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Let's Ask the Other Side: Teaching Gymnasium Plant Biology from a Teacher's Perspective

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Abstract: It has been repeatedly found that plant biology is less attractive for students than other biology fields. We, therefore, focused on the opposite and, through an online questionnaire, we asked biology teachers at gymnasia throughout Slovakia how they teach plant biology and where they experience problems. Almost 30% of teachers characterized technical equipment as insufficient but use some visual aids for ca. 50% of lessons. Despite the dominant use of microscopy, teachers admit that students' biggest shortcomings are found in the anatomy of organs, photosynthesis, ontogenesis and its regulation by exogenous/endogenous factors, or when connecting knowledge about tissues with their functions. About half of the teachers rate their knowledge of plant anatomy and physiology as sufficient, but these teachers rate only about 20% of their students in the same way. Based on the negative correlation between the use of aids and the lack of student knowledge, and, at the same time, the positive correlation between the activity of teachers and better technical equipment, we conclude that the mainly neglected technical infrastructure does not allow for a better practical education (e.g., only 13.7% of gymnasia have analytical balances and only 1.6% a spectrophotometer). Furthermore, almost 90% of teachers mentioned that online education during COVID-19 pandemic negatively affected students' knowledge. We hope that our research can contribute to changes in the Slovak educational curriculum focused on plant biology in a more scientific direction and inspire research in other countries, with the aim of exchanging knowledge regarding the species diversity of plants around the world and their importance for people and the environment.

Keywords: learning; plant tissue; science education; scientific literacy

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1. Introduction

Current education faces higher demands regarding the content and scope of knowledge; this also represents a challenge regarding the support of the technical infrastructure. Motivating and meaningful teaching therefore requires that the teacher has enough aids and equipment. However, deficient school equipment has been identified in several studies worldwide [1–4].

It has been repeatedly found that plant biology is less attractive than other biology fields for pupils and students in various countries including Slovakia, although the Slovak gymnasium plant biology curriculum represents up to ca. 1/3 of the biology content [5–7]. For this reason, not only adequate technics but also motivated teachers with sufficient and complex knowledge, as well as informal learning [8,9], could improve students' attitudes and knowledge, and thus the "popularity" of plant biology [10,11].

Several studies identified gaps in students' knowledge of botany [12–14] while the gaps in the knowledge of teachers have rarely been reported [13,15]. It is, therefore, important to make botany lessons interesting using visual aids, which can also have a positive impact on knowledge [16,17]. The lower quality of today's education (or at least its perception by the general public) is not only related to botany. For example, only 25% of Americans think that today's education is better than what they had [18].

Specifically, the COVID-19 pandemic required all teachers to change their teaching patterns. There were no choices: online teaching was the only approach [19]. Research into the online teaching was already ongoing before the pandemic [20], but much more attention has been paid to such research during or after the pandemic, with the generally negative opinion of teachers [19,21] probably due to the eventual technical problems and lower interest of students, leading to weaker knowledge. On the other hand, at-home laboratories for plant biology may be established as a part of online education [22].

In Slovakia, in contrast to elementary school students and various other subjects, no attention has been paid to high schools/gymnasia students in relation to plant biology. We specifically use the term "gymnasium/gymnasia students" because it is a part of high school education (ISCED 3), but gymnasium students have a general focus on various subjects that prepare them for university studies (unlike high schools, which are specifically focused on economics, agriculture, technics, etc.). Unlike many studies focusing on identifying student knowledge gaps through direct testing, our research represents a pioneering survey of gymnasium teachers' views on their working conditions and students' knowledge. We greatly appreciate that teachers were willing to admit the eventual shortcomings in their own knowledge, because this provides the opportunity to create teaching aids and enables subsequent work on directly identifying problems with students.

2. Materials and Methods

2.1. The Online Questionnaire for Teachers

The online questionnaire was prepared using platform MS Forms and contained 44 questions focused on: (i) general information about teachers (age, district, Alma Mater or subjects they studied), (ii) sources for education and teaching aids/equipment (national/foreign textbooks, web sources, use of microscopy, models, physiological experiments), (iii) areas of plant anatomy and physiology where the teachers use individual aids, (iv) self/critical assessment of teachers' and students' deficiencies (individual topics of plant anatomy and physiology where teachers feel their own deficiencies and knowledge gaps of students), and (v) the impact of COVID-19 on education and knowledge. Questions are mentioned in the heads of figures/tables, or see the full questionnaire in the Supplementary Materials.

The questionnaire was sent via e-mail to directors of all gymnasia registered by the Ministry of Education of the Slovak Republic, together with a description of the aim. The questionnaire was online available during August–October 2021 and was filled in by 124 respondents from 100 gymnasia, representing ca. half of all gymnasia in Slovakia (233).

Based on official statistics, about 4500 teachers provide general education subjects (including biology) in Slovak gymnasia, which represents ca. 19 teachers per gymnasium (4500/233). Based on our questionnaire (considering the number of teachers given by one respondent for each gymnasium), we estimate that the number of biology teachers at all gymnasia in Slovakia is about 700 (and ca. 3 biology teachers per gymnasium), which, with the 124 respondents of our questionnaire, represents a response rate of approx. 18%. The average time to complete the questionnaire was 37 min 49 s. Cronbach's alpha for two scaling questions (no. 43 and 44) was 0.59 and 0.67, respectively.

2.2. Statistical Analyses

For easier interpretation, results were calculated as a percentage from all respondents (n = 124 = 100%). To determine the correlation between teaching aids, equipment and activities of teachers versus knowledge of students, respective questions were counted as the number of activities/aids/equipment mentioned by individual respondents from the options offered in the relevant question of the questionnaire. Thereafter, correlations were analyzed between parameters and are provided in the form of a heat map. Graphs, heat map and Spearman's correlation analyses (at 0.05 level) were performed using software GraphPad 9.4.1.

3. Results and Discussion

3.1. The Profile of Respondents

Based on the official statistics, there is 233 gymnasia in the Slovakia, with the majority of them (144) being founded by the state [23]. Also, more than half of gymnasia realize both school programs (i.e., 4-year or 8-year study within ages 15–19 or 11–18, respectively). Slovakia is formally divided into eight regions and previous quantitative facts, along with the relatively similar distribution of respondents within regions, was obtained in our questionnaire (Figure S1A–C). It was a positive finding that 124 respondents from 100 gymnasia filled in the questionnaire, allowing for objective results to be obtained throughout the country. Our findings indicate that most gymnasia have 2–4 biology teachers (average of 3), 79% of whom are women within the age range 41–50 years with active teaching experiences of 16–25 years, who mainly studied biology with chemistry at any faculty of natural sciences at Slovak universities (Figure S2A–F). The faculty of education as an Alma Mater of biology teachers was mentioned by only 19.7% of respondents (Figure S2E,F); therefore, the data processing did not differentiate faculty type.

3.2. Attractiveness of Plant Biology, Education Approach and Technical Equipment

None of the respondents feel that botany is attractive, but rather consider human biology or genetics as attractive for students (Figure S3). In agreement with our results, Elster [5] observed that 14–17-year-old students in Germany were most interested in human biology (67.5% of maximum score) and the least interested in botany (52.5% of maximum score) and Uitto [6] observed that 16-year-old students in Finland were more interested in human biology + health (76.3% of maximum score) and cell biology + gene technology (72% of maximum score) than in living organisms (55% of maximum score). Marbach-Ad [24] reported that university students of biology stated that general interest in biology (94% of maximum score) and in humans (84% of maximum score) was a more significant factor than interest in plants (42% of maximum score). Botanical illiteracy results from several interacting factors, including infrequent exposure to plant science before students reach college [10], and specific courses may increase appreciation for plants by students [11]. We feel that it is a challenge for teachers and ministry of education to set up the curriculum in a way that builds students' relationships with plants and science and to monitor the results of education: in the Slovak Republic, there is a lack of independent verification of the education results of gymnasia students (ISCED 3, secondary education) or university students (ISCED 6 and ISCED 7, tertiary education) studying teaching (meaning they will be teachers in the future). In this context, we may mention, e.g., independent verification by PISA tests, where 15-year-old Slovak students lag behind the OECD average in science literacy (e.g., Polish and Czech students had higher scores, by 6.6% and 9.2%, [25]). To our knowledge, no information is available in Slovakia about the problematic areas of plant biology for teachers and their students, so we focused on the self-critical assessment of teachers' own shortcomings, and we greatly appreciate that a representative percentage of gymnasia teachers admitted shortcomings that can be worked on (see Section 3.4).

In the era of widespread Internet access, teachers have many options when obtaining information to prepare for teaching, as was also confirmed on the American continent, where 51% of 2462 high school and university teachers use the Internet [26]. Less than 10% of our respondents only use state gymnasium textbooks, although both available state textbooks are used by 42% of respondents. It is, therefore, positive that most teachers also work with other resources, e.g., Slovak/Czech university textbooks (49%) and even English textbooks (33%, Figure S4A), to prepare for teaching. However, most teachers rely on materials created by other teachers (e.g., web page zborovna.sk), which corresponds with teachers' statement that "the quality of state textbooks is excellent" (strongly/agree only 42% of respondents). At the same time, the majority of teachers "would welcome new practical materials and worksheets" (strongly/agree 96% of respondents). Since other sources provided by the state, e.g., materials of Methodological and Pedagogical Centre or portal viki.iedu.sk (digital repository of the Ministry of Education), are much

less used (Figure S4A), it is a challenge for experts in individual areas of plant biology to get involved in the creation of modern gymnasium textbooks (the state textbooks are from 1999 and 2012).

Figure 1

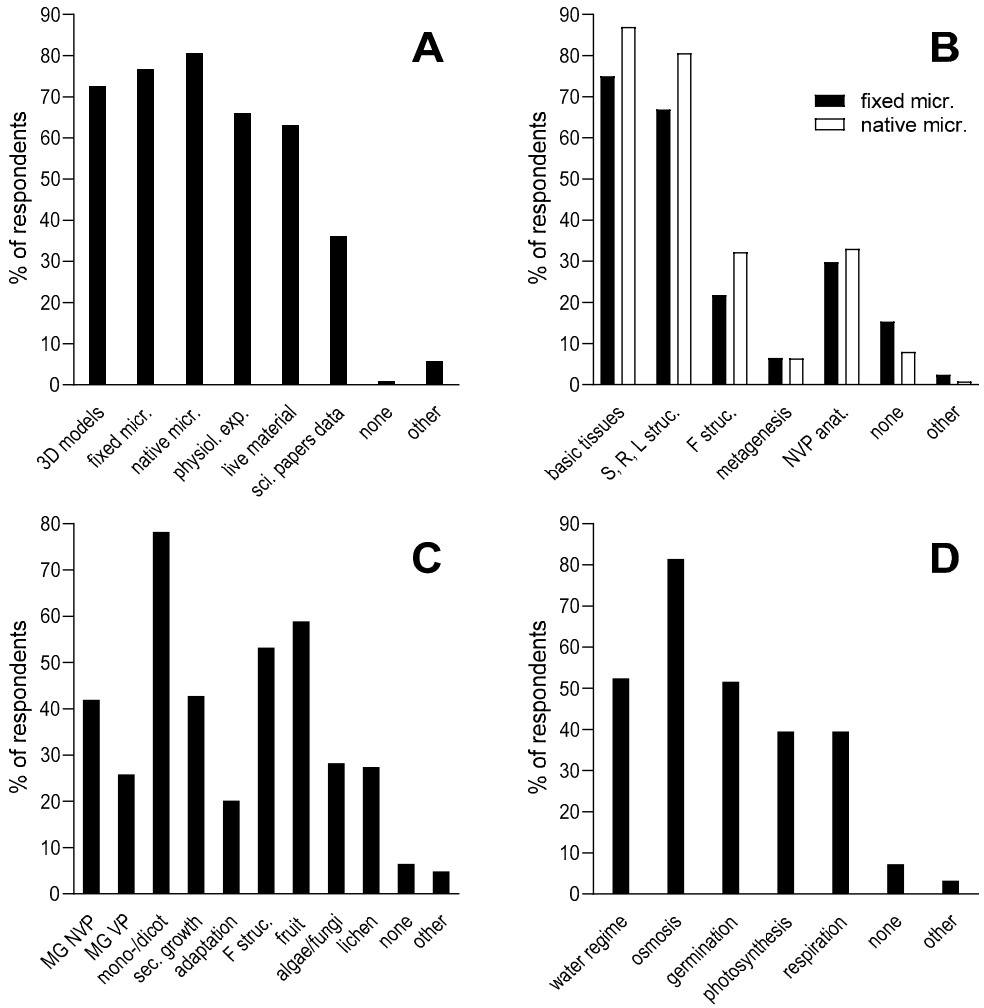

Figure 1. Answers to questions (**A**) "*What types of teaching aids do you use in plant biology education?*" (3D models = plastic/acrylic models, fixed micr. = fixed microscopy, native micr. = native microscopy, physiol. exp. = physiology experiments, live material = macroscopic observation of live material, sci. papers data = data from scientific papers), (**B**) "*What topic do you use native/fixed microscopy for?*" (S, R, L struc. = stem, root and leaf structure, F struc. = flower structure, NVP anat. = anatomy of non-vascular plants), (**C**) "*What topic do you use live plant material for?*" (MG NVP-VP = metagenesis of non-vascular plants/vascular plants, mono-/dicot = monocot/dicot structure, sec. growth = secondary growth, adaptation = ecological adaptations of plants, F. struc. = flower structure, fruit = fruit structure, algae/fungi = algae/fungi thallus structure, lichen = lichen thallus structure), (**D**) "*What topic do you use physiological experiments for?*". Data are a percentage of the total number of respondents (124 teachers). The sum of percentage is higher than 100, as the respondents could choose several answers.

It was, therefore, not surprising to find that teachers who utilize more resources are more active in teaching overall (as a sum of values derived from types of visual aids/Figure 1A, fixed microscopy/Figure 1B, native microscopy/Figure 1B, macroscopic observation/Figure 1C, physiological experiments/Figure 1D and number of taxa/Figure S6), which was confirmed by the significantly positive correlation (Figure 4, derived from data in Figure S4A and Figure 1A–D + Figure S6). Subsequently, a positive correlation was also found between the number of resources used by teachers and the students' lack of

knowledge of plant anatomy (see Figure 4, derived from Figures S4A and S8A,B), and also when connecting knowledge (Figure 4, derived from Figures S4A and S8E,F). This reflects the simple assumption that a more active teacher with more knowledge will identify more of the students' shortcomings. Therefore, in the subsequent work, we will focus on identifying the knowledge gaps in gymnasia students from plant biology as, to the best of our knowledge, no official data are available.

Teaching aids have several functions, but motivation, attention and better understanding are their main advantages [27]. It was, therefore, a positive finding that teachers (93.55%) provide an education using a combination of verbal interpretation + images/ppt presentations + visual aids (Figure S4B). However, poor technical equipment is one of the reasons why teachers do not implement practical exercises more commonly [28]. In agreement with this, a significant portion of teachers (29%) feel that the technical equipment is insufficient based on a simple question with the option to respond with yes or no (in addition to the detailed description of equipment availability in Table 1). A quarter of schools have inadequate microscopes, which may be one of reasons for students' lower ability to identify plant tissues. Similar deficiencies were found in Croatia, with 30% of microscopes found to be inadequate [4].

Table 1. The list contains an overview of various aids for theoretical and practical teaching. The respondents could choose any number of options; therefore, the sum is higher than 100%.

Selected Tools	% of Respondents
Basic equipment	
PC + data projector	98.39
inadequate microscope	25.81
quality microscope	70.16
microscope connected to PC	43.55
Chemicals and small consumables	
magnifying glass	80.65
histology stains	33.06
acrylic models	74.19
permanent/fixed microscope slides	74.19
inorganic chemicals	49.19
organic chemicals	43.55
laboratory glassware	89.52
laboratory plastic materials	45.97
tweezers	87.90
More expensive tools	
analytical balances	13.71
automatic pipettes	6.45
centrifuge	0.00
spectrophotometer	1.61
chromatograph	1.61
cultivation device	0.81

The more expensive equipment needed for precise science education (such as spectrophotometer) are almost unavailable (Table 1), and only 13.71% of respondents have analytical balances, which is a minimum tool for the exact preparation of various solutions. In general, deficiencies in equipment also impacted the quality of teaching: respondents with more equipment (Table 1) are more active in teaching, they use more types of teaching aids (Figure 1A), native and fixed microscopy (Figure 1B), observations of live material (Figure 1C) and physiological experiments (Figure 1D), as confirmed by the positive correlation (see Figure 4, derived from Table 1 and Figure 1A,D).

However, the problem of underfunded education is not limited to Slovakia but was found in other studies, e.g., Lyimi et al. [3] found that Taiwanese teachers agreed with the statements "There is lack of laboratories" or "There are ineffective science laboratories" while Chavan [2] found that Indian teachers do not have sufficient tools to teach some

topics practically. A recent comparison shows that Slovakia invests in higher secondary education (general programs), comprising only 0.6% of the total public expenditure, while the EU22 average is 0.9% and the OECD average is 1.2%. The same is also visible in tertiary (university) education [29], which represents a long-term challenge for every government.

3.3. Illustrative and Practical Activities Used in Teaching

Owing to the common availability of inexpensive microscopes, they are widely used in education [4]. In Slovakia, teachers most often use a native microscopy (Figure 1A), but only 41.13% of teachers use five or six types of visual aid (e.g., native microscopy, fixed microscopy, 3D models) in teaching (derived from data in Figure 1A). Fixed and native microscopy is mainly used by teachers to demonstrate plant tissues and stem, root or leaf structure, but less frequently used for fertile organs and metagenesis (Figure 1B). However, only 33–40% of teachers used fixed/native microscopy for three or more lessons (derived from data in Figure 1B). We consider the use of microscopy only in a few lessons to be insufficient, since the school textbooks contain only drawings of plant organ anatomy, and students may struggle to identify the tissues on a real slide. In line with this, almost 50% of teachers feel that students have difficulty identifying plant organ tissues on a real microscope slide, but do not find it difficult to identify tissues in drawings. Only 35.48% of teachers use macroscopic observation in teaching for five or more topics, e.g., for mono-dicot differences, and fruit or flower structure (derived from data in Figure 1C). Additionally, a relatively low percentage of teachers (only 27.42%) used physiological experiments for 4–5 topics (derived from data in Figure 1D). All correlations between the rate at which these teaching aids are used in given activity are significantly positive (derived from data in Figure 1B–D), e.g., teachers who use more native microscopy are also more active overall in the use of other teaching aids (Figure 4). Further detailed investigations could determine whether the quality of education is actually lower than in the past, but, for example, a public survey in the USA reported that only 25% of Americans think that today's education is better than the education they received [18].

A report from primary schools in Croatia found that most biology teachers use teaching aids in class at least once a month, while the fewest teachers use teaching aids only once a semester [30], which is in line with our results (Figure S5A). The importance of teaching aids in biology education is well-known, e.g., Shabiralyani et al. [17] found that 70% of teachers and students agreed with the statement: "visual aids improve motivation in teaching" and 75% of students and teachers agreed with statement: "visual aids help in explaining lessons". Effiong and Igiri [16] found that 67% of students and teachers agreed with the statement "Instructional materials make learning lessons interesting", and 62% of students and teachers agreed with the statement: "instructional materials promote retention". These data are consistent with the responses we found (Table S1). The most frequent reason for not teaching with visual aids is a lack of time. This is a relevant reason, and teachers often complain about the amount of subject matter that need to be covered, e.g., "I try to apply practical teaching in at least 50% of my lessons. Unfortunately, the amount of subject matter does not allow me to do this" (anonymous personal communication).

When teaching biology, it is also essential to provide students with opportunities for direct contact with live material in the classroom [31,32]. Many educational trails are being built in Slovakia, focusing more on animals, but we have no information about more indepth nationwide pedagogical activities in the context of botanical education. The most used plants in teaching botany are those that are easily available (dicot/monocot herbs or gymnosperms). However, non-native plants (e.g., palms) or algae are used less (Supplementary Figure S6). Teachers who use more plant taxa in teaching use more native and fixed microscopy, macroscopic observations of living plant material and physiological experiments, as confirmed by the significantly positive correlation (Figure 4, derived from data in Supplementary Figure S6 and Figure 1B–D).

3.4. Self-Critical Evaluation of Teachers' and Students' Shortcomings

Almost half of the teachers perceive their own deficiencies at least in one area of plant anatomy or physiology, beyond the scope of the gymnasium curriculum (Figures 2A and S7A). Biology teachers most often experience a lack of practical skills and knowledge in plant anatomy in topics related to secondary meristems, the secondary growth of root and stem, and types of vascular bundles (Figure S7A). This is a new finding, as most research was focused on deficiencies in areas related to plant reproduction [13,14]. In plant physiology, teachers felt gaps in topics related to factors affecting plant ontogenesis/growth, plant movement, respiration and photosynthesis (Figure S7B). Gaps in topics related to plant movement, respiration and photosynthesis were also observed in several previous studies [13,15], while gaps related to factors affecting plant ontogenesis/growth are new. We found that 36.29% of teachers perceived deficiencies in three or more areas of plant anatomy and/or physiology. Only teachers who feel more deficient in their knowledge use less fixed and native microscopy, as well as macroscopic observations of live plant material, as confirmed by the significantly negative correlations (Figure 4, derived from Figure S7A,B and Figure 1B,C). We assume that teachers with weaker knowledge are not motivated to create/use practical activities on given topics compared to colleagues who feel comfortable in the given field.

Figure 2

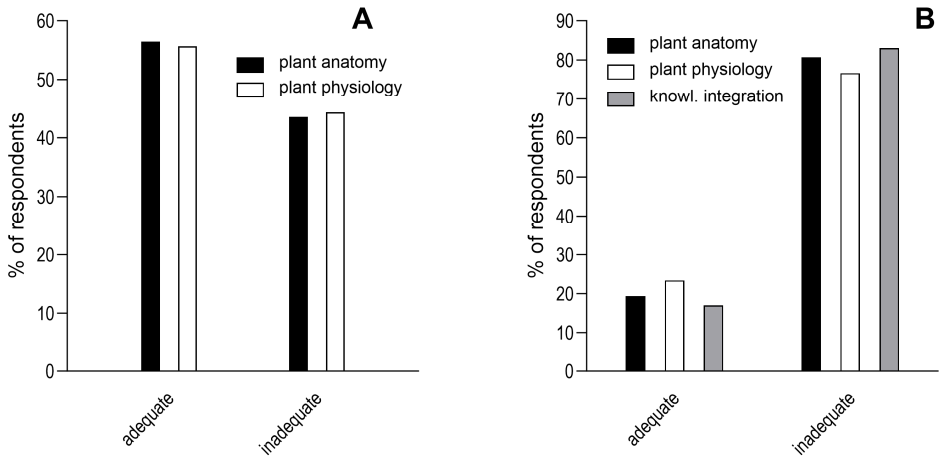

Figure 2. Self-assessment of the shortcomings of teachers (**A**) and their students (**B**) in the anatomy and physiology of plants (+linking knowledge of these areas by students). Column adequate means that teachers consider their own or students' knowledge in the offered areas to be sufficient, while the inadequate column means insufficient knowledge in at least one of the offered options. A detailed analysis of areas that are problematic for teachers or students are presented in Supplementary Figures S7 and S8. Data represent the percentage of the total number of respondents (124 teachers).

Most teachers identified gaps in students' knowledge in at least one area of plant anatomy, physiology or knowledge integration (=column "inadequate", Figure 2B). Unfortunately, teachers report that 64.52% of their students are deficient in five or more areas (derived from data in Figure S8A–F). Within anatomy, detailed analyses revealed that teachers identified students' deficiencies, especially in locating the tissue in the stem or root and in the identification of basic tissue (Figure S8A,B). These deficiencies may be due to the underuse of microscopes (Figure 1B) or working with inadequate microscopes (Table 1), but also to shortcomings in teachers' knowledge of plant anatomy (teachers' anatomy deficiencies, Figure S7A, vs. students' anatomy deficiencies, Figure S8A,B, $r = 0.401$). Widodo et al. [33] found that students with a better ability to use a microscope are better at the visual representation of plant tissues. Students, according to teachers' opinion, have fewer deficiencies in the area of plant reproduction (differences between sexual and asexual reproduction, or differences between pollination and fertilization; Figure S8A,B), although several studies have focused on these subjects [12–14].

Within plant physiology, teachers feel that students have the biggest problems with explaining the principle of the light and dark phases of photosynthesis, as well as describing the basic phases of plant ontogenesis and its regulation by exogenous and endogenous factors (Figure S8C,D). The deficiencies of high school students in photosynthesis and respiration were previously found [13], and the connection between photosynthesis and other metabolic processes (such as biosynthesis of amino acids) is also unclear for 80% of students [34]. However, students' problems with describing the basic stages of ontogenesis and its regulation by exogenous and endogenous factors have not been monitored in other studies. Though this sounds like a narrow topic, it includes many areas from plant hormones, through mineral nutrition to oxidative stress and climate changes. Therefore, "plant physiology" is not only a field of biology but also involves bio/chemistry, and a more complex shift in education is needed. However, unfortunately, such connections are not included in the Slovak curriculum. Although one can partially agree with the arguments of the Ministry of Education of the Slovak Republic that "memorization is not crucial" and rather focuses on the development of scientific literacy, we unequivocally claim that, without basic knowledge, it is not possible to "discover" or "deduce". Therefore, we warn against "simplification" and the constant "reforms" of education that appear in the Slovak Republic with the arrival of almost every minister of education.

During knowledge integration, according to teachers, students most often have difficulties identifying plant tissues on a microscope slide, although they can identify tissues on drawings (Figure S8E,F), which may be due to the low intensity of microscope use, as well as the actual quality of microscopes used in the classroom, the absence of photographs of real slides in Slovak gymnasium textbooks and their replacement by drawings. Also, students have difficulties explaining the importance of the secondary cell wall for the mechanical strength and evolution of plants, formulating a connection between vascular/mechanical tissues and identifying the gametophyte of plants, in addition to their evolutionary and morphological changes (Figure S8E).

Teachers who admit more gaps in their knowledge also admit more gaps in students' knowledge, which is confirmed by the significant correlations between teachers' (Figure S7A) and students' deficiencies in anatomy (Figure S8A,B, r = 0.401), physiology (Figure S7B vs. Figure S8C, r = 0.380) and overall teacher deficiencies vs. overall student deficiencies (r = 0.441, Figure 4, derived from data in Figures S7A,B and S8A–E). This suggests that the source of students' deficiencies may be the teachers themselves, which was also confirmed in the case of misconceptions regarding evolution [35]. Furthermore, 50% of teachers feel they have no gaps in their knowledge (adequate, Figure 2A), but only 20% of the teachers think that their students have no gaps (adequate, Figure 2B). These relationships are indirectly confirmed by the negative correlation between the number of aids used by teachers and students' deficiencies (Figure 4, derived from data in Figure 1A–D + Figures S6 and S8A–E), so teaching aids may considerably reduce gaps in students' knowledge.

Informal learning may improve the current situation (poor knowledge and low interest of students in botany), as confirmed previously [8]. The level of implementation of informal learning by Slovak teachers is relatively high (Figure S9). Thus, it seems that teachers "would do more", but technical limitations (i.e., insufficient technical equipment) affect the creativity and possibilities of teachers. Considering the fact that authentic research in the classroom increases appreciation for plants [11], it is a challenge for state organs in Slovakia to establish "science education" more practically, at least at gymnasia: "*we plan to create a network of regional centers to support teachers within the framework of the Recovery and Resilience Plan of the Slovak Republic, Component 7 Reform 1—Curricular and textbook reform: provide support for teachers in the regions in the implementation of the new basic education curriculum in the form of mentoring and counselling*" [36]. The corresponding author of this paper is a Slovak expert in plant anatomy/physiology (and a member of the editorial boards of four international journals focused mainly on plants) but has no information about the preparation of new textbooks/materials for secondary schools/gymnasia. We strongly

believe that subject matter experts should not be left out of the debate on the direction of education, with the argument that education is a matter for didactics experts. Without scientific knowledge, it is not possible to "simplify" difficult subjects, certainly not for gymnasia students preparing for university studies.

Figure 3

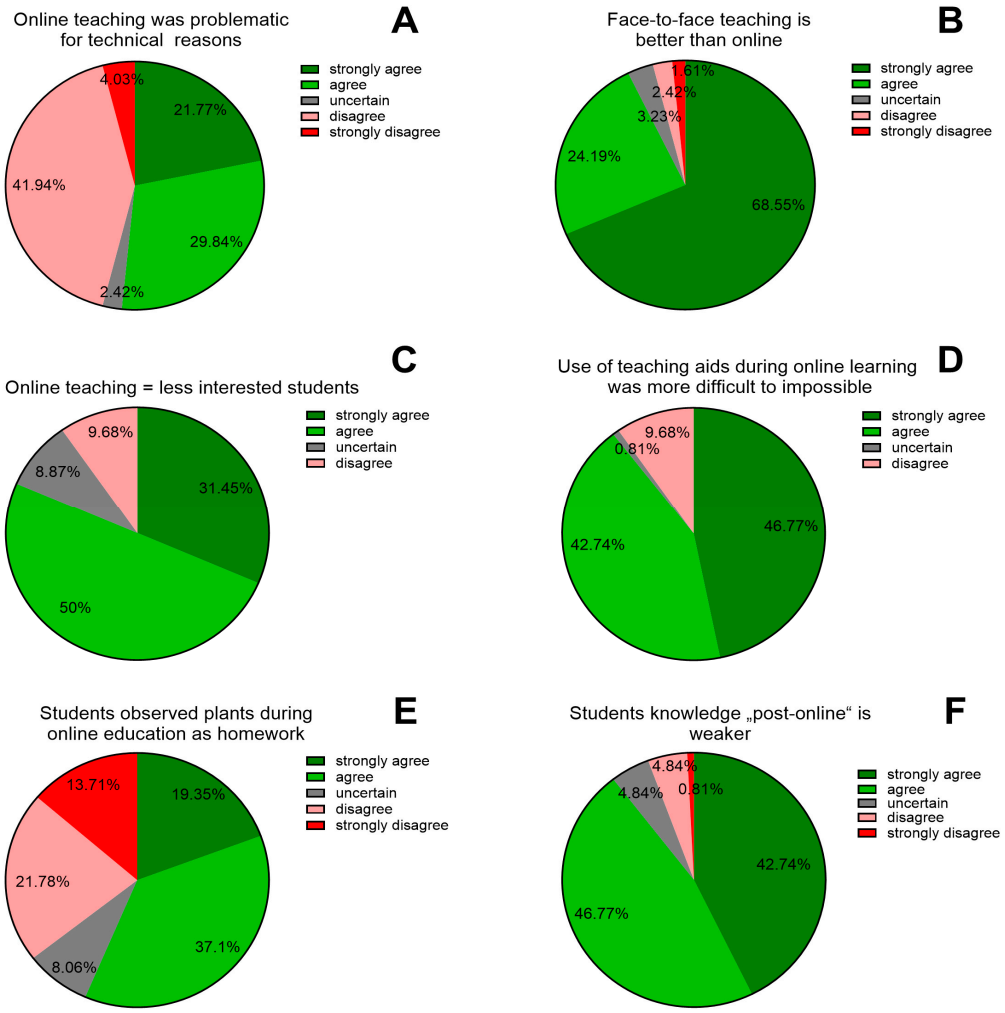

Figure 3. An answer to scaling questions about online learning during the COVID-19 pandemic. Individual questions are mentioned above the individual graphs. Data are the percentage of the total number of respondents (124 teachers).

3.5. The Impact of COVID-19 on Students' Learning and Knowledge

The questionnaire also included scaling questions examining teachers' views on the online teaching of plant biology during COVID-19 pandemic. The graphs (Figure 3) clearly show that the respondents had a negative view of teaching, except for two statements. The statement "Online teaching was problematic for technical reasons" (Figure 3A) showed various attitudes. In our opinion, some teachers (especially older) may experience problems with technology, while younger teachers may not, which would explain the different attitudes of the individual respondents. Technical problems during online teaching were also found in a survey by the Ministry of Education at schools in Slovakia [21]: 26.3% of teachers did not have fast enough Internet, and about 35% of teachers thought that students did not know how to use the technology in online education. Problems with technology could be one of the reasons why up to 92.74% of respondents think that face-to-face teaching is better than online teaching (Figure 3B). Fauzi and Khusuma [19] found that up to 80% of teachers felt dissatisfied with online education. There could be several

reasons for the negative opinion about online teaching: one of them is the lower interest of students (81.45% of teachers strongly agree/agree, Figure 3C). The negative impact of online teaching on students' interest in biology (31.5% of students) and science (37.5% of students) was also felt by the students themselves [37]. Another reason for the negative opinion on online teaching could be more difficulties using teaching aids (Figure 3D).

Figure 4

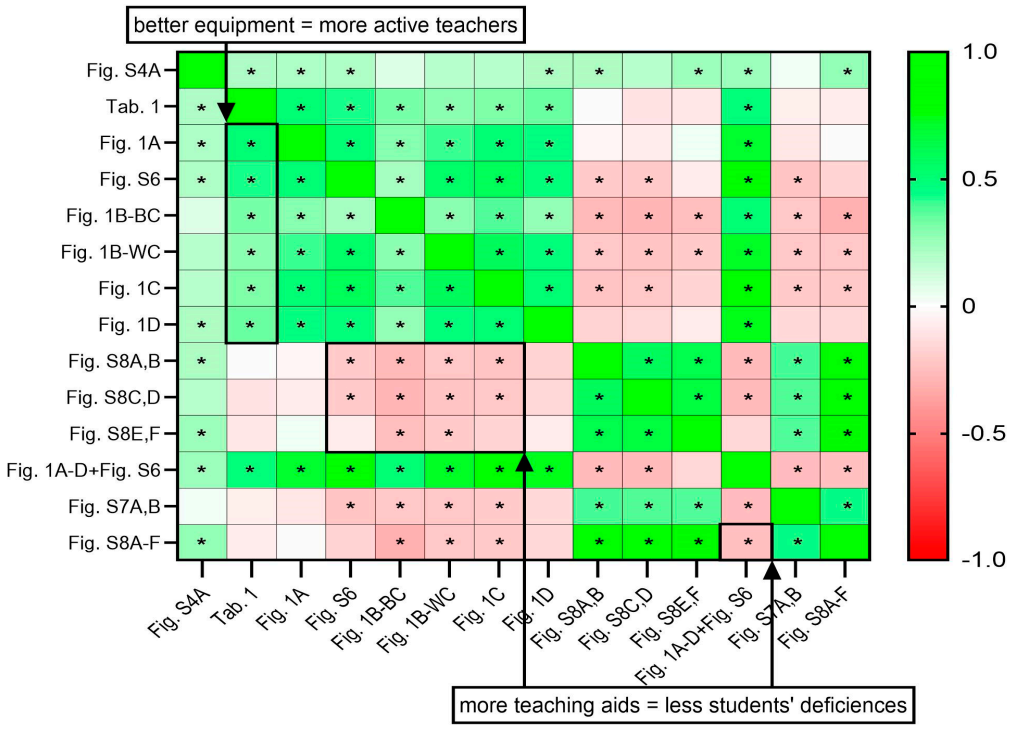

Figure 4. Heat map from Spearman's correlation analysis of the teachers' responses to questions in selected areas. To determine the correlation between teaching aids, equipment and activities of teachers versus knowledge of students, respective questions were counted as the number of activities/aids/equipment mentioned by individual respondents from the options offered in the individual questions. * The corresponding correlation in R is considered significant because the off-diagonal element of P was smaller than the significance level of 0.05. Green and red squares indicate significantly positive or negative values, respectively. BC and WC denote black and white collumns in the respective graph. Arrows indicate the main findings of our research in terms of equipment, activity and knowledge gaps.

The non-use/less frequent use of teaching aids could be the reason for lower interest of students, as up to 78.23% of teachers think that, if they use teaching aids, students are more interested (Table S1). The teachers' opinion on online teaching was also probably influenced by the non-use/less frequent use of aids, as up to 77.42% of teachers mentioned that "I explain the material better" with aids (Table S1).

The attitude of teachers was unclear regarding the statement: "Students observed plants during online education as homework" (Figure 3E), indicating that some teachers gave plant observation as homework to students, while others did not. Technical problems, reduced student interest, or the less frequent use of aids by teachers could be the reason for the reduction in knowledge after online teaching. A total of 89.51% of teachers strongly agreed that students had less knowledge after online teaching (Figure 3F). Low levels of retention during online teaching were found in several studies [20]. MESRS-SR [21] found that up to 80% of teachers think that students learn more effectively during face-to-face teaching compared to online teaching. Even the students themselves (69.1%) think that online teaching had a negative impact on their learning [37], and the implementation of so-called at-home laboratories [22] may be an efficient tool for the future.

4. Conclusions

Our research represents pioneering research of the opinions of gymnasia teachers regarding their working conditions and the knowledge of students, which enables further work on directly identifying problems with students. We note that, in Slovakia, in contrast to elementary school students, no attention has been paid to high school/gymnasia students in terms of botany/biology curriculum/textbooks, although these students are preparing for university studies and some of them will also study some field of biology. We greatly appreciate that teachers admitted any shortcomings in their own knowledge, because this provides the opportunity to create teaching aids that will motivate teachers and students. A clear negative correlation was found between the use of aids and the lack of student knowledge; at the same time, a clear positive correlation was found between teachers' activity and better technical equipment: it is, therefore, a necessary challenge for the Ministry of Education of the Slovak Republic to create decent working conditions for teachers, which will support the creativity of teachers and thereby increase students' interest in biology. We also call for the involvement of scientific experts from individual fields of (plant) biology to participate in the creation of textbooks, because the scientific literacy of Slovak students still lags behind the V4 countries and the OECD average.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci13111140/s1, Figure S1: Answers to questions regarding general information about the gymnasium at which the respondents of this questionnaire teach; Figure S2: Answers to questions regarding general information about the respondents; Figure S3: Answers to the question "*Which field of biology do you find most attractive for students?*"; Figure S4: Answers to questions (A) "*When preparing for teaching, you use:*" and (B) "*When teaching plant biology, you explain the subject with the use of:*"; Figure S5: Answers to questions (A) "*In how many plant biology lessons do you use visual aids?*" and (B) "*Do you use a microscope when teaching plant biology?*"; Figure S6: Answers to the question "*What groups of plants do you use in teaching plant biology?*"; Figure S7: Answers to questions (A) "*Do you feel a shortcoming (you as a teacher) in any of the following areas of plant anatomy beyond the gymnasium curriculum?*" and (B) "*Do you feel a shortcoming (you as a teacher) in any of the following areas of plant physiology beyond the gymnasium curriculum?*"; Figure S8: Answers to questions (A,B) "*Do you observe in teaching plant anatomy that students have difficulty with any of these topics?*", (C,D) "*Do you observe in teaching plant physiology that students have difficulty with any of these topics?*" and (E,F) "*Do you observe in your teaching that students have a problem with some of these topics when integrating their knowledge of anatomy and physiology?*"; Figure S9: Answers to the question "*What type of informal learning do you implement?*"; Table S1: Answers to the question "*What are your reasons for using/not using visual aids in education?*". Questionnaire for teachers is also shown in the Supplementary Materials (starting on page 13).

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Informed Consent Statement: The respondents were informed about the objectives in the introductory part of the online questionnaire and, by filling it out, they agreed to participate in the questionnaire.

Data Availability Statement: Data presented in this study are available upon reasonable request from the corresponding author (data from the questionnaire in an Excel file in the Slovak language).

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