Peltenburg, 2008). The aim of the present study was to further investigate SE students' potential in solving combinatorics problems. The study was carried out in the Netherlands.

Combinatorics in primary school

Combinatorics is the branch of mathematics that involves systematic listing and counting. Several mathematics didacticians have argued that combinatorics should be integrated in the school mathematics curriculum at all grade levels (e.g., English, 1993), because combinatorics can help to develop students' reasoning skills, that is, making conjectures, generalizing and thinking systematically. Despite this recommendation, combinatorics often remains ignored in primary school (English, 1993). This also applies to primary education in the Netherlands and in particular to the mathematics curriculum in SE.

Research questions

The present study builds on the work of English (1993) who investigated regular primary school students' performance in solving two- and three-dimensional combinatorics problems. Our study will investigate whether the performances of SE students in solving combinatorics problems differ from those in regular education (RE) and how the performances in both groups change over grades.

METHOD

Participants

In total, 84 students from five SE schools and 76 students from five RE schools participated in the study. To enable a comparison of SE and RE students with respect to their mathematics competence level we asked the teachers of each school to choose randomly four students who scored near the 50th percentile on the mid-grade levels M2, M3, M4, and M5 of the CITO LOVS test. The LOVS test is frequently used in the Netherlands and mainly contains items on calculation. Table 1 shows that for each mid-grade level, the average mathematics test scores of the SE students were slightly lower than those of the RE students as confirmed by the small negative effect sizes *d*.

Table 1: CITO LOVS mathematics scores of SE and RE students

	CITO LOVS mathematics scores										
	SE					RE					
LOVS test	*N*	*M*	*SD*	Min	Max	*N*	*M*	*SD*	Min	Max	*d**
M2	19	47.7	4.1	38	53	20	49.8	4.5	41	56	-0.14
M3	22	67.5	5.5	53	80	20	71.0	4.5	63	78	-0.24
M4	20	82.0	3.8	76	91	19	85.6	4.3	79	93	-0.25
M5	23	97.2	7.7	83	119	17	100.3	5.4	90	107	-0.24

*Cohen's *d* was calculated by using the standard deviation of the CITO reference sample in regular education

The students in RE were 7-11 year old (*M*=9,4; *SD*=1,3) and the SE students were 8-13 years old (*M*=11,1; *SD*=1,1).

Materials and procedure

For the data collection, we developed an ICT-based assessment, which included a series of six combinatorics problems. The first three problems have an *XxY* structure (2x3, 3x2 and 3x3 respectively) and the last three problems have an *XxYxZ* structure (2x2x2, 2x2x2 and 2x3x2 respectively).

For each problem the students have an infinite supply of little figures available that can be dressed with different types of clothing items (t-shirts, skirts and pairs of shoes) presented in different colors. A drag-and-drop function allows moving both the figures and the clothing items to an empty field. In this field the student can dress the figures and rearrange or remove them.

The students individually completed the ICT-based assessment. For each problem, the researcher asked the students how many different outfits were possible with the available clothing items and how they found their answer. The students' on-screen work and their verbal comments were recorded by screen video software.

Analysis

We coded the students' answers as correct or incorrect. Because the number of students within each school type was not equal for each mid-grade level (see Table 1), we applied a weighing procedure resulting in a weighted sample size of 20 students for each combination of mid-grade level and school type. For example, in the cell of SE students of grade level M2 all students in this cell got a sample weight of 20/19=1.053. Taking sample weights into account is relevant for comparing the success rate of SE and RE students. Sample weights were also included in analyses of variance in the Results section.

RESULTS

Age and mathematical level

Figure 1 illustrates the relation between students' ages and their mathematical level at the CITO LOVS test.

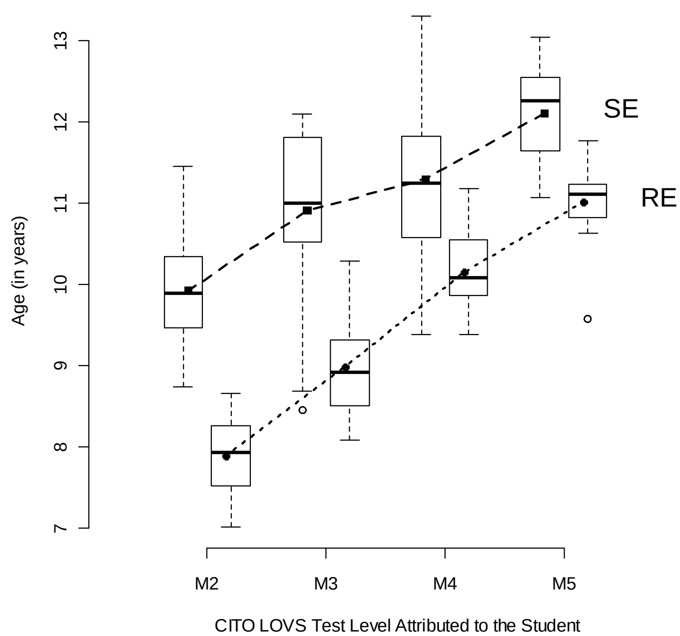

Figure 1. Age-related increase in mathematical level as indicated by the CITO LOVS test for SE and RE students

At level M2 and M3 the SE students were about two years older than the RE students on the same mid-grade level. At level M4 the difference in ages decreased and at level M5 the SE students were only about one year older than the RE students.

Success rate in the combinatorics items

In total, the SE students solved the combinatorics items in 56% of all cases (students *x* items) correctly and the RE students solved 57% of all cases correctly. These success rates were calculated using sample weights.

The success rate in the combinatorics items appeared to be positively related to the students' mathematical level for both the SE and RE students (see Figure 2).

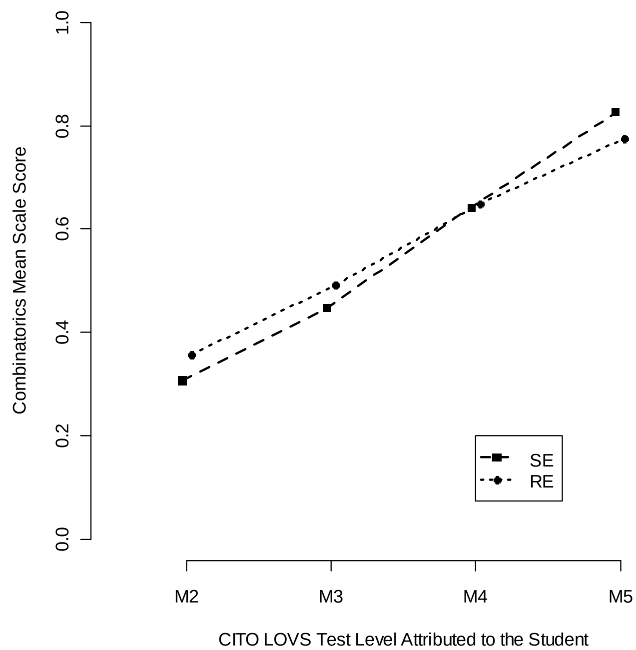

Figure 2. Relation between percentage success rate on the combinatorics test and CITO LOVS mathematical level for SE and RE students.

At level M2 and M3 the SE students solved slightly less combinatorics problems correctly than the RE students on the same mathematical level. However, at M4 level the SE students reached the same mean success rate as the RE students and at M5 level the SE students even solved slightly more combinatorics problems correctly than the RE students.

To further investigate differences between the SE and RE students, we carried out an analysis of variance in which we specified three different models containing different sets of predictors: mathematical level, age and school type (see Table 2).

In Model 1 mathematical level was found to be a significant predictor ($F(3,152) = 24.83$, $p < .01$, $\eta_p^2 = .329$) whereas it was not the case for school type ($F(1,152) = 0.10$, $p = .75$, $\eta_p^2 = .001$). However, the interaction effect of school type and mathematical level, that was suggested in Figure 2, did not appear to be significant either ($F(3,152) = 0.33$, $p = .80$, $\eta_p^2 = .007$). This means that we found similar success rates for SE and RE students for each mathematical level.

Table 2: Results of analysis of variance of success rates from different models with Age, Mathematical level and School Type

		Model 1 (Mathematical level, School type)			Model 2 (Age, School type)			Model 3 (Mathematical level, Age, School type)		
	df	*F*	*p*	η_p^2	*F*	*p*	η_p^2	*F*	*p*	η_p^2
Math level	3	24.83	0.00	0.329				5.57	0.00	0.100
Age	1				36.45	0.00	0.189	0.00	0.95	0.000
School type	1	0.10	0.75	0.001	0.10	0.76	0.001	0.53	0.47	0.004
Math level*School type	3	0.33	0.80	0.007				0.38	0.77	0.008
Age*School type	1				0.03	0.88	0.000	0.52	0.47	0.003
R^2		0.34			0.19			0.34		

In Model 2, age was found to be a significant predictor ($F(1,156) = 36.45$, $p < .01$, $\eta_p^2 = .189$). Like in Model 1 the main effect of school type was not significant which was also the case for the interaction of age and school type. Finally, in Model 3, all three predictors were included. Only mathematical level appeared to be significant ($F(3,150) = 5.57$, $p < .01$, $\eta_p^2 = .100$). In contrast to Model 2 age was found to be non-significant. In summary, in all the three models school type did not appear to be a significant predictor after controlling for mathematical level and age. This means that no differences were found in success rate for the SE and RE students.

CONCLUSIONS

The findings indicate that SE students are able to solve combinatorics problems equally as successful as RE students. In both school types a significant and similar increase in success rates takes place for the mathematical levels 2 to 5.

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