*Scientific paper*

# Opportunities for Learning: Analysis of Czech Lower-Secondary Chemistry Textbook Tasks

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## Abstract

Tasks in Czech lower-secondary chemistry textbooks were analysed to describe their position in textbook chapters, required response type, overall task nature, as well as cognitive requirements. The results showed older textbooks contain task banks at the end of chapters suggest a transmissive teaching paradigm, whereas newer textbooks containing tasks within the chapters. As far as the nature of the tasks is concerned, a strong stereotypical genre was found in the chemistry textbooks. Most of the textbook tasks require open-ended answers and target: factual and conceptual knowledge remembering or procedure application. The authors therefore suggest several changes to the tasks, including their position in chapters, cognitive difficulty as well as the required response type in order to meet chemistry education goals.

**Keywords**: tasks; textbook analysis; chemistry education; lower-secondary school; ISCED 2

## 1. Introduction

Changes in society, together with an increasing amount of information, place demands on education's transformation. The demands for effective participation in society led to key competences for lifelong learning formulation.[1] As part of the educational process, the emphasis on students was also strengthened. A key element in thinking about education and thus in changing the curriculum is the effort to move from a traditional approach exercising algorithm-based, lower-order cognitive skills to an approach stressing higher-order cognitive skills associated with asking questions, critical or system thinking, decision making and problem solving.[2] Changes in access to education are gradually being incorporated into the curriculum at a national level. A responsible approach to the changes requires an evidence-based approach. Unfortunately, many curriculum reforms take place without adequate research evidence or mapping educational reality.[3]

Although the objectives and education content are set out in state curricular documents, textbooks play an important role in the implementation of teaching. These bring a concrete transformation of educational content and, compared to the higher levels of the curriculum, represent the concretization of the intended curriculum[4] into concrete activities. They thus represent not only the selection of particular subject-matter, but also its transformation using specific methods and the form of its mediation.

The role of textbooks is twofold: they can be used directly by students as well as by teachers for lesson preparation – which seems to be one of their domineering role.[5] Textbooks' effect is given by their structural components' utilization. The main structural components in textbooks to mediate the educational content is naturally the text.[6] The interpretive text itself is not yet a learning tool, as it does not evoke a specific learning activity. The emphasis on the direction of students' own learning activities also comes to the fore with regard to the science (chemistry) education objectives, namely science literacy,[7] which includes not only the mastery of certain knowledge, but also the development of various science-oriented skills. In order for textbooks to perform their function, they cannot be perceived only as educational content intended for simple memorization. Functional textbooks are an aid that helps to condition the diverse learning situations leading to the students' development in a broad sense.

Students' attention as well as their activity is directed by learning tasks. They represent the students' *opportunity to learn*[8] and are the key to student activation. Since there is a relationship between questions and answers,[9] the form of questions and their context determine students' activity, i.e. what about and in what way they think. The authenticity and context of the tasks also influence the students' skill in solving problems[10] and tasks should be relevant not only to the teaching process but also to address authentic issues[11].

Students' activation can be accomplished by using textbook. Xin[12] found that task distribution in textbooks affects students' ability to solve certain types of tasks. Yet, as argued by Yang et al.[8], that task representation in textbooks does not directly show the textbooks' quality.

Through textbook tasks, students are also presented with the nature of science (NoS), as they are directed towards the way of thinking in a given scientific discipline.[13] In addition to tools to develop general competences, textbooks can also be a means of scientific enculturation. This puts pressure on the form of textbook tasks so that the NoS presented to students is consistent with real science. As pointed out by Wood,[14] unlike the classical school concept of natural science teaching, in real chemical (science) problems there is usually more than one correct solution, and in many cases only the most appropriate and achievable solution is sought. In this respect, "school tasks" frequently designed to evaluate students deflect from the real tasks as a certain response is needed in order to grade the answer.

It is natural to expect these tasks to be placed inside the chapters as they represent the learning content itself, whereas the role of tasks placed at the end is to evaluate the learning progress. Mediating real science practices in school teaching is one of science education's key challenges.[15]

As shown by Andersson-Bakken et al.[13], a number of studies focusing on textbook tasks showed a specific culture is evolving in individual school subjects. Bakken and Andersson-Bakken[16] even identified textbook tasks to be a specific genre not only in science textbooks. Textbook tasks are thus influenced by the characteristic standards of their formulation, purpose and educational objectives. The field-specific culture regarding used tasks is further strengthened by textbook use by teachers.

A significant proportion of teachers was found to use textbooks for teaching preparation.[5, 17] Teachers consider textbooks to be the main source of educational content.[18–19] At the same time, they also adopt the teaching concept from textbooks and using textbook models [20], teaching methods and organizational forms suggested in textbooks.[21] Since textbooks thus represent curricular material for many teachers (cf.[22]) and the conception gives teachers a certain example how to deliver its content.[21] Textbooks thus represent a potentially implemented curriculum[23] with a direct impact on students. Elaborating on textbook components then plays a vital role in understanding the teaching-learning process.[35]

The abovementioned trend was observed[24] with significant similarities between the questions used by chemistry teachers in their lessons and the questions in the textbooks they use. Efforts to innovate the curriculum can thus be significantly limited by the lack of textbook innovation. Although textbooks follow different curriculum concepts with different emphases and educational objectives, this is not always clearly reflected in their content. Even in textbooks following a reformed curriculum declaring a focus on developing students' competences, only a limited proportion of tasks targeting higher-order thinking was found.[25] Orientation to tasks, i.e. student activity, remains implicit.[26]

As seen from the above, by analysing textbook tasks, it is possible to identify both the learning opportunities presented to students and the NoS understanding that textbooks convey. However, these aspects have so far received rather partial attention in science textbook research internationally.[27]

## 2. Research Aim and Research Questions

As suggested above, from a certain point of view, task elaboration offers a model of curriculum implementation as seen via the student activity perspective. Textbooks therefore become a tool influencing curriculum conception (when textbooks are being used in education) and tasks in them reflect the potential for active learning.

Textbook tasks reflect the potential of students' active learning given the textbook is being used. As research shows, textbooks are an important support for teachers in their work, showing them not only what to teach, but also what methods to use,[20,22,28] therefore the use of textbook does not mean it is only used in the class with students, but also for teachers' lesson preparation. Understanding current tasks is thus an important element for understanding the current state of the concept of teaching. If certain deflections from an ideal appear, this information is a starting point for innovations.

For these reasons, the aim of the research was to find out *what tasks are contained in lower-secondary school chemistry textbooks* and *What differences there are between the particular lower-secondary school chemistry textbooks in terms of tasks*. These aims were further specified by the following research questions:

- In which parts of lower-secondary chemistry textbooks are tasks placed?
- What type of response is required in the lower-secondary chemistry textbook tasks?
- What are the required cognitive processes and the required types of knowledge in the *in* lower-secondary chemistry textbook tasks?

The placement of tasks in textbooks shows their authors' intended conception of chemistry subject-matter presentation – student activation. There are basically two scenarios: Tasks either induce students' active learning and bring the initial motivation and student activation leading, to their acquisition of new subject-matter, or tasks are designed to fixate subject-matter transmitted by a teacher, therefore conclude non-active methods.

Different types of response required in assigned tasks correspond with a different type of thinking and development of problem-solving strategies. While close-ended tasks require analysis and differentiation of individual submitted claims, open-ended tasks aim to create an individual response. Each type of task therefore aims at a different science education or literacy goal and are supposed to be balanced.

Similarly, the focus on different cognitive processes and types of knowledge shows the emphasis of textbooks on students' specific thought operations and skills. At the same time, they contribute to the formation of a specific picture of scientific knowledge.

# 3. Methods

To answer the research questions, a quantitative approach based on textbook task closed-coding was chosen.

## 3. 1. Research Sample

The most commonly used chemistry textbooks (textbooks used at less than 5% of schools were excluded) for lower-secondary schools in Czechia[5] were analysed. With regard to one textbook's publication of a new edition, this textbook was included in the sample too. It is a direct follow-up to the previous series, and it is therefore reasonable to assume that it will continue to be used, replacing the earlier edition. The analysed textbooks are referenced using abbreviations – see Table 1. All the analysed textbooks are intended for the 8$^{th}$ grade. These are textbooks designed for teaching in the first year students encounter chemistry in the Czech Republic. By analysing these textbooks, the basis of chemistry education is thus evaluated. All analysed textbooks focus on six thematic areas from *Framework education programme for basic education* (state curricular document): *Observation, experimentation and safety*, *Mixtures*, *The molecular composition of substances and chemical elements*, *Chemical reactions*, *Inorganic compounds* and *Chemistry and society*. In Textbooks FR and nFR attention is also paid to the thematic area *Organic compounds*. Only the topic of fuel is included in the textbook nFR in addition. The textbook FR includes the thematical area *Organic compounds* topics hydrocarbons and hydrocarbon derivates and less attention is paid to the topic of chemical reaction. Entire textbooks were analysed to obtain a comprehensive insight covering both the content of individual chapters as well as the complementary tasks.

## 3. 2. Procedure and Research Tools

In the first step, all textbook tasks in terms of the means of inducing, guiding and supporting students' learning activities[29] were identified and quantified. The identified tasks were further evaluated with regard to their position in the chapter/unit, required response type, cognitive skills and types of knowledge.

The coding was inspired by Gillette and Sanger[30] in the categories that corresponded to the component distribution in textbooks as identified by the analysis of textbook didactic equipment.[31] The following categories were identified:

- *Inside the chapter* – Tasks are integrated between image and text components and are thus part of the explanatory part of the textbook.
- *End of page* – Tasks are used separately from other textbook components on the page. They are placed in the context of the chapter/unit, but after the exposition part.
- *Page margins* – Tasks are placed visually separately within the chapter/unit among other additional information.
- *Tasks banks* – Tasks are classified in separate parts of the textbook separately from the other components included in the chapters.

*Closed-ended tasks* and *open-ended tasks* were identified as the type *of response* requested. In this sense, tasks were distinguished only according to the form of the requested response. The response type was further specified on the basis of task typologies according to Kalhous and Obst[32] and Jeřábek and Bílek[33]. The categories were the following:

**Table 1:** Analysed textbooks

| Textbook title text | Authors | Year of publication | Publishing house | Referenced in the |
|---|---|---|---|---|
| Základy chemie 1 | Beneš, Pumpr, & Banýr | 1993 | Fortuna | ZCH |
| Základy praktické chemie1 | Beneš, Pumpr, & Banýr | 1999 | Fortuna | PCH |
| Chemie 8 | Škoda, & Doulík | 2006 | Fraus | FR |
| Chemie 8 | Mach, Plucková, & Šibor | 2016 | Nová škola | NŠ |
| Chemie 8 (new generation) | Škoda, & Doulík | 2018 | Fraus | nFR |

- *Closed-ended tasks* – multiple choice – multiple-answer, multiple choice – single-answer, dichotomous, coupling/pairing, ordinance,
- *Open-ended tasks* – short answer, gap filling, table filling, long answer.

Based on the previous qualitative analysis of textbook tasks,[34] tasks with no required verbal response (non-response tasks) were further coded. Typically, these are tasks consisting of an instruction, e.g. observation, but it is not specified that students should express their observations verbally.

To assess the tasks' cognitive and knowledge domains, Revised Bloom's taxonomy[35] was used. Despite its criticism (e.g.[36]), this taxonomy is used for curricular objectives[37–39] as well as textbook task evaluation.[40–41] For this reason, it was also used for the purpose of this study. The highest task potential was considered, and the required student activity was decisive for task categorization. For cognitive processes, the categories: *remember*, *understand*, *apply*, *analyse*, *evaluate* and *create* were used. In the knowledge domain, *factual*, *conceptual*, *procedural* and *metacognitive knowledge* were considered.[35]

### 3. 3. Data Analysis

The data was processed in MS Excel. To verify that the coding was correct, a randomly selected sample of 10% of the tasks was coded by a second researcher and a match was assessed using the Cohen's kappa coefficient. The kappa values in the individual categories ranging from 0.886 to 1 were found, which can be interpreted as almost perfect or perfect agreement (cf.[42]) in the 95% confidence interval. With regard to research issues, the data was further quantitatively processed and descriptively evaluated.

**Table 2:** Number of tasks in lower-secondary chemistry textbooks

| Textbook | Tasks in total | Laboratory activities | Tasks from other fields (interdisciplinary) |
|---|---|---|---|
| ZCH | 561 | 157 | 4 |
| PCH | 320 | 74 | 3 |
| FR | 651 | 181 | 103 |
| NŠ | 517 | 73 | 16 |
| nFR | 695 | 163 | 131 |

## 4. Results

### 4. 1. Frequency of Tasks in Textbooks

In the chemistry textbooks for the 8th grade of lower-secondary school, relatively high numbers of 695 to 1000 tasks were identified (see Table 2).

The different total of tasks in each textbook is mainly related to the different textbook scopes and the topics included. The highest range for chapter pages in textbooks was found in nFR (120), FR (116) and ZCH (114), which corresponds to the overall higher number of tasks (see Table 2). In contrast, the lowest number of tasks was found in the PCH textbook, which has the lowest range of chapter pages (62). Although the average subchapter range corresponding to one comprehensive teaching unit ranges from 1.6 to 2.8 pages, the average number of tasks included in one subchapter is similar among all analysed textbooks (see Table 3).

Differences were identified among the tasks in the individual textbooks. While in most textbooks, about a quarter of the tasks (ZCH and FR – 28%, PCH and nFR – 23 %) fall into the laboratory activities category, i.e. experiment or tasks related to the demonstration of substances and their properties, in the NŠ textbook there are only 14%. Significant differences were also identified in the classification of tasks related to educational content of other fields than chemistry. These were found mainly in FR (16%) and nFR textbooks (19%), while other textbooks contain only a few of these tasks (see Table 2).

### 4. 2. Task Locations

Significant differences were identified in the location of the tasks in the textbooks. While earlier published textbooks tend to place the tasks at the end of the page (ZCH) or in the task bank (PCH), in the newly published textbooks, FR, NŠ and nFR, the tasks being included directly in the chapters prevails. It shows a shift towards greater individual component interconnectedness in the chapters of newer textbooks. In FR and nFR textbooks, page margins are also used as the only ones for assigning additional tasks (see Table 4).

**Table 3:** Subchapter in textbooks and the tasks they contain

| Textbook | Number of chapters | Number of sub-chapters | Mean chapter length (number of pages) | Mean number of tasks in sub-chapters |
|---|---|---|---|---|
| ZCH | 9 | 41 | 2.8 | 13.7 |
| PCH | 9 | 40 | 1.6 | 8.0 |
| FR | 17 | 55 | 2.1 | 11.5 |
| NŠ | 6 | 43 | 1.9 | 11.2 |
| nFR | 18 | 55 | 2.2 | 12.3 |

**Table 4:** Task location in the textbooks

| Textbook | Inside the chapter (%) | Page margins (%) | End of page (%) | Tasks bank (%) |
|---|---|---|---|---|
| ZCH | 19 | 0 | 69 | 12 |
| PCH | 22 | 0 | 0 | 78 |
| FR | 62 | 36 | 0 | 2 |
| NŠ | 68 | 0 | 14 | 18 |
| nFR | 61 | 36 | 0 | 3 |

In the tasks located in each section, differences in the tasks' nature were found in terms of their link with laboratory activities. The tasks included inside the chapters are practically exclusively related to experimental activities in the ZCH and PCH textbooks (ZCH – 95%, PCH – 100%). Other textbooks include theoretical tasks (tasks related to laboratory activities: FR – 41%, NŠ – 17%, nFR – 33%) as a reaction to more safety restrictions as well as plausible usefulness.[43]

In all the analysed textbooks, the presence of task banks was found. However, their classification in relation to the content of the chapters varies. While in the ZCH and PCH textbooks, task banks are connected with the chapter (in PCH textbooks, it is the main method of consolidating the course), in the FR, NŠ and nFR textbooks, there is also a separate section at the end of the book devoted only to tasks that serve either to repetition of the whole year subject-matter or do not have an direct connection to the subject-matter from the chapters. In the NŠ textbook, 41% of the tasks are placed in the task banks. In the FR and nFR textbooks, all tasks included in task banks are classified in this way and are typically tasks related to laboratory activities (FR – 86%, nFR – 100%). However, compared to other textbooks, the number is low in these categories (cf. Table 4). Tasks linked to laboratory activities are represented in task banks and other textbooks (except for inside the chapter placement, this is the second typical classification of laboratory activities). 58% of tasks placed in task banks in the ZCH textbook are linked to laboratory activities. However, in the PCH textbook, this is only 1%. In the NŠ textbook, 14% of tasks are associated with laboratory activity in the task bank, which is related to the overall lower proportion of these tasks in this textbook (see Table 2).

## 4. 3. Requested Response Type

In view of the response type required, the analysed textbooks are very similar. In all the textbooks, open-ended tasks significantly dominate. They account for 70 to 92% of all assigned tasks (see Table 5) in textbooks. With the exception of FR and nFR, the most frequently required answers are represented only by individual words or phrases, mainly in the form of free short answers, or by completing a table or filling the gaps. Gap-fill and table-fill is typical, especially for the ZCH textbook (both 5% of tasks). In NS textbooks, 3% of tasks are table-fills, in the case of other textbooks, adding answers appears only for single tasks. In the FR and nFR textbooks, this type of task is non-existent, but open-ended tasks with a long answer dominate, representing more than half of all in the textbooks of the assigned tasks.

None of the close-ended task types (*multiple-answer*, *single-answer*, *dichotomous*, *coupling/pairing*, *ordinance*) were represented in any textbook in more than 5% of cases. The most close-ended tasks were found in the ZCH and PCH textbooks (see Table 5). Both textbooks include tasks of all types. However, *coupling/pairing* tasks in the ZCH textbook (3%) and multiple choice – single-answer tasks in the PCH textbook (4%) were represented more than once. All types of close-ended tasks were also identified in the NŠ textbook, but only in limited numbers, dichotomous tasks (2%) are the most abundantly represented. Dichotomous tasks are also the most abundant type of close-ended tasks in the FR and nFR textbooks (3%). These contain the lowest variability of close-ended tasks, non-dichotomous tasks did not occur or were represented by only one task.

**Table 5:** Tasks in textbooks according to the type of response requested

| Textbook | Long answer (%) | Short answer (%) | Tables and gaps filling (%) | Closed-ended tasks (%) | Non-answer tasks (%) |
|---|---|---|---|---|---|
| ZCH | 31 | 30 | 9 | 9 | 20 |
| PCH | 29 | 38 | 2 | 10 | 20 |
| FR | 52 | 40 | 0.5 | 4 | 4 |
| NŠ | 32 | 46 | 5 | 5 | 12 |
| nFR | 51 | 42 | 0.6 | 3 | 3 |

A significant proportion of tasks with no required answer were identified in the ZCH, PCH and NŠ textbooks (see Table 4). In all textbooks, most of these tasks are related to laboratory activity (ZCH – 87%, PCH – 98%, FR – 61%, NŠ – 87%, nFR – 79%). The form of laboratory activities is thus reflected in the non-answer tasks. While in the ZCH, PCH and NŠ textbooks, most tasks associated with laboratory activities do not require a response (62%, 86% and 71% of tasks related to laboratory activities) and are only instructions, in the FR and nFR textbooks, tasks associated with laboratory activities are typically open-ended (83 and 82% respectively). Close-ended tasks follow laboratory activities only in the FR and nFR textbooks, in which they represent 9% of tasks related to laboratory activities and are limited in ZCH textbooks (3%).

## 4. 4. Cognitive and Knowledge Domains in Textbook Tasks

The tasks' cognitive domain analysis also showed significant similarities between textbooks. In all the textbooks, a significant prevalence of tasks focused on lower cognitive operations was identified. The tasks focused on *analyse, evaluate* and *create* were not identified in more than 2% of the tasks (see Figure 1), i.e. textbooks practically do not aim at these operations.

Tasks targeting understanding account for the highest share in all textbooks (50–63%). The lowest proportion of these tasks was identified in NŠ textbooks, thanks to a higher representation of tasks aimed at remembering (31%).

About a third of the tasks focused on *remember* were also found in FR and nFR textbooks (37 and 32% respectively). These textbooks however contained the highest variety of tasks compared to the other textbooks. A higher proportion of remember-oriented tasks is influenced by a significantly higher proportion of tasks focused on other educational areas (see Table 2), most of which (79 and 61% of these tasks) aim at *remember*. The remaining tasks in other educational areas in these textbooks are almost exclusively aimed at *understand*. The low representation of application-oriented tasks is also specific to FR and nFR textbooks. Although in other textbooks these tasks represent 1826%, in FR and nFR textbooks it is only 5 and 4% respectively. This difference partially reflects the different classification of the topic of chemical calculations, which in the case of the FR and nFR textbook series are included in the textbook for the 9th grade which was not analysed. While in the ZCH and PCH textbooks the numerical tasks represent 8% and in the NŠ textbook they represent 7%, in the FR and nFR textbooks they constitute less than 1% of the tasks. However, the main difference is due to a different

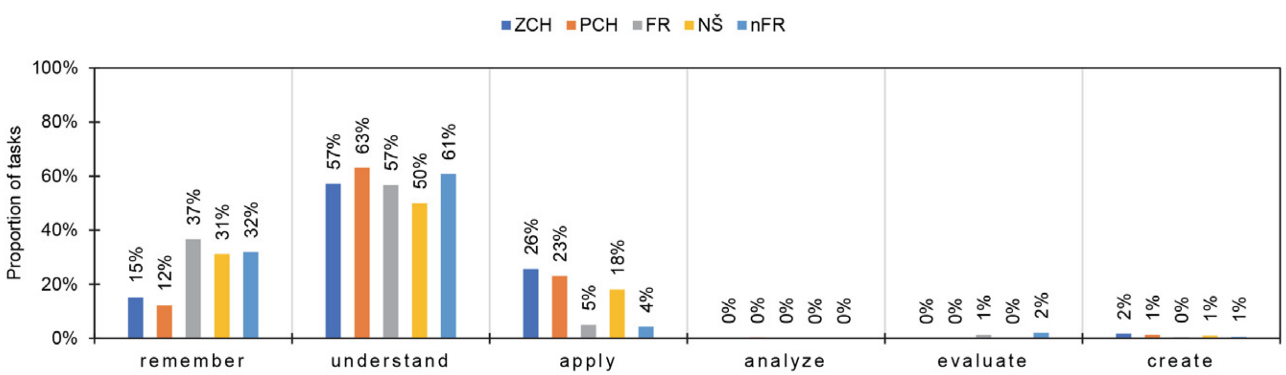


**Figure 1** Proportion of tasks in textbooks according to required cognitive operations

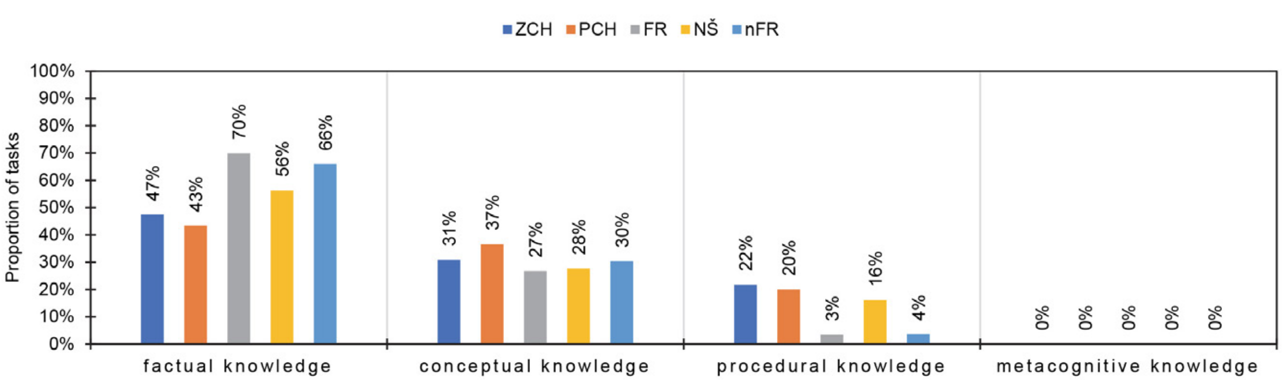


**Figure 2** Proportion of textbook tasks according to required knowledge types

approach in the chapters focused on selected substances. Most application tasks are focused on chemical nomenclature and balancing chemical equations. These skills are significantly less stressed in FR and nFR textbooks, and on the contrary, the connection in the wider context and with everyday life is emphasized significantly more.

The abovementioned differences of FR and nFR textbooks are also shown in the tasks according to the required types of knowledge. A lower proportion of chemical nomenclature and equations balancing tasks, respectively calculations, is reflected in a lower proportion of tasks requiring *procedural knowledge*. These represent only 3 and 4% of the tasks in FR and nFR textbooks, compared to 16–22% in other textbooks (see Figure 2).

As far as the knowledge types are concerned, significant similarities were identified between the textbooks' knowledge. Factual knowledge prevails in all textbooks (47–70% of tasks), and the focus on conceptual knowledge was found in about a third of the tasks. No metacognitive knowledge tasks were identified in any of the textbooks.

The higher proportions of tasks requiring *factual knowledge* in FR and nFR textbooks partly reflect the inclusion of tasks focused on other educational areas / school subjects, which target factual *knowledge* (94% and 90% of these tasks, respectively). Even if these tasks were removed from the sample, the proportion of *factual knowledge tasks is* still the highest of all analysed textbooks (65 and 60%, respectively).

**Table 6.** Most frequent tasks in textbooks

| Textbook | Remember factual knowledge (%) | Understand factual knowledge (%) | Understand conceptual knowledge (%) | Apply procedural knowledge (%) |
|---|---|---|---|---|
| ZCH | 15 | 31 | 26 | 21 |
| PCH | 12 | 31 | 32 | 19 |
| FR | 35 | 35 | 22 | 3 |
| NŠ | 27 | 29 | 21 | 15 |
| nFR | 31 | 34 | 26 | 3 |

A more detailed analysis taking into account both cognitive and knowledge domains identified only four types of tasks that occur in at least 5% of textbook tasks (see Table 6). In the ZCH and PCH textbooks, the most commonly represented task types are the ones on *understand factual knowledge* and understand *conceptual knowledge*. The FR, NŠ and nFR textbooks also include tasks focused on *remember factual knowledge* more abundantly. Tasks from the other fields included mainly in FR and nFR (see Table 2) textbooks are reflected in this category of tasks. When analysing only tasks focused on chemical content, the tasks targeting *factual knowledge remembering* in these textbooks represent 27 and 24% respectively.

# 5. Discussion

The analysed lower-secondary chemistry textbooks contain a relatively high number of tasks, which is also typical for textbooks in other countries.[16] On average, there are 8 to 14 tasks per subchapter/unit. Due to the usual number of two teaching lessons per week,[44] the subchapters basically represent the content of one lesson. As the teaching content does not consist only of tasks, the textbooks offer (1) more tasks for teachers to choose from and/or (2) tasks of a nature that allow for short, quick answers. Based on Bakken's[45] findings, it is reasonable to expect teachers to have the tendency to cover all textbook content. Previous research[5] showed teachers' use questions and tasks from textbooks often. Therefore, the impact of the tasks is immense. As long as the tasks are an integral part of the textbook (mainly the case of the newer textbooks), those which fit this approach need to be short. This corresponds to the results of the qualitative analysis[34] – the tasks in Czech chemistry textbooks typically consist only of a question possibly supplemented by a short accompanying text (maximum a few short sentences). Due to this concept, chemistry textbooks lack tasks focused on working with content representations and a more complex context.

The results of this study fully agree with Bakken and Andersson-Bakken.[16] From various angles, textbook tasks are a very specific genre whose concept, however, is worth reconsidering. Although most of the assigned tasks have an open form of response which seems to require a more complex student answer, if all of them were used, there would not be enough time in class for thorough thought or answer. The culture of using learning tasks is therefore very probably not exploiting the potential of open-ended tasks fully: teachers transform the questions into the format which fits the time constraints[46] or leave students a very short time to think about the answer after asking a question.[47] Either way of using the tasks does not leave enough space for the students' learning activity itself and does not provide learning opportunities for all students, thus not fully exploiting the tasks' potential.

Although the analysed textbooks are similar as far as the structural components are concerned,[31] connecting these components within the chapters differs significantly. Task analysis then offers better understanding to the textbook authors' conception of chemistry teaching reflected in their textbook. In this study, this was revealed in the textbooks' focus on students' activity, accent on science literacy and, a domain dominated by science education, experimental activities.

The positioning of tasks suggests the required course of the learning activity. In the formerly published ZCH and PCH textbooks (first published before the contemporary curriculum was released), tasks are placed at the end of the chapter. This in itself is an indicator of a proposed learning conception which builds upon an initial transmissive transfer of knowledge to end with questions and task designed to evaluate students' knowledge, i.e. the shape of textbooks from the 90's.[48] In newer textbooks, tasks are typically placed inside chapters which suggest their authors' attempt to activate students earlier, during new knowledge presentation.

The concept of scientific literacy spread mostly thanks to the PISA project. Naturally, textbooks published before 2000 did not have it incorporated in them. Nevertheless, as curriculum analysis showed, despite not explicitly being named, the content of scientific literacy is reflected in the national curriculum for chemistry.[49] The declaration that all the chemistry textbooks with a valid approval clause,[5] are in accordance with the curriculum, is not fully valid. It is the interconnectedness of topics and especially their links to other fields of human knowledge which is (or is not) reflected in textbook tasks. Only the textbooks by one publishing house (FR) contain such links. Other textbooks seem to concentrate on chemistry only, containing interdisciplinary relations only in individual cases.

Another aspect of scientific literacy specific to science disciplines is the accent of experimental activities. Notwithstanding the safety issues, especially in chemistry experiments, see e.g.[50], educational experiments are cornerstones of science teaching. In this respect, chemistry textbooks with the exception of NŠ textbook maintain the status quo, containing about 25% of the tasks aimed at laboratory activities. However, laboratory activities in Czech chemistry textbooks are typically only demonstrations performed by the teacher and not experiments in the true sense of the word, i.e. laboratory activities performed by students.[34] This explains Rusek et al.'s findings[43] about demonstrations predominating all chemistry experimental activities in chemistry lessons in Czechia. Moreover, in this particular respect, there seems to be a contradiction between textbook content and teachers' actions. Textbook use reported worldwide shows several aspects teachers from different countries share. They were reported to follow textbooks for the content, i.e. subject-matter (e.g.[18,19]), used analogies,[20] questions[24] and also methods[21] – sometimes even feeling under pressure, considering them compulsory.[51] Yet, as far as laboratory activities are concerned, despite textbooks being found to contain a high share of experimental tasks, such activities are only seldom.[43] Due ZCH, PCH and NŠ's focus on identical topics, the lower proportion (although the absolute number is still high) of the laboratory tasks in the textbook NŠ seems to reflect a school practice more. The fact this textbook is most preferred by majority of Czech teachers[5] indicates a shift in thinking about didactic transformation in chemistry education. There is also a thought deviation from school experiments visible, which, after all, corresponds to the overall trend of chemistry teaching.[44] This is, naturally a serious finding as it may lead to students' underdevelopment in one of crucial parts of chemistry/scientific literacy (cf.[52–53]).

As shown in the requested task answer analysis as well as the targeted cognitive and knowledge domain, the genre is not represented only by the tasks' structure. This inertia seems to block any distinct change. A similar phenomenon was also captured by Abd-El-Khalick et al.[54] in American science textbooks. The impact of former curriculum is therefore being strengthened not only by teachers' relationships to the familiar and well-tried, but also by even new textbooks taking over former structures, including teaching conceptions (see[55]), including tasks. Although the intended curriculum declares a shift in teaching conception, the school reality, i.e. the implemented or experienced curriculum[56] reflects this shift only in a limited way.

The required task response type analysis showed a strong task culture. All the analysed textbooks significantly predominate open response type tasks, which represent 70–96% of all tasks. In all analysed textbooks, both tasks with a required short and long answer are abundantly represented. In contrast, close-ended tasks are represented only from 3–10%. Although the use of open-ended tasks can be viewed positively due to the students' need to formulate their own response, thus also develop students' communication competence (see e.g.[57]) this significant imbalance in all textbooks points to the one-sidedness of assignment wording. Textbooks thus do not provide students with tools to adopt strategies for comparing, evaluating and selecting the options offered. In contrast, the currently close-ended tasks are widely used for both admission procedures and national and international surveys aimed at students' scientific literacy.[7,58]

Differences between textbooks in the area of required response type were shown, in particular for tasks related to laboratory activity. While in the ZCH, PCH and NŠ textbooks, tasks associated with laboratory activities are typically formulated without specific verbal response requirements, FR and nFR textbooks typically use open-ended tasks. Students' attention in these textbooks is more clearly directed in the case of these tasks, so it is possible to guide them.[29]

The high homogeneity of the tasks was also identified in their cognitive demands. All analysed textbooks are dominated by tasks aimed at understanding, followed by tasks focused on remembering and application. On the contrary, tasks targeting higher-order cognitive operations are almost neglected in textbooks (only 1–3% of tasks were identified). This fact, however, is in contrast with the required students' problem solving skills,[59] as these students' skills remain underdeveloped,[60] probably partly because of the lack of emphasis on problem solving in the textbooks.

This is another aspect of textbooks only partial alignment with the national curriculum. Compared to the curricular objectives' cognitive demands (see[38]), it was expected that most tasks would target understanding followed by remembering and application. Nevertheless, the share of objectives on evaluation is also significant. Although outcomes in the state curriculum target mostly concepts (53%), followed by facts (28%), procedures (21%), but also metacognitive knowledge (20% cit.[38]). The textbook task analysis, however, revealed that factual knowledge prevails (47–70% of tasks), conceptual knowledge is covered by about one third of the tasks. With the exception of the FR and nFR textbooks, procedural knowledge is represented in about 20% and no metacognitive knowledge tasks were identified in any of the textbooks.

Given the fact the procedural knowledge was represented by considerably one-sided tasks (training nomenclature, balancing formulas and performing calculations), even this category which, judging by the numbers, fits the curriculum needs to be considered only partially fitting.

When combined, most objectives – translated in tasks – are supposed to target understanding concepts, remembering facts, applying procedure and evaluating concepts. The oldest textbooks meet the curriculum in their focus on understand *conceptual knowledge*. The FR, NŠ and nFR textbooks include tasks focused on remember factual *knowledge*, especially when only the chemistry-oriented tasks in FR and nFR are considered. None of the textbooks addressed concept evaluation.

This phenomenon, however, is not caused by the nature of the field requiring only a certain type of questions or tasks. Kácovský et al.'s[38] analysis showed Polish or Slovenian curriculum contains a wider range of objectives than the Czech chemistry curriculum. In cases when even curriculum objectives do not contain larger objective variability than the students' cognitive activities', it is not reasonable to expect them in textbooks. This suggests a certain chemistry education culture in Czechia. To confirm, analysis of Polish or Slovenian textbooks tasks needs to be performed. Also, in their analysis of Turkish chemistry textbooks, Zorluoglu, et al.[41] identified not only tasks targeting students' remembering , understanding and application as expected. A significant proportion of tasks targeting evaluation were identified. This is especially surprising in connection to the Turkish curricular objectives' analysis[37] which showed the intended chemistry curriculum not to significantly target this cognitive domain. This example then shows a textbooks' positive role in developing the state curriculum in the required manner. Rethinking educational content and its didactical transformation with regard to active learning and the objectives of science education is thus shown to be crucial in the creation of new textbooks.

The fact that the Czech chemistry textbooks which claim their alignment to the curriculum do not even contain the range from the curriculum, is alarming. Considering the textbooks' effect and the number of tasks, more elaboration, not less, was expected from the textbooks. This finding then stresses an important issue in chemistry (science) education. Despite various efforts to change science education at the level of the intended curriculum, the continued emphasis on knowledge transfer and thus the low proportion of tasks accentuating higher-order cognitive operations is also shown in other countries (cf.[26]). However, as shown by Gillette and Sanger,[30] many studies found that the ability to solve tasks requiring simple knowledge equipment, or their direct application, does not translate into the ability to solve tasks requiring higher cognitive operations. Understanding the concepts of educational content does not in itself lead to the development of skills to analyse, evaluate or create. Surely, many students who underwent such an education (with such textbooks) developed their cognitive skills, though the effect or even contribution of school is disputable. Also, these students' skills could have been developed to a greater extent if addressed at school.

As proved by Robinson,[61] learning to solve tasks algorithmically often leads to mere manipulation with variables according to the learned procedure. Simple task repetition requiring simple application of a known procedure does not lead to understanding scientific concepts the tasks' solution is based on, and learning becomes just a mechanical imitation. In view of the effective learning and deep development of field knowledge and skills, the full absence of metacognitive knowledge tasks identified in all the analysed textbooks also seems problematic. Students are supposed to be encouraged to learn how to learn through textbook tasks, estimate their performance and eventually adapt their learning approach. As shown by Pappa and Tsaparlis,[62] this aspect is also a challenge for curriculum in Greece.

Systematic work with tasks in curricular materials is also proving desirable from the NoS point of view. The analysis performed in this study identified only four dominant types of tasks in which there is only limited scope for students' autonomy in their solution. Therefore, the nature of chemistry (NoS) emphasizes existing knowledge as fixed, while lacking the procedural aspect of the NoS and room for new (out-of-the-box thinking). Simon and Budke[63] in their textbook research reached similar conclusions. They identified stress on goals associated with content as opposed to tasks related to methodological aspects and competence development. As pointed out by Osborne,[15] freely paraphrasing scientific literacy definition, natural science knowledge does not only consist of factual knowledge, but also highlights the way science works, how individual phenomena are related to other aspects, and how knowledge is acquired. These aspects of the NoS in relation to the analyzed textbooks are all the more important as chemical education begins in the 8th grade in the Czech Republic. Since the abovementioned aspects of natural sciences cannot be developed solely through lower cognitive operations, there is a risk of consolidating the image of chemistry as mere isolated, mostly symbolic,[59] facts students are supposed to acquire (cf.[64]). This tradition needs to be revisited and incorporated into pre-service teacher training as a part of the teachers' professional vision (see[65]) since it is this exact domain in which the content meets the pedagogy.[66]

There are some limitations to the approach presented in this study. First, only the intended curriculum was analysed. In connection with international research, the results provide a vivid picture about the teaching practice, however, without analysing the implemented curriculum, i.e. the textbook tasks in action, conclusions need to be formulated carefully. For this reason, students' activity, performance and results are the next logical step in this area of research.

Second, this study contains results of 8$^{th}$ grade textbooks tasks analysis, despite chemistry is mostly being taught in both 8$^{th}$ and 9$^{th}$ grade (the last two years of compulsory, lower-secondary school in Czechia). Nevertheless, the textbooks are published by the same teams of authors. As a pilot sample of tasks from 9$^{th}$ grade textbooks showed no differences in the tasks' conception, the second books were not submitted to a thorough analysis.

Third, with respect to the analysis' focus, other tasks' qualities should such as their relation to the key competences as the major curricular goal, their accent on science literacy or the Nature of Science be investigated. These are topics which would inform all actors in the field of chemistry education about necessary steps in order textbooks – as the most influential medium in contemporary school – to aim at contemporary (not former) goals of chemistry/science education.

## 6. Conclusions

This study is directed at chemistry lower-secondary textbook tasks' analysis. It showed several trends which confirm other findings worldwide as well as several specifics which revealed trends in Czech chemistry education conception.

Particular chemistry textbooks differ in task placement. Whereas formerly published textbooks contain tasks at the end, newer textbooks contain them within the chapters. These show authors' effort to connect the tasks with other structural textbook elements and the field's content.

The textbooks contain a relatively large number of tasks offering a vast database to be used in education. The analysis of tasks from Czech chemistry textbooks confirmed there is a certain task genre from a required answer type to a required performance. Textbooks were found to follow the curriculum as far as the subject-matter is concerned, however they vary from the curriculum as far as the required cognitive processes are concerned.

The textbooks' integral culture consists in the tasks' nature: open-ended tasks predominate, followed by tasks of laboratory nature without required answers. Higher task variability is required. With respect to students' more complex development, richer response types as well as more varying information explanation are suggested. A greater variability is also suggested from the cognitive operations' point of view. Tasks on remembering or understanding facts and conceptual knowledge predominate in the textbooks. Three out of four most often used chemistry textbooks in Czechia also contain procedure application. Tasks on analysis, evaluation or creation, or tasks operating with metacognitive knowledge are lacking. With respect to scientific literacy development, it is important to focus on these domains too.

So far, Czech chemistry textbooks were found to be a suitable educational tool for students to master factual and conceptual knowledge. Their use for skills or developing creative thinking and chemistry (science) problem solving is considerably limited. This study then shows possible ways for future textbook development.

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## Povzetek

Analizirali smo naloge v čeških učbenikih kemije za nižje srednje šole, da bi opisali njihovo umestitev v poglavjih učbenika, vrsto zahtevanega odgovora, splošno naravo naloge in kognitivne zahteve. Rezultati so pokazali, da starejši učbeniki vsebujejo banke nalog na koncu poglavij, kar kaže na transmisivno paradigmo poučevanja, medtem ko novejši učbeniki vsebujejo naloge znotraj poglavij. Kar zadeva naravo nalog, je bila v učbenikih za kemijo ugotovljena stereotipna zvrst. Večina učbeniških nalog zahteva odprte odgovore in je usmerjena v pomnjenje dejanskega in konceptualnega znanja ali uporabo postopkov. Avtorji zato predlagajo več sprememb nalog, vključno z njihovim položajem v poglavjih, kognitivno zahtevnostjo ter zahtevano vrsto odgovora, da bi izpolnili cilje kemijskega izobraževanja.