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EVALUATION OF CZECH NON-CHEMICAL VOCATIONAL SCHOOL CHEMISTRY TEXTBOOKS' TEXT DIFFICULTY

Abstract: The paper follows the first author's continuous work on chemistry textbook analysis. In the previous paper published in CERP, attention was given to the procedure and results for analysing text-difficulty in lower-secondary chemistry textbooks in Czechia. In this paper, attention was given to non-chemical vocational school chemistry textbooks. They are intended for the most numerous group of upper-secondary students. The goal of the study was to assess the to what extent could students read the textbook texts on their own with appropriate understanding. Therefore, only the textual component was evaluated. The same method (Nestler-Prucha-Pluskal) as in the previous paper was used to analyse the textbooks' text-difficulty (readability). The results show there are two books which are suitable for students' own learning. However, there are four textbooks which contain text of high difficulty, including too many scientific terms that they are suitable as teacher's guide through terms rather than student's textbooks. The analysis may serve teachers with their textbook choice as well as researchers who operate in the same field who can easily adopt the methodology and compare results.

Keywords: textbook analysis, text-difficulty, vocational school chemistry, chemistry education

Introduction

Upper-secondary chemistry education in Czechia underwent a significant twist after the last curricular reform in 2009. Before the reform, chemistry was only being taught at grammar schools (upper-secondary schools of general focus) and specialized vocational and apprentice schools such as (environmental analytics, chemical operation etc.). However, the situation has changed and chemistry is being taught at the majority of upper-secondary schools with a diverse focus, only with a limited number of lessons. The reason for this change was to introduce so-called general education school subjects to the broader public. At chemistry or science-oriented schools (study programmes), the reform meant no significant change in this respect. However, at non-chemical schools, this, naturally, brought a need for new (experienced) teachers as well as teaching materials. This situation's urgency was only multiplied by the amount of students targeted by this change. Considering the upper-secondary students' structure, about 22 % attend grammar schools, and only about 15 % of the rest do not undergo chemistry even to a limited extent [1]. Given there are about 100 000 students entering upper-secondary education in Czechia each year, this change concerns about 65 000 students each year [1].

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Teaching chemistry as a marginal school subject bears several specifics which need to be considered when teaching. These are: results showed several issues which needed special attention:

- qualified teachers - due to a reduced time allocation, chemistry as a marginal school subject is just added among other teachers' teaching duties (sometimes those who did not study chemistry or chemistry education),
- students' motivation towards chemistry - the level of these students' motivation towards a subject which does not relate to their field of study in any way and is not incorporated in their final exams is low,
- the effect of chemistry's appearance in vocational schools' curricula measured via both gained knowledge and attitude showed a certain progress can be made under certain circumstances.

The conditions and present state stress the need of quality support. Teachers at these schools need a source for instruction which can be provided by textbooks, see e.g. [2]. This is especially true for those who are not qualified to teach chemistry [3, 4]. As shown by Johansson [5] or Chou [6], textbooks are the main source of information for teachers - which is only stressed under the aforementioned conditions at vocational schools. Except for the subject matter, teachers were reported to use textbooks as a source of education methods too [7]. Many teachers were also reported to consider textbook's content obligatory [8]. The role, or the impact of textbooks is then extremely vast.

In general, recently published textbooks are expected to contain modern approaches to education and mainly react to the situation. However, the lengthy process of their preparation, publishing and dissemination into schools, together with teachers familiarity with the textbook they have been using, makes the process of textbook change difficult. This only shows the school curricula's time lag dilemma, see e.g. [9] has an impact on these schools.

Moreover, the Ministry of Education, which was responsible for new curriculum's introduction in Czechia, probably underestimated the role of textbooks in a system based on a free textbook market and left it in private publishers' hands instead of providing schools with new textbooks in alignment with the new curriculum and its ideas, as well as modern methods and educational forms.

As far as the role of textbooks in the field of science education is concerned, more attention has been paid to this issue in recent years [10]. The authors mostly focus on the textbook content, i.e. the included subject-matter [11-13], topics' order [14, 15], included learning concepts and their integration [16, 17], non-textual (visual) representations [18-20] or the effect of textbooks on students' learning [21, 22].

The latter is closely linked with textbook tasks [23, 24] and the key textbook component - learning text. This field of textbook research focused on the terms used in textbooks [25], students' strategies when reading a book [26] or the use of eye-tracking to monitor these phenomena [27]. This is mainly due to the paradigm which stands students in the centre of activity in the learning process [28, 29]. With this in mind, activities in which students work with textbooks make complete sense under the described circumstances. In order to do so, however, textbooks need to fulfil several criteria. Above all, it is a textbook's text readability or text-difficulty which supports students' learning [30, 31]. As the language which carries chemistry instruction is vital for the actual learning activity [32, 33], textbooks' effect on education can be observed via textbooks' text-difficulty analysis. This is the purpose of this paper.

Method

Textbook selection for analysis

Only chemistry textbooks for non-chemical vocational schools were selected for the analysis. Textbooks for grammar schools or chemistry-oriented upper-secondary schools, summaries, overviews etc., were not included as they focus on a different student group and do not fulfil general ideas of a textbook [34]. The analysed textbooks are listed in Table 1 together with the designation, which is used for them later in the text.

Table 1

Analysed non-chemical vocational schools' textbooks

Textbook name and authors	Publisher*
Chemie pro studijni obory SOS a SOU nechemickeho zamereni [35]	SPN-SOSaSOU
Chemie pro SS - Kratochvil, Muck, Svoboda - Scientia [36]	Scientia
Chemie pro SS [37]	SPN-SS
Zaklady prirodovedneho vzdelavani [38]	Fortuna
Chemie pro SOS nechemickeho zamereni [39]	Eduko

*The publishers' name will be used as references to particular textbooks

The method of analysis

The Neslerova-Prucha-Pluskal method [40] is widely used to evaluate the difficulty of textbook text [41, 42]. The method allows analysis according to the total text-difficulty (*D*), syntactic difficulty (D_{st}), conceptual (semantic) difficulty (D_{sm}) and coefficients of scientific information density in the sum of all words (*i*) and in the sum of terms (*h*).

According to the method used, the syntactic difficulty T_{sm} over the number of words *N*, the number of verbs in a certain form *U* and the number of sentences *V* determine the text-difficulty itself, where:

$$T_s = 0.1 \cdot \frac{N^2}{U \cdot V}$$

The conceptual (syntactic) difficulty D_{st} includes, in addition to the total number of words *N*, the total number of terms P contained in the text. These are further divided into common *P*1, scientific *P*2, factual *P*3, numerical *P*4 and repeated *P*5, whereby:

$$T_p = 100 \cdot \frac{P}{N} \cdot \frac{P1 + 3 \cdot P2 + 2 \cdot P3 + 2 \cdot P4 + P5}{N}$$

The coefficients were chosen by the methods' authors on the basis of their influence on increasing text-difficulty. In addition to conceptual difficulty, texts analysed by this method are evaluated according to the proportion of numerical data, the proportion of repeated terms, the coefficient of numerical data density and the coefficients of technical information density, always in the sum of words. The contribution of information to the teaching text is evaluated by the proportion of scientific, factual and numerical terms in the total sum of words (*i*) and the total sum of terms (*h*) calculated as follows:

$$i = 100 \cdot \frac{\sum P2 + \sum P3 + \sum P4}{\sum N}$$

$$h = 100 \cdot \frac{\sum P2 + \sum P3 + \sum P4}{\sum P}$$

The chosen method of text-difficulty evaluation is performed on a continuous text of at least 200 words. In a textbook, this radically lowers the topics' selection.

The original intention was to select the same topics as in the previous research on lower-secondary textbooks [42]. Due to the low number of words on the topic of air in some textbooks, the topic of water was analysed. The topics selected for assessment therefore were: water, hydrogen, neutralization (acids and bases), alkanes, carboxylic acids, proteins.

Analysis procedure

The texts were analysed independently by two researchers. In case of disagreement in the code, consensus by agreement was sought. The obtained values were then evaluated for a set of analysed textbooks, further compared with the suggested text-difficulty values given by Prucha [34] and the values known from lower-secondary chemistry textbook analysis [41, 42].

For the first year of grammar school (the corresponding year for chemistry at the majority of secondary schools), the recommended total text- difficulty D = 35 [34]. In the tested textbooks this was 36.6 [34]. The values of D_{sm} and D_{st} have not been reported in the literature yet. For comparison, the values of lower-secondary chemistry textbooks are given in Table 2.

Table 2

Lower-secondary chemistry textbook text-difficulty analysis results [42]

Parameters	D	D_{st}	D_{sm}	I	h	Proportion of repeated terms	Proportion of scientific terms
Values range	34-50.2	8.2-14.5	25.8-35.7	14.9-20.1	38.4-49.5	11.5-18.2	12.8-17.6

Results and discussion

Total text-difficulty (D)

The values for the vocational school textbooks' total text-difficulty (D) take on the values 33.6-52.6 (Fig. 1). The results show that the text difficulty is mostly caused by the semantic factor.

The analysed textbooks do not differ much from the chemistry textbooks for primary schools as far as the total text-difficulty (D) is concerned. According to the decreasing value of D, the textbooks Eduko (52.6), SPN-SS (51.8), SPN-SOSaSOU (51.4) with high text-difficulty stand out. On the contrary, the Fortuna (40.1) and Scientia (33.6) textbooks' text-difficulty correspond with the cited recommendations and could therefore be considered more suitable for the given purposes. To compare, grammar school textbook text-difficulty was 33.5 [43]. The authors of the Eduko and both SPN textbooks probably did not respect or even consider the text readability requirements in the subject-matter presentation.

Due to the fact that the texts are intended primarily for first-year upper-secondary school students, the almost 50 % increase in text-difficulty compared to textbooks for lower-secondary schools can be considered over the reasonable perceptual level of these students. Even regarding these students' expected lower study-success and their non-chemical specialization, the values can be assessed as too high when compared to grammar school textbooks. The chances are students will not be able to use the textbook for

their own study. Naturally, this premise needs to be further tested, however, if proven right, this means these textbooks do not fulfil their primary purpose.

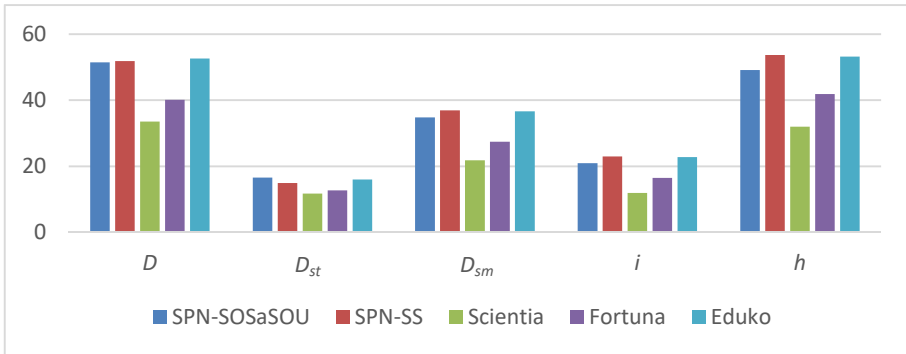

Fig. 1. Evaluated textbooks' text-difficulty parameters**.** *D* - total text-difficulty, D_{st} - syntactic difficulty (difficulty of the language structure), D_{sm} - semantic difficulty (difficulty caused by the used words/terms), *i* - coefficients of scientific information density in the sum of all words, *h* - coefficients of scientific information density in the sum of scientific terms

A very promising research methodology is eye-tracking which will bring new information especially from this specific domain [27].

Syntactic difficulty of the text (D_{st})

More detailed information about the text-difficulty is provided by observing the two components that make up the overall difficulty, i.e. the syntactic difficulty (D_{st}) and the semantic difficulty of the text (D_{sm}). From the D_{st}'s point of view, the sentence composition affects the ease with which students read the text. According to the D_{st} values, the analysed textbooks can be separated into three groups:

1. SPN-SOSaSOU (16.6) and Eduko (16.0) with the highest values of D_{st},
2. SPN-SSaSOU (14.9) with a mean value of D_{st}
3. Fortuna (12.7) and Scientia (11.7) with the lowest D_{st}.

In the first group, high values are given by the sentence length and the average length of sentence units. The longest sentences were then used in the Eduko textbook. On the contrary, textbooks included in the third group are characterized by the shortest sentences. The Scientia textbook set contains the most verbs per sentence. The SPN-SS textbook was also included in Klecka's research [44] which also placed them in the middle of the D_{st} values. This result confirms the method's validity.

Compared to chemistry textbooks for lower-secondary schools, D_{st} values are higher (often up to twice as high). They even exceed the textbook values for the first years of grammar schools [44]. This finding further clarifies in which aspects the authors of both SPN and Eduko textbooks probably did not respect the target group of students. Thus, in addition to its abstractness and students' perceived difficulty and insignificance, the student's understanding of the curriculum is further complicated by a text which is too demanding.

Semantic (conceptual) difficulty of the text (D_{sm})

Significant differences were also found between the D_{sm} values. The textbooks can be divided into two groups: 1. SPN-SS (36.9), Eduko (36.6) and SPN-SOSaSOU (34.8) and 2. Fortuna (27.4) and Scientia (21.8).

The results are practically identical with lower-secondary chemistry textbooks' D_{sm}. However, for example, 9th grade biology textbooks' D_{sm} was 18.5-29.5 [45], which points to the excessive semantic difficulty of three chemistry textbooks - SPN-SS, Eduko and SPN-SOSaSOU. They use too many terms which makes the text difficult.

Only a small number of factual terms were found in the textbooks. In this criterion, the Scientia textbook deviates from the others with seven factual terms in the analysed passages. This is in contrast especially with the SPN-SOSaSOU textbook, in which no such term was found. Compared to chemistry textbooks for lower-secondary schools, a higher ratio of numerical terms was found, namely in the Eduko and both SPN textbooks. However, insight into the text-difficulty is offered by a deeper analysis of the general, scientific and, given the nature of the analysed books, repeated concepts. An interesting deviation from the expected trend is the reverse ratio of common and scientific terms in the Scientia textbooks. All other textbooks, in accordance with the lower-secondary school textbooks, contain more technical than common terms. However, the differences between the proportions of these groups of terms vary considerably, from 0.75 (Scientia) through 1.15 (Fortuna), 2.44 (Eduko) and 2.50 (SPN-SOSaSOU) to 3.12 (SPN-SS). This shows the different conception of the Scientia textbooks (translated textbook series) as opposed to the rest of the analysed books whose conception follows the established textbook style [24, 46].

A similar factor is the proportion of repeated and technical terms. Although the repetitive terms include repetitive common terms, this indicator shows the extent to which the textbook respects terms such as foreign words in language teaching and works with them [32]. The Scientia textbooks occupy a unique position - 52 % of repeated terms were found. On the contrary, in Fortuna or Eduko textbooks, this value is 42 resp. 44 %.

Coefficients of scientific information (*i* and *h*)

In relation to the informational value of the textbook text, the coefficients of scientific information in the sum of words (*i*) and the sum of terms (*h*) are significant. Their values in the analysed textbooks follow a similar trend as the text-difficulty values. The Scientia textbook with $i = 11.9$, together with the Fortuna textbook ($i = 16.5$) contain the least number of scientific information in the text. In contrast, SPN-SS (20.9), Eduko (22.8) and SPN-SOSaSOU (23.0) contain up to twice as many scientific terms. The Scientia textbooks' *i* value is below the defined limit of textbooks for lower-secondary schools which can be considered too little for a textbook. The Fortuna and SPN-SS textbooks correspond to the chemistry textbook values for lower-secondary schools, the other two of which exceed these values. Nevertheless, they are significantly lower than the values found by Prucha [34].

According to the coefficient *h*, it is possible to divide the textbooks into several groups again. This finding was expected due to the reported (recommended) *h* range (33.5-82.9) [29] and the findings for lower-secondary chemistry textbooks (38.4-49.5) [41, 42]. According to the *h* values, the textbooks are comparable with those for lower-secondary schools. This further strengthens the conclusion about the compact approach towards textbook design [46]. The highest values found in: SPN-SS (53.7), Eduko (53.2),

SPN-SOSaSOU (49.1) correspond with grammar school textbooks, i.e. textbooks designed for students whose cognitive and also reading abilities are expected to be on a higher level. The values of the first two exceed the highest value of 49.5 found in the lower-secondary textbooks. Chemistry textbooks for non-chemical vocational schools can be considered less saturated (oversaturated) by terms as compared to the lower-secondary textbooks with regard to the coefficients of scientific information.

Overall, based on the findings, the five analysed textbook series can be divided into two groups. The first consists of textbooks published by Scientia and Fortuna publishers, whose text-difficulty is at an appropriate level with a lower ratio of technical terms. The textbooks by Scientia are unique among the analysed textbooks in its approach to the general explanation of topics without using a large number of scientific terms. The text is, therefore, readable and the potential for students to understand to it (and also its use in their own chemistry learning) is higher. With respect to its target group - students whose study focus is far from science - this approach is reasonable. The Fortuna publisher's textbook is, with its concept of text-difficulty, more similar to chemistry textbooks for lower-secondary schools. Again, for students whose aspirations do not lie in chemistry education, this represents a pacific transfer. The textbooks placed in this group, at least as far as their readability is concerned, show both the authors' awareness of the target group and their effort to introduce students to texts they can consume without teachers' support, i.e. learn about chemistry on their own.

Textbooks placed in the second group significantly exceeded the recommended values by their text-difficulty. These textbooks can be considered less suitable for independent student work as far as the text is concerned. An interesting finding is that two of these textbooks were published in the 1990s (SPN-SS and SPN-SOSaSOU) - representing the former chemistry teaching paradigm - but also the newest textbook (Eduko) follows in the "classic style". By their content, these textbooks are more designed for teachers [47] as an overview of topics and terms explained in context. Apart from the text-difficulty, both textbooks from the SPN publishing house also excel in the highest ratio of scientific information, caused probably by the time of their publishing burdened by the already mentioned chemistry teaching paradigm and different chemistry teaching goals at secondary schools [48]. The SPN-SS textbook stands out with the highest semantic difficulty and the highest proportion of scientific terms. The latest textbook on the market from the Eduko publishing house is characterized by the highest overall text-difficulty, caused mainly by long sentences and the second highest conceptual difficulty. At the same time, this textbook is one of the two least repetitive as far as the terms are concerned.

One of the limitations in this study is that only six topics were chosen from each textbook. With the exception of the Scientia textbooks, however, it means six topics from one book, i.e. six text 200+ word blocks, which already gives a clear image as was shown in previous studies. Another limit in this study is that the text-difficulty has been judged based only on text analysis according to several guidelines and in comparison with other textbooks, although students' point of view should be added too. In order to gain a more precise overview, eye-tracking method should be employed to check for the students' textbook text reading difficulty. Last, but not least, data about a mean time of textbook use in each class would complete the picture of this phenomenon's impact on education. This, however, represents a longitudinal, systematic lesson inspection approach.

Conclusion

This paper provided results of non-chemical vocational school textbooks' text-difficulty. The current knowledge about Czech chemistry textbooks was thus completed with another element - books designed for the most numerous upper-secondary student group. The reason for this work was therefore to contribute to knowledge about chemistry education for the general public in the area of the intended curriculum.

Since students' use of textbooks in chemistry education practice has not been studied yet, the authors now plan to analyse the difficulty of individual topics, which is another interesting indicator of textbook processing. Due to the growing attention paid to the issue of textbook research and the need to support teachers in their selection, further analyses are planned (didactical equipment [see 49], teachers' use of textbooks and other materials [see 46] followed by structure of concepts).

One of the main messages this study delivers is that teachers are, literally, not supposed to judge a book by its cover. A new facelift does not necessarily mean the book is suitable for students. Chemistry teachers at non-chemical vocational schools can surely benefit from using a textbook with more difficult text. However, when using textbook texts belongs among a teacher's applied methods, this study brings important results which can help decide which textbook to choose.

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