First and second language' learners: Differences at the Austrian standardized final exam in mathematics

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Abstract

Austria introduced a standardized final exam in mathematics which will come into effect in 2014/15. A fairly large part of the exam will consist of word problems. We studied whether this will be a disadvantage for students whose first language is not the language of teaching, exacerbating already existing disadvantages for non-first-language learners in the Austrian school system.

Keywords: standardized final exam, first- and second-language learners, text complexity of word problems
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Introduction

The PISA 2006 study shows a quite large difference in mathematics' achievements between those students whose first language is the language of teaching and those where this is not the case. Some authors (e.g. Breit 2009) claim this is mainly due to socio-economic factors, while others (e.g. Penner 1998) demonstrate that the achievements of non-first-language learners at word problems are consistently lower (while the achievements on purely numeric and algebraic tasks are not). Despite this, the newly introduced standardized final exam in mathematics at Austrian secondary schools is mainly based on word problems, which are formulated in the language of instruction, i.e. German. We conducted a study to find out whether this is a hindering factor for students whose first language is not the language of instruction.

Standardized final exam in mathematics in Austria

Up until now, the final exam (i.e. the exam at the end of secondary school, qualifying students to attend university) in all subjects has been governed by federal law in its regulations, yet the actual content of the exam has been school specific. The new final exam will be structured in three parts: A pre-scientific thesis, three/four written exams, and two/three oral exams. The topic of the thesis and the oral exams are still decided by the schools, yet the content of the written exam in most subjects (also in mathematics) will be decided centrally by a federal body, the BIFIE (federal institute for educational research, innovation and development of the Austrian school system). The written exam in mathematics will cover a list of basic competences, divided into four thematic areas: Algebra and Geometry, functional dependencies, Calculus, and Probability and Statistics. Two types of tasks will be given to students: Type 1 tasks, or basic tasks (each task will cover one of the basic competences and will be assessed as "correct" or "incorrect"), and type 2 tasks, or advanced tasks (each task will connect several competences, and they have to be used in several contexts). Most of these tasks, particularly those of type 2, will be word problems of some sort (i.e. the task is described mainly in words, not in symbols or graphic representations; the solution might either be in words, or in symbols/graphic representations, or in both). The written exam (actually, the whole exam) will be in the language of teaching, which in regular schools means it will be in German.

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This exam claims to give “equal conditions to all students” and to ensure “quality and fairness while finishing school” (BIFIE 2012). In our study, we will not discuss whether these claims are fulfilled by this type of exam, or whether they can be fulfilled by any type of centralized or decentralized exam. We will also not discuss the fairly poor results of all students, regardless of their language background, in the past pilot tests. Rather, we want to find out whether the fairly heavy reliance on word problems in the written exam part (particularly in the type 2 tasks) will disadvantage students whose first language is not German.

Understanding text

Many studies (e.g. Cummings 1988) show difficulties of students in solving word problems in mathematics. Some studies (e.g. Cuevas 1984) show that non-first-language learners have aggravated difficulties in these areas, more than their first-language learner contemporaries.

First, let’s define what we mean by the term *active reading competence*: This is “the ability to independently read text and use the information contained within for further thinking, speaking or writing" (Portmann-Tselikas 2002). One can clearly see that this is the basis for understanding and solving word problems (see Kintsch/Greeno 1985). The research of Penner (1998) shows deficits of non-first-language learners particularly in this area, specifically with articles, quantifiers, context-specific vocabulary, and structural propositions. Cummings (1979) developed the iceberg model of language interdependence, from which he deducts that, although non-first language learners develop Basic Interpersonal Communicative Skills fairly fast and are therefore perfectly able to communicate orally in the language of instruction, they might need a much longer time to develop the Cognitive Academic Language Proficiency necessary to successfully deal with more complex word problems. This might lead to teachers (and parents) erroneously assuming a language proficiency of students at a level that is not really there, therefore also assuming that word problems are of the same difficulty for non-first-language learners as they are for first-language learners.

Quantifying text complexity

Linguistics knows several models to quantify text complexity. Flesch (1948) developed the Reading-Ease equation

$$RE_{eng} = 206.835 - 0.846 \cdot wl - 1.015 \cdot sl$$

where *wl* is the number of syllabi per 100 words (i.e. a measure for the word length), and *sl* is the number of words per sentence (i.e. a measure for the sentence length). This results (in English language) mostly in a number between 0 and 100, where 0 means the text is practically illegible, and 100 means the text is very easy to read. To allow for the (on average) higher number of syllabi in the German language, Mihm (1973) has adjusted this equation to German texts:

$$RE_{ger} = 206.835 - 0.846 \cdot wl - 1.015 \cdot sl + 20$$

Analyzing a typical task (Task 9, pilot test 4, as described in BIFIE 2012b, shortly BIFIE# D409) from the pilot test of the written part of the final exam in mathematics described above, one receives a Reading-Ease value of $RE_{ger} \approx 47$, which classifies it as a difficult text on the level of technical literature.

This model does however not take into account many aspects that might be important for understanding and solving word problems, e.g. the complexity of representation, the complexity of sentences, the use of subject-specific vocabulary etc. We will therefore also present the model of Text Complexity by Langer, Schulz and Tausch (1990), which classifies a text by the following dimensions. Each dimension is therein classified subjectively by ++, +, 0, –, or – –, depending on how much this dimension leans towards the left or right side of the following diagram:

Simple	**++**	**+**	**0**	**–**	**– –**	**Complex**
simple representation						complex representation
short, easy sentences						long, complex sentences
known words						unknown words
subject-specific words are explained						subject-specific words are not explained
Concrete						Abstract
Descriptive						non-descriptive

Fig. 1 Text Complexity model according to Langer, Schulz and Tausch

To have a numeric value that allows us to compare this measure with the Reading-Ease value of Flesch etc. we scale these classifications as follows: ++ corresponds to a value of 4, + to a value of 3, 0 to a value of 2, – to a value of 1, and – – to a value of 0. The values of all dimensions are added, and the result is multiplied by $4\frac{1}{6}$. This again gives us a value between 0 and 100.

Analyzing the same task as above (which is a subjective analysis of course), we receive the following:

Simple	**++**	**+**	**0**	**–**	**– –**	**Complex**
simple representation		*				complex representation
short, easy sentences				*		long, complex sentences
known words			*			unknown words
subject-specific words are explained			*			subject-specific words are not explained
concrete			*			Abstract
descriptive				*		non-descriptive

Fig. 2 Text Complexity analysis of task BIFIE# D409

Scaling this as described above, we received a value of 46, which is nearly identical to the Reading-Ease value. This is not always the case of course, so in the empirical part of the study we will give both values for each task that we analyzed.

Empirical study: Description

We handed out questionnaires to 90 students from 4 classes (grade 12, i.e. the final grade in secondary school) in 2 schools in Vienna. All the mathematical content that is relevant for the final exam in mathematics has already been taught to these students. In the first part of the questionnaire, the language and eventual migration background was determined. The second part contained various mathematical tasks from the written part of the future final exam (taken from the pilot exams done by the BIFIE). All questionnaires contained the same first part, but several different versions of the second part were used. In some of them, two type 1 tasks have been used, while others contained one type 2 task, from various content areas. When handing out the questionnaires we saw to it that in each class all the different questionnaires were distributed, i.e. in sum each of the 4 classes solved all of the different tasks.

Each task was analyzed according to its Reading-Ease value and its Text Complexity value. The tasks and their quantified complexities are given in the figure below.

BIFIE#	Type	Name	Reading-Ease	Text Complexity	Content area
A202	1	Men and Women	33	42	Linear eq. systems
A2	1	Swimming	86	66	Linear functions
B214	1	Pyramid	48	58	Vectors in plane
D405	1	Points + Arrows	67	67	Vectors in space
B216	1	Bacterial growth	55	50	Exponential growth
A206	1	Radioactivity	32	38	Radioactive decay
B220	1	Reading glasses	44	46	Conditional Probability
D424	1	Confidence	22	25	Confidence interval
B19	1	Billiard	53	63	Trigonometry
D409	1	Shadow	57	48	Trigonometry
D493a	2	Income tax	17	29	Percentage etc.
D491	2	Line gradient	-3	33	Representing lines
B293a	2	Net income	15	25	Arithmetic mean etc.

Fig. 3 Reading-ease and Text Complexity values of the used tasks

One can see that despite using randomly chosen tasks with a wide variety of content areas, most of the tasks have a fairly high complexity level, mostly independent of which of the measuring models are used. Particularly the three type 2 tasks can be classified as very hard (from the point of view of text understanding), comparable with the text complexity of scientific literature.

Empirical study: Results, part I – All is well

First of all, we classified the students into three groups: German as first language with at least one first-language parent (L1, L1), German as first language with non-first language parents (L1, L2), and German as second language (L2), and calculated the arithmetic means of the grades of the students in mathematics in these three groups. These means were then compared using a T-test with significance $\alpha = 0.05$. The test showed no significant difference in the mathematics' grades of the three groups. To cross-check these results we also conducted a Mann-Whitney-U-Test with the same significance level. This test also showed no significant differences between the groups with respect to their mathematics' grades. In the perception of the teachers, and in particular of the parents (where the grade is often the only feedback they receive), this might mean that the students are equally well educated in mathematics, and hence equally well prepared to tackle the final exam, regardless of their language background.

Next, we analyzed both the text understanding (data gained from the required rephrasing of the tasks, evaluated as percentage) and the solutions of the tasks (data gained by assessing the solution according to the BIFIE assessment framework, evaluated as percentage). Again the students were classified into the three groups described above. Comparing the arithmetic means of the text understanding and of the solution (assessment results), using a T- and a U-test with significance level $\alpha = 0.05$, no significant difference between the groups has been found. All groups achieved, at an average level, similar assessment results.

Empirical study: Results, part II – … or not

However, we also compared the correlation between the text understanding and the solutions of the tasks. And here, a very significant difference between the groups has been found. While with the students of group L1, L1 there is only a medium correlation ($r \approx 0.5$) between text understanding and assessment results, the students of groups L1, L2 showed a somewhat higher, and the students of group L2 showed a very high correlation ($r \approx 0.8$) between these two variables. This means for non-first language learners it is very important to understand as many aspects of the text as possible to be able to solve the corresponding task, much more so as with first-language learners. Can we assume that understanding many aspects of a text is very difficult (particularly for L2 learners) if the text has a high complexity level? Correlating text understanding and text complexity in all tasks, we received a correlation coefficient $r \approx 0.6$ for both quantifications of text complexity, i.e. the common-sense assumption that text understanding is more difficult for more complex texts holds true. As we showed in Fig. 3, a lot of the chosen tasks, though not all of them, have a high complexity level. This also means that the particular choice of the tasks for one concrete final exam, done only according to mathematical complexity, might have a much higher impact on the solvability of these tasks by non-first language learners as it would have on the solvability by first language learners, in case these tasks accidentally have a high text complexity (which, given the numbers in Fig. 3, is fairly likely).

Conclusions

At first glance, the proposed final exam for secondary school students seems fair – there is no significant difference in the assessment results of the groups with different language backgrounds in our study. However, the authors of the exam claim it to have "equal framework requirements for all students". But these equal framework conditions are not given for all students, because for non-first language learners it is much more important (and much harder) to grasp as many text aspects as possible to be able to solve the given tasks, particularly if they have a high text complexity. The current proposal (or at least the published pilot tasks of the current proposal) has a very high number of tasks with a high level of text complexity, making it fairly likely for non-first language learners to be disadvantaged at their final exam. It should be considered to reduce the text complexity of the tasks in such a way that it is no longer a hindering factor for non-first language learners – after all, the exam proposes to assess and evaluate the mathematical competences of the students, and not their language competences.

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Nina Steinhardt has recently obtained her masters' degree in mathematics and philosophy & psychology teaching. In her research she focuses on the differences in problem solving and text understanding of first and second language learners concerning the standardized final exam in mathematics.

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