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Analysis of Plant Reproduction Representations in Austrian Biology Textbooks

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Abstract

Understanding plant reproduction is an important goal in science education since plants build the basis for many ecosystems. The presented project analyses the representation of this topic in Austrian biology textbooks in secondary schools. This analysis is embedded in a multi-perspective research project, investigating educational aspects of plant reproduction following the Model of Educational Reconstruction. The textbook analysis includes 18 different biology textbook series from the 5th grade in which plant reproduction is typically taught in Austria. The textbook analysis focuses on the representation of core ideas of plant reproduction and on aspects relevant for the development of students' conceptions, such as the use of terms, examples, and metaphors. Results show that all textbooks represent plant reproduction in much detail, including all processes of sexual reproduction. The results also indicate potential difficulties for students, such as the use of misleading terms, examples, or metaphors. Moreover, only few books include the advantages and disadvantages of the different pollination mechanisms and most books discuss the variety of plants and pollinators insufficiently. This could lead to difficulties in understanding how mechanisms and adaptions developed from an evolutionary perspective. The presented results provide direct implications for teaching plant reproduction and for a beneficial use of textbooks.

Keywords: Biology education; Educational Reconstruction; Textbook analysis; Pollination; Plant reproduction

1. Introduction & Theoretical background

Understanding reproduction of plants is an important goal in science education. Plants are essential for almost every ecosystem and play a crucial role in preservation aspects, as food, and in fighting climate change. Despite their importance, plants and their relevance are often overlooked, which is described as "Plant blindness" [1]. Plant blindness affects learning on several ways: Teachers devote little time on teaching about plants [2], schoolbooks contain less information about plants than about animals [3] and students are less interested in plants than in animals [4]. In addition, studies prevailed that students have difficulties in understanding various aspects of plant reproduction such as the connection between flowers and fruits [5].

To improve learning about plant reproduction as a central botanical topic, we have started a research project, focusing on various educational dimensions of plant reproduction (scientific backgrounds; students' conceptions; teachers' perspectives; analysis and development of educational material). To connect all aspects of this project, the Model of Educational Reconstruction [6] was chosen as a framework. In this paper, we focus on the analysis of textbooks as educational materials, since these textbooks are important, widely used, and therefore potentially powerful resources for teaching.

The aim of this study is to systematically analyse the contents on plant reproduction in Austrian school textbooks based on three main research questions:

- *Which contents about plant reproduction are represented in Austrian school textbooks from the 5th grade and how are specific terms and examples used in these books?*
- *How are the sections on plant reproduction structured?*
- *How does the content in these sections about plant reproduction relate to students' conceptions and scientific backgrounds?*

2. Methods

The main analysis was conducted in spring 2018 and included 18 different Austrian textbooks for the 5th grade (list of all analysed books in [7]), representing almost all textbook series used in Austria [8]. The 5th grade (children aged 9-11) was chosen because the national curriculum for this grade refers to structure, function, and biology of plants [9]. Even though the topic "plant reproduction" is not

mentioned explicitly in the curriculum, all analysed schoolbook series included reproduction of (flowering) plants as a part of a separate chapter about plants. The analysis focused on the complete chapter about plants, any other potential information about plants in other chapters was not analysed.
We analysed the school textbooks adapting a method of Roseman, Stern & Koppal [10], which uses a concept map representing the key ideas of a topic. Therefore, we first developed a concept map including major aspects of plant reproduction based on existing scientific overviews. In addition to the map, general questions about examples, metaphors and the structure were answered for each book. This method was then tested independently by two researchers with nine schoolbooks in a testing phase. The agreement of the testing results between the researchers was very high and only minor differences existed, which were solved in a consensual discussion. The same map was also successfully applied in a parallel project to analyse science content in scientific books [11].
After the testing phase, one researcher systematically analysed each schoolbook and all contents included in the book were marked in a separate map. After this step, all topics which were absent in a schoolbook were deleted from the map and topics mentioned only implicitly were set semi-transparent. This improved readability of the concept map also simplified further comparison between the schoolbooks. The progress from the initial map to the application of the method by hand and the simplified version of the map for one schoolbook is included in the appendix (see appendix 1). All results where then transferred in a table to support further comparison.

3. Results

The analysis allowed detailed insights into every schoolbook (see [7] for the complete analysis in German). In this paper, we will focus on the most important outcomes from six areas (a)-(f) and we will also provide an overview showing in how many books certain aspects occur (numbers in brackets).

(a) General structure: The chapters on plants cover between 13-24 pages, representing approximately 10% to 20% of each schoolbook content for 5th grade. Typical contexts inside the plant chapters include early bloomers (15x), useful plants (10x) and plant families (8x). Many books (11x) follow a clear chronological order when describing the processes of sexual reproduction (pollination, pollen tube growth, fertilisation, seed development, seed/fruit dispersal, germination of seeds). The seven remaining books interrupt explanations or switch between different topics or examples. 16 books also include asexual reproduction. Despite this representation of both sexual and asexual reproduction, the biological importance of sexual recombination is stated in one book only.

(b) Flower structure & specific terms: All books provide a detailed description of the (hermaphrodite) flower structure, which is often represented by a cherry flower (10x) or an abstracted “model” flower (6x). Other examples (tulips, snowdrops, apple) are used only in few books. All books provide appropriate definitions for most terms and use terms consistently. The only exceptions are the (wrong) synonymous use of the terms *carpel* and *pistil* (5x) and a lack of differentiation between *pollen grain* and *pollen* (12x).

(c) Pollination: 17 books refer to pollination by wind and by animals. However, advantages or disadvantages of these ways of pollination are mentioned in only one book explicitly and in six books implicitly. Self-pollination is mentioned in 10 books with some books even referring to mechanisms which reduce self-pollination. But none of the books refer explicitly to positive aspects of self-pollination. Typical botanical examples in the context of pollination were the same as in the description of the flower structure with few additional examples to illustrate phenomena (*Primula*; *Salvia*; *Corylus*). The books include the following examples for animal pollinators: insects in general (18x); (honey)bees (18x); bumblebees (9x); butterflies (5x), birds (4x), bats (4x), flies (3x), ants (3x). Relevant morphological differences between insects such as different mouthparts are only addressed in five books. The main reasons for animals to visit flowers described are foraging (18x) and being attracted by colour (12x) or scent (8x). None of the books differentiate between flower visitors and pollinators.

(d) Pollen tube growth, fertilisation, and seed development: All books describe the growth of the pollen tube and the following fertilisation process. Nearly two thirds of the books (11x) also mention the competition between different growing pollen tubes. All books describe the relation between flowers and fruits, which is often illustrated with images showing the development of a fruit. Most texts describe that the ovary alone builds the fruit. Most books (14x) use cherries (*Prunus*) to illustrate the

development from the flower to the fruit. Additionally, some books compare the development of different flowers to show the relation between flowers and fruits (7x).

(e) Dispersal of fruits and seeds: All books include information on dispersal types with a clear focus on the vectors wind and animals. In addition, seven books include a broad morphological classification of fruit types, six books include a smaller selection of fruit types. The examples of plants which are often mentioned in the context of fruit and seed dispersal are: dandelion (*Taraxacum*) (15x); touch-me-not (*Impatiens*) (14x); burdock (*Arctium*) (12x); maple (*Acer*) (9x); poppy (*Papaver*) (9x), violet (*Viola*) (8x); lime tree (*Tilia*) (6x); All other plant examples are mentioned in fewer than 5 books. Most books do not only refer to animals in general in the context of seed/fruit dispersal, but also refer to specific groups: birds (13x); ants (12x); squirrels (4x); mammals in general (4x) and mice (2x).

(f) Synonyms & Metaphors used: In the context of pollen, many schoolbooks mention that they contain either "sex cells" ("Geschlechtszellen" in German) or "seed cells" ("Samenzelle" in German) (4x). Typical metaphors in the context of pollination describe a "transport" of pollen from one flower to another by insects (6x), describe "travelling" (of pollen grains) (3x), or describe pollination as a "work" or a "task" for insects (2x).

4. Discussion

(a) The observed link with useful plants in many books is a good approach to connect to students' interests in useful plants [12]. Presenting the processes of sexual reproduction in a complete chronological order is important to show how the processes of the life cycle are related to each other, which has been reported as a major difficulty for students [5] [13]. The importance of sexual recombination should be highlighted, since this importance is fundamental for explaining the variety of flowers and pollination mechanisms.

(b) The number of terms in the context of floral structure is considerably high [11], which makes precise definitions and a consistent use of these terms very important for learners. The terms for the female parts of a flower are particularly difficult, since one or more carpels can be involved in the formation of one pistil. The oversimplification "carpel equals pistil" could lead to further difficulties in understanding morphological fruit types. The visualization of different flowers and how they develop to fruits could be an effective way to improve understanding (see (d)).

(c) It is important to discuss advantages and disadvantages of the different vectors involved in pollination and to highlight the advantage of cross-pollination. This is fundamental to understand the (co-)evolutionary development of flowers and animal pollinators. Another prerequisite to achieve a co-evolutionary understanding is to see and understand the diversity of both flowers and animal pollinators. Most books contain few examples on both sides and hardly describe specific interactions and adaptations. Surprisingly, ants are mentioned as pollinators in three books, even though they do not play a significant role in pollination, but rather in seed dispersal (*Viola*). This could reflect a confusion of pollination and seed dispersal, which is also observable in students' conceptions [13]. It would also be important to differentiate between flower visitors and pollinators, since not every visiting animal is a pollinator [11].

(d) All schoolbooks represent pollen tube growth and fertilisation in much detail. Even though the processes are visualized, the process of double fertilisation includes many inherent difficulties from a scientific perspective [11], which is a challenge for the young learners from 5th grade (aged 9-11). Analyses of students' conceptions in Austrian students show that the process of pollen tube growth is almost absent in students' descriptions about plant reproduction [13]. A possible solution is to highlight pollen tube growth as a vivid and fascinating process and to add experiments or models to make this process visible. Illustrating the development of different flowers to fruits should be added in all books, because it highlights the connection between flowers and fruits and shows how floral parts transform.

(e) The schoolbooks focus on the ecological aspects of dispersal, which is understandable regarding the complexity of morphological fruit types. The examples include almost all types of dispersal via wind (*Taraxacum; Papaver; Acer; Tilia),* animals (*Prunus; Arctium; Viola*) and self-dispersal (*Impatiens*). However, the examples could lead to a misleading impression of the quantity of these dispersal forms – explosive mechanisms (in *Impatiens*) and seed-dispersal through ants (in *Viola*) are

fascinating but rather exceptional ways of dispersal. An explanation could be the focus on early bloomers in many books including *Viola* as an example.

(f) Finally, the term "seed cell" ("Samenzelle" in German) for the male sperm cell inside the pollen is misleading and can contribute to the mixing of pollen and seeds, which is observable in students' conceptions. The metaphors "transport", "pollentaxi" or pollination as a "task" should be avoided or at least critically discussed, since they suggest a deliberate transfer of pollen, which might support students' ideas of a deliberate pollination, which is observable in students' conceptions [14].

In summary, the quality of all books was suitable for the 5th grade. The study provides insights of possible sources of misunderstanding in the context of plant reproduction and could, therefore, be highly relevant for teachers, schoolbook authors and educational researchers. It shows that teachers need to discuss certain aspects (terms, examples, metaphors) contained in schoolbooks critically, particularly regarding existing students' conceptions and difficulties. The results also imply the necessity to highlight the diversity of the involved organisms and to provide opportunities to discuss (evolutionary) advantages/disadvantages of structures.

5. References

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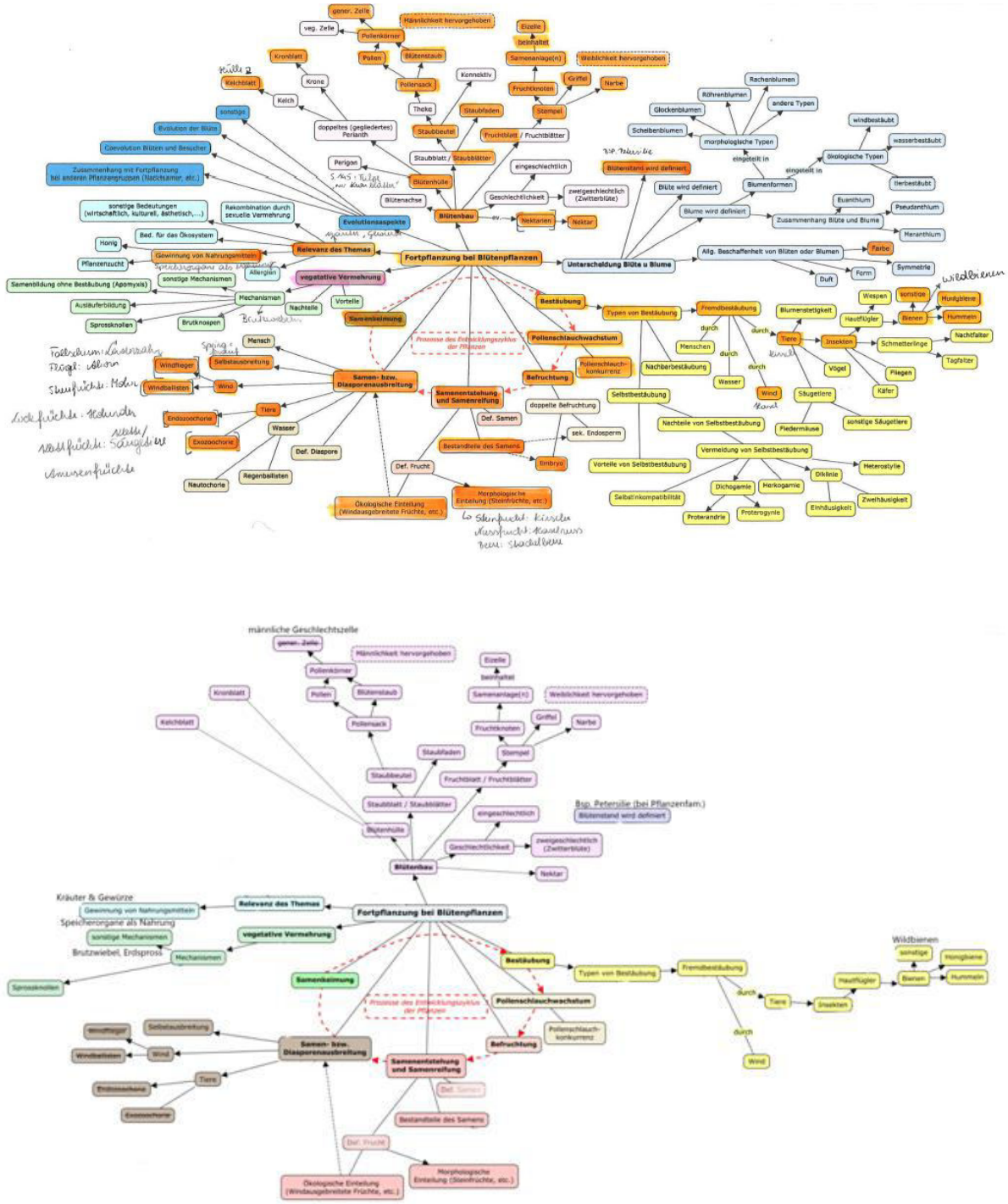

Appendix 1: Concept map for the textbook “Gemeinsam Biologie 1” [15] before analysis (top) and after the removal of concepts that were not found in the respective textbook. Concepts mentioned only implicitly are formatted semi-transparent.