Questions as a basis for comparison of biology textbooks and workbooks

Vprašanja kot izhodišče za primerjavo bioloških učbenikov in delovnih zvezkov

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Abstract. This study focused on the analysis of three biology teaching sets and one textbook for 8th and 9th grade of elementary school. As a criterion we used the number and structure of questions assessable by Bloom's taxonomy of the cognitive domain.

It is obvious from the differences in the number and type of questions that the authors of the teaching materials differed in their understanding of the role of textbooks and workbooks in the teaching process. The analysed teaching sets included between 1.1 and 1.4 questions per page; most of them found in workbooks. The exception was one textbook with no questions for the students. The analysis of the questions using Bloom's scale of cognitive levels showed statistically significant differences between teaching sets. The average cognitive level of the questions in a teaching set was between 1.7 and 2.1.

The questions represent only one of indicators that show to what extent the didactic aspect was considered in the teaching sets, but the results suggest biology teaching material for elementary school is overly focused on lower cognitive levels, mostly recognition, not providing enough knowledge of higher cognitive levels.

Key words: textbooks, evaluation, Bloom's taxonomy of the cognitive domain.

Izvleček. V raziskavi smo analizirali tri učbeniške komplete in en učbenik za biologijo v 8. in 9. razredu osnovne šole. Za kriterij smo izbrali število in strukturo vprašanj, ki jih je mogoče vrednotiti po Bloomovi taksonomiji kognitivnih ciljev.

Pisci učnih gradiv očitno različno pojmujejo vlogo učbenika in delovnega zvezka v učnem procesu, saj so se pokazale razlike tako v številu kot v tipu vprašanj. Obravnavani učbeniški kompleti vsebujejo od 1.1 do 1.4 vprašanj na stran, večinoma je večji delež vprašanj v delovnih zvezkih. Posebnost je en učbenik, v katerem ni vprašanj za učence. Analiza vprašanj po Bloomovi lestvici kognitivnih stopenj je pokazala statistično pomembne razlike med učbeniškimi

kompleti. Povprečna vrednost kognitivne stopnje vprašanj v učbeniških kompletih se giblje med 1.7 in 2.1.

Vprašanja so samo en pokazatelj didaktične obdelanosti učbeniškega kompleta, vendar rezultati kažejo, da so v osnovnošolskih bioloških učnih gradivih preveč poudarjeni nižji kognitivni cilji, predvsem poznavanje, premalo pa je višjih kognitivnih ciljev.

Ključne besede: učbeniki, evalvacija, Bloomova taksonomija kognitivnih ciljev

Introduction

Biology in lower grades of elementary school forms part of various subjects, but in 8th and 9th grade it becomes a separate subject. Teaching material for new programmes is issued by various publishers, which has its advantages as well as disadvantages. A wider choice gives teachers a chance to select a teaching set they see best suited for their students and at the same time conforms to their teaching methods.

There are several dilemmas surrounding the use of science textbooks. Should biology teachers use textbooks or not? Should the textbooks be the focus of a course or just supplemental material? Who should determine textbook content and what should this content be? (KIRK & al. 2001). It turns out that a textbook is a valuable, and in many cases central, component of biology education that contributes to achieving biology teachers' goals. Many science teachers, new teachers in particular, use the assigned textbook as their content outline and story line for their courses (CHIAPPETTA & al. 1993, BYBEE 2001, GARINGER 2001). A study, conducted on a sample of Slovene elementary school teachers (VERČKOVNIK & STRGAR 2003), showed that for 60.0 % of teachers the textbook still represents a guide for their course and not a resource for unassisted student home work. Since textbooks have been shown to have tremendous impact on curricula, this is one variable of science instruction that needs further investigation (LLOYD 1990).

What constitutes a good science textbook and how can we identify it? The lists used in textbook selection are long and include such items as content accuracy, clear definition of terms, end-of-chapter questions, graphics and physical characteristics, pictures and diagrams, in-text laboratory activities, etc. (CHIAPPETTA & al. 1993). Others promote the evaluation of teaching material beyond simply their contents and instead focusing on cognitive and affective factors (GARINGER 2001). The study by LOWERY & LEONARD (1978) examined the questioning style among four widely used high school biology textbooks in terms of types, frequency, and placement of questions in textual reading materials. It also examined the science/learning (inquiry) processes elicited by the questions. TAMIR (1985) and ELTINGE & ROBERTS (1993) tried to assess the degree to which science was portrayed as a process of inquiry in high school biology textbooks, as the opposite of a portrayal of science as a collection of facts. ANDERSON & BOTTICELLI (1990) analysed textbooks based on explicit and implicit content analysis techniques. The purpose of LLOYD'S (1990) analysis was to identify text-based concepts and to describe how these concepts are elaborated in three biology textbooks. CHIAPPETTA & al. (1993) wanted to determine if the textbook under consideration reflects the themes of scientific literacy that science educators believe are important. CONRAD (1996) investigated linguistic variation in biology textbooks and articles. NINNES (2000) evaluated the ways in which secondary science textbooks incorporate and represent indigenous knowledge. HARRISON (2001) investigated the ways that models are used in school science textbooks. The study reported by KESIDOU & ROSEMAN (2002) focused on examining how well science textbooks meet the Project 2061 content and instruc-

tional criteria. DIMOPOULOS & al. (2003) analysed the pedagogic function of visual images included in school science textbooks.

According to the Slovene biology curricula for 8th and 9th grade of elementary school, students should learn in an active way; gain cognition through their own research and investigation; reveal the point of the given content by collecting data from different sources; compare information and employ critical thought; learn to analyse and make connections and generalizations. The curricula therefore prescribes attaining not only data but also knowledge of a higher cognitive level. Based on the finding that biology textbooks and workbooks have a central role in achieving the goals of the curricula, our intention was to evaluate to what extent they contribute to these objectives. The number and structure of the questions set in textbooks and workbooks serve as criteria. It was hypothesized that:

• There would be no differences among the texts in the ratio of questions per page.
• Bloom's taxonomy of the cognitive domain would show no significant differences among the texts.

The results would provide guidance for teachers. This kind of analysis should also be of help to the authors of new textbooks and workbooks.

Material and methods

The study, conducted in 2003, focused on the teaching material (textbooks and workbooks) in biology for 8th and 9th grade of elementary school. Their authors distributed content and categories between textbooks and workbooks at their own discretion. From the student's point of view we can regard the textbook and workbook as a complete whole – a teaching set. At the time of the study, two biology teaching sets for 8th grade were approved, as well as one teaching set and one textbook for 9th grade.

The list of the biology textbooks and supplemental workbooks analysed is as follows:

Textbook for the 8th grade of elementary school (Biologija 8. Učbenik za 8. razred devetletne osnovne šole. Novak Bernarda. Ljubljana, DZS, 2000.)

Workbook for the 8th grade of elementary school (Biologija 8. Delovni zvezek za 8. razred devetletne osnovne šole. Novak Bernarda. Ljubljana, DZS, 2000.)

Textbook for the 8th grade of elementary school (Biologija 8. Učbenik za 8. razred devetletne osnovne šole. Kralj Metka, Podobnik Andrej. Ljubljana, TZS, 2001.)

Workbook for the 8th grade of elementary school (Biologija 8. Delovni zvezek za 8. razred devetletne osnovne šole. Kralj Metka. Ljubljana, TZS, 2002.)

Textbook for the 9th grade of elementary school (Biologija 9. Učbenik za 9. razred devetletne osnovne šole. Svečko Marina. Ljubljana, DZS, 2002.)

Workbook for the 9th grade of elementary school (Biologija 9. Delovni zvezek za 9. razred devetletne osnovne šole. Svečko Marina. Ljubljana, DZS, 2001.)

Textbook for the 9th grade of elementary school (Biologija 9. Učbenik za 9. razred devetletne osnovne šole. Kordiš Tatjana. Ljubljana, Modrijan, 2002.[*])

[*] The supplemental workbook had not yet been published at that time.

Textbooks and workbooks were evaluated by analysing the questions for students. FISH AND GOLDMARK (1966) stated that the kinds of questions used in instruction determine the kinds of operations student perform (as cited in LOWERY & LEONARD 1978). The value of particular types and usage of questions in textbooks depends on certain assumptions. If one starts from the assumption based on Piagetian research that indicates direct and active experience is more valuable to students' learning than indirect and passive experience, then one would judge textbooks that ask questions within the experiential realm to be more desirable than those that ask non-experiential questions. We can also assume that asking a high proportion of questions is important or agree with many researchers that all forms of teaching (in this case, textbooks) should make greater use of »higher level« questions (LOWERY & LEONARD 1978).

As a criterion we took Bloom's Taxonomy of the Cognitive Domain that has already been used by CHALL & CONARD (1991) and SKIERSO (1991) to assess the processes and skills textbooks require learners to perform (as cited in GARINGER 2001). This method was chosen following positive experience in the preparation of tests for graduation from elementary school and graduation from grammar school (baccalaureate). These require an adapted three-level Bloom scale which makes the procedure more practical while retaining adequacy, but we decided on a full six-level scale nevertheless. All the questions assessable by taxonomy of the cognitive domain were collected in grid diagrams, distributed into cognitive levels, and statistically processed. The rating of a textbook will directly reflect the level of skills it demands. For example, a book that uses synthesis and analysis would rate higher than one that demands only comprehension (GARINGER 2001).

The questions were sorted by two independent evaluators. Where their assessment differed, the question was ranked after discussion and agreement. The questions were sorted into cognitive levels with regard to other texts in the teaching material. Evaluated out of context, many questions would be sorted into other categories. A question that was demanding at first glance, but was provided with an answer in the preceding text, was placed in a lower category. If the answer was given in the following text, the question was placed higher. Similar questions could therefore be arranged into different cognitive levels.

Important factors in the measurement of the effect of a textbook on pupils are the teacher's use of the textbook and his method of teaching. Experience teaches us that the course of teaching often encourages students to learn by heart. In this context MARENTIč POŽARNIK (1992) stressed the importance of a well designed education and training for teachers to prepare them for proper selection and creative use of textbooks. Our analysis assumed an ideal teacher who promotes unassisted work and thinking and does not offer definite solutions, maintaining the potential value of the questions in the textbooks and workbooks.

Results and discussion

The teaching sets examined included between 1.1 and 1.4 questions per page (Tab. 1). A detailed analysis showed that in the set EF this ratio was the same for the workbook and the textbook, while sets AB and CD placed most questions in the workbooks. In Slovenia, textbooks are not designed so as to allow them to be written in, so the results are not surprising.

An exception is textbook G that can be classified as a classic textbook on the basis of its structure, and is at the moment the only one of that type among elementary school textbooks. A textbook can encompass a whole range of levels, and can therefore be a textbook with a strong didactic component, or, at the other end of the spectrum, a classic textbook with the content presented systematically and in language and style suitable for target readers, but does not include special didactic techniques, such as a motivating introduction, activity encouraging questions, knowledge testing questions, knowledge

reinforcement questions, etc. Given that the workbook to accompany this textbook has not yet been published, the suitability of such design cannot be assessed. Since textbook G does not include questions for students, which were the basic element of our work, it was not included in further analysis.

Table 1: Ratio of questions per page in the teaching sets examined.

Teaching set	Ratio
AB	1.4
CD 1.1	
EF	1.4
G* -	

*The supplemental workbook had not yet been published at that time.

The hypothesis that there would be no differences among the texts regarding the ratio of questions per page can therefore be refuted, since the results show that the authors of teaching material took various approaches, which leads to the conclusion that they hold different views of the role of the textbook in the teaching process. As MARENTIČ POŽARNIK (1992) stated, each textbook reflects the author's view of the learning and teaching processes, his or her undestanding of knowledge and of the pupil's abilities.

Tab. 2 shows the percentage of questions of individual cognitive levels in each of the teaching sets. The three sets examined include between 201 and 323 questions that we were able to analyse using Bloom's taxonomy of the cognitive domain. The average cognitive level of the questions in the teaching sets was between 1.7 and 2.1. The differences between percentages of questions of individual cognitive levels among these three teaching sets are statistically significant ($\alpha=2P<0.1$, $\alpha=2P<0.001$). The results show that most questions fit into the first cognitive level (49.3 – 60.2 %). It is interesting that both 8th grade sets (AB and CD) have approximately the same percentage of questions of this level. All sets include considerably fewer questions of the second cognitive level (15.3 – 25.4 %). There are approximately the same number of questions of the third cognitive level in sets CD and EF (15.9 – 18.4 %), while the percentage in set AB is substantially lower (7.7 %). Set AB deviates in the fourth cognitive level as well, but this time in the other direction, since it contains as much as 17.3 % of the questions of this level, while the other two sets include considerably fewer (4.9 – 6.5 %). There are very few questions of the fifth and sixth level (up to 3.0 %).

Table 2: Distribution of questions of individual cognitive levels in the teaching sets using Bloom's scale.

Cognitive level	Percentage of questions		
	Set AB	Set CD	Set EF
1.	49.8	49.3	60.2
2.	20.7	25.4	15.3
3.	7.7	15.9	18.4
4.	17.3	6.5	4.9
5.	1.9	3.0	0.8
6.	2.5	0.0	0.4
Total	100	100	100

From the percentages of individual cognitive levels it is possible to deduce the teaching goals achievable with these sets. The National Examination Commission in Slovenia prepares the biology test sheets for the final examination for elementary school using an adapted Bloom's scale of the cognitive domain. It merged the 2nd and 3rd levels, and 4th, 5th and 6th levels, thus creating a three-level scale instead of a six-level scale. The Commission reached an agreement that the national biology examinations should include 35 % of questions regarding recognition, 50 % of questions regarding comprehension and 15 % of questions regarding higher cognitive levels (Tab. 3).

Table 3: Evaluation scale of cognitive levels for national examinations.

Cognitive level	Description	Percentage
1. recognition	recognition of facts, data, concepts, definitions, theories, formulas	35 %
2. comprehension, application	connecting causes and effects, seeking examples, giving own examples, solving new problems, translating of one type of symbolic record into other	50 %
3. independent problem solving, independent interpretation, analysis, synthesis, assessment	unknown situations, original solutions analysis, comparison, abstract thinking, generalization, deduction, synthesis, independent argumentation independent and critical assessment of phenomena, theories and solutions, supported by argument	15 %

Comparison of the National Examination Commission recommendations with the analysed teaching sets shows that the differences in the percentages of the questions of individual cognitive levels are substantial. There are approximately 15-25 % too many questions regarding basic knowledge, which are first level questions (Tab. 4). At the second-level, concerning comprehension and application of knowledge, the teaching set CD with 41.3 % comes closest to the recommendations of the Commission. The other two sets include only around 30 % of these questions, which is 20 % less than the Commision advises. The results regarding questions of the highest category are surprising. Set AB with 21.7 % of these questions is the only one that meets and even exceeds the recommended percentage. There are too few of these questions in the other two sets (9.5 % and 6.1 %).

Questions for pupils are only one of the indicators that show to what extent the didactic aspect was considered in the teaching sets. Other elements, which were not taken into consideration in our study, are also very important. But the results show that elementary school teaching material puts too much emphasis on lower cognitive levels, especially recognition. Basic knowledge is of course a necessary foundation that students must acquire, but the teaching process should include a wider scope of higher levels.

Table 4: Distribution of questions of individual cognitive levels in the teaching sets using an adapted three-level scale.

Cognitive level	Percentage of questions		
	Set AB	Set CD	Set EF
1.	49.9	49.3	60.2
2.	28.5	41.3	33.7
3.	21.7	9.5	6.1
Total	100	100	100

Similar conclusions concerning textbooks were also reached abroad. ELLIOT & NAGEL CARTER (1987) established that natural science textbooks adequately present natural science content, but do not encourage scientific thought. The authors of that study think that the most important message of the current natural science textbooks is that the natural sciences are a collection of findings that must be learned by heart. The textbooks therefore stress the content and learning of facts and principles, but there is little application and suitable activities to help the student understand nature and connect natural sciences with the problems of the modern world. They summarized their findings into a claim that the textbooks' stress is largely on the products of the natural sciences and less on the character of the natural sciences and its processes. A review of the 10 most popular high school biology textbooks in the US also found numerous facts, but little to explain the underlying scientific importance of the facts. The evaluators rated all 10 textbooks poor in »demonstrating use of knowledge« and »encouraging students to reflect on their own learning« (HOFF 2000).

Conclusions

The following are the most important findings:
• The teaching sets differ in number of questions per page. They include between 1.1 and 1.4. The workbooks contain the majority of the questions.
• The average cognitive level of the questions in teaching sets is between 1.7 and 2.1, which indicates an emphasis on recognition and a lack of higher cognitive levels.
• The difference in the structure of the questions of the teaching sets, analysed by Bloom's taxonomy of the cognitive domain, is statistically significant.
• The authors of teaching sets have a different perspective of the role of teaching materials.

Povzetek

Izhajajoč iz ugotovitve, da imajo biološki učbeniki in delovni zvezki osrednje mesto pri doseganju ciljev učnega načrta, je bil naš namen ovrednotiti, v kolikšni meri lahko pripomorejo k doseganju teh ciljev. Za kriterij smo izbrali število in strukturo vprašanj v treh učbeniških kompletih in enem učbeniku za 8. in 9. razred osnovne šole. Predpostavili smo, da med besedili ne bo razlik glede na število vprašanj na stran, in da ne bo statistično pomembnih razlik glede na Bloomovo taksonomijo kognitivnih ciljev. Vsa vprašanja, ki jih je mogoče vrednotiti po taksonomiji kognitivnih ciljev, smo

zbrali v mrežnih diagramih, jih po zahtevnosti razvrstili v kognitivne stopnje in statistično obdelali. Ocena je bila neposredno odvisna od nivoja zahtevnosti, ki ga učbeniški komplet omogoča razvijati.

Rezultati kažejo, da so imeli pisci učnih gradiv raznolik pristop. Ugotovili smo namreč, da obravnavani učbeniški kompleti vsebujejo od 1.1 do 1.4 vprašanj na stran. Večinoma je večji delež vprašanj v delovnih zvezkih. Posebnost je učbenik G, v katerem ni vprašanj za učence. Tega zato nismo mogli vključiti v nadaljnjo analizo. Po Bloomovi taksonomiji kognitivnih stopenj so se pokazale statistično pomembne razlike med učbeniškimi kompleti. Rezultati kažejo, da je največ vprašanj prve kognitivne stopnje (49,3 – 60,2 %), kar je približno 15-25 % preveč glede na priporočila Komisije za vodenje nacionalnih preizkusov znanja. Pri vprašanjih 2. in 3. stopnje, ki zajemajo razumevanje in uporabo znanja, se priporočilom Komisije najbolj približa učni komplet CD z 41,3 % takih vprašanj. V drugih dveh kompletih jih je okoli 20 % manj premalo. V najvišji kategoriji, torej vprašanjih 4., 5. in 6 stopnje pa komplet AB z 21,7 % presenetljivo dosega in celo precej presega želeni delež teh vprašanj. V drugih dveh kompletih je teh vprašanj premalo (9,5 % oz. 6,1 %). Povprečna vrednost kognitivne stopnje vprašanj v kompletih se giblje med 1.7 in 2.1.

Vprašanja so samo en pokazatelj didaktične obdelanosti učbeniškega kompleta. Zelo pomembni so tudi drugi elementi, ki jih v naši raziskavi nismo zajeli. Vendar dobljeni rezultati kažejo, da so v osnovnošolskih bioloških učnih gradivih preveč poudarjeni nižji kognitivni cilji, predvsem poznavanje, premalo pa je višjih kognitivnih ciljev. Tudi nekatere raziskave učbenikov v tujini so prišle do podobnih zaključkov.

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