HOW DO TEACHERS TEACH BOTANY AT GYMNASIA? A SURVEY IN SLOVAKIA

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Abstract

We investigated the experiences of high school biology teachers in teaching botany. A questionnaire was chosen as a research tool, which was filled out by a total of 124 gymnasium teachers from 4 regions (capital city Bratislava 19 teachers, west SK 40 teachers, central SK 31 teachers, east SK 34 teachers). Gymnasia teachers do not have adequate equipment at their disposal (e. g. only 42.1% of quality microscopes in Bratislava and 73.5 – 77.5% in other regions), but they are relatively active (e. g. 73.5 – 87.1% of teachers use native microscopy and 64.5 – 84.2% of teachers use 3D models in teaching). They also use various plant materials, but algae, mosses and ferns are used less frequently (mainly by teachers from Bratislava). Also, most teachers do not consider students' knowledge of plant biology to be adequate and have identified which areas of plant biology are problematic for students. In addition, even the teachers admit that their knowledge of plant anatomy and plant physiology is not adequate (29.4 – 57.5 % in individual regions). We also found positive correlations between the number of gaps in teachers' knowledge and the number of gaps in students' knowledge (r = 0.4892). The relationship between the number of tools available to teachers and their activity, i.e. the number of aids and equipment they use in teaching, was also found (r = 0.5063).

Keywords: *plant biology, education, science, teacher, teaching aids*

1. INTRODUCTION

Botany is less attractive to students compared to other areas of biology, which has been confirmed in several studies. Students in Germany aged 15-17 showed the greatest interest in human anatomy and the least in botany (Holstermann and Bogenholz 2007). For 16-year-old students from Finland, the area "living organisms", which includes plants and animals, is less attractive compared to human biology or genetics (Uitto 2013). Also, the number of university graduates who would have a degree in botany is several times lower compared to other fields of biology, for example zoology or genetics (Stroud et al. 2022). However, if we want to improve the teaching of botany, it is necessary to find out the opinions of teachers, because only they can provide a real picture of its teaching. However, such research was not carried out. Kletečki et al. (2023) investigated teachers' opinions on how to improve the teaching of plant botany, and according to teachers, it is necessary to "*connect teaching content more with everyday life*", "*conduct more field classes with workshops in nature*" or "*carry out more practical work in class*". However, the implementation of practical exercises is dependent on sufficient equipment, and few studies identified deficiencies in material equipment (Chavan 2016; Lyimi et al. 2017; Ruščić et al. 2018).

Several studies have been carried out that have identified deficiencies in the area of plant biology. Most research seeks to identify misconceptions and gaps in students' knowledge (Helldén 2000; Chattopadhyay 2005; Barman et al. 2006; Sánchez and Ortega 2022). Some research examines deficiencies in students studying to teach biology (Mak et al. 1999; Yürük et al. 2011). However, research examining gaps in teachers' knowledge except for Bebbingtion et al. (2005), according to our information, was not implemented.

2. METHODS

2.1. The online questionnaire for teachers

The online questionnaire was prepared on the MS Forms platform, and consisted of two parts: i) in the first part, we found out general information about the respondents (region where their gymnasium is located), ii) in the second part, we found out what teaching aids/devices are available at the gymnasium, the areas where teachers use specific aids and which areas of plant biology are problematic for them and their students. Gymnasium is a type of upper secondary education that prepares students for subsequent university education.

2.2. Statistical analyses

Within Slovakia (SK), we have established four areas (capital city Bratislava, western SK, central SK and eastern SK). For easier interpretation, the results were calculated as a percentage of all respondents in a given area of Slovakia and processed into a graphic form using GrahpPad 9.5.1 software. To find out the relationship between the number of visual aids, teachers' activity and deficiencies in the knowledge of teachers/students, the relevant 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. For better clarity and clear conclusions, we created areas whose values were obtained by summing up the values of specific questions: teachers' activity (questions investigating what types of visual aids teachers use, what taxa, for which topics they use native, fixed microscopy, macroscopic observation and physiological experiments), deficiencies in teachers' knowledge (questions identifying areas of plant anatomy/physiology in which teachers feel deficiencies) and deficiencies in students' knowledge (questions identifying areas of plant anatomy/physiology and linking information between these areas, which according to teachers are problematic for students. Correlations between parameters were then analysed using Spearman's correlation analysis (at the 0.05 level), and graphs were generated from these analyses using GraphPad 9.5.1 software.

3. RESULTS AND DISCUSSION

In biology teaching, in the classroom or in the laboratory, creating a multi-faceted environment for effective teaching is important in terms of teacher-student interaction and communication. The basic elements for creating a multifaceted environment are the equipment used in education to support and enrich teaching and to facilitate and make learning more efficient (Sayan and Mertoglu 2020). For this reason, we investigated the availability of aids and equipment in four regions of Slovakia (Fig. 1). Biology as a natural science, which is taught in primary and secondary schools, includes many terms not visible to the naked eye. To understand important structures and terms not visible to the naked eye, a microscope is essential (Ruščić et al. 2018). Therefore, it is disturbing that 17.6% to 36.8% of gymnasium teachers have an inadequate microscope. Similar level of inadequate microscopes was found by Ruščić et al. (2018) in primary and secondary schools in Croatia. However, apart from microscopes, other aids and equipment are also unavailable in Slovak gymnasiums. Organic chemicals are available to only 31.6% (Bratislava) – 58.1% (central SK) and inorganic chemicals to only 37.5% (west SK) – 61.3% (central SK) of gymnasium teachers. Without organic and inorganic chemicals, teachers cannot implement practical exercises. The unavailability of laboratory materials or reagents is one of the reasons for not implementing practical exercises (Dan-Ologe and Shittu 2012).

The importance of visual aids in teaching is best described by a sentence: "*People generally remember 10% of what they read, 20% of what they hear, 30% of what they see, and 50% of what they see and hear*." (Treicher 1967). Even the students themselves are aware of the importance of aids. Effiong and Igiri (2015) found that 67% of biology students agree with the statement: "*Instructional materials make learning lesson interesting*" and 62% of biology students agree with the statement: "*Instructional materials promote retention*". Shabiralani et al. (2015) also found that 70% of teachers and students think that teaching aids increase motivation and 75% of teachers and students think that teaching aids help clarify the subject matter. The level of use of individual teaching aids by gymnasium teachers is presented in Fig. 2A. It is pleasing that teachers use the individual types of aids at a relatively high rate

despite the lack of equipment and aids available to them. Gymnasium teachers mostly use fixed/native microscopy in teaching (72.5 – 80.6% / 73.5 – 87.1%), indicating that despite poor equipment, most teachers do their best to implement practical teaching. Teachers use data from scientific papers the least during teaching, which is probably caused by the language barrier and poorer access to individual journal articles, but this is changing nowadays due to the increasing number of open access journals.

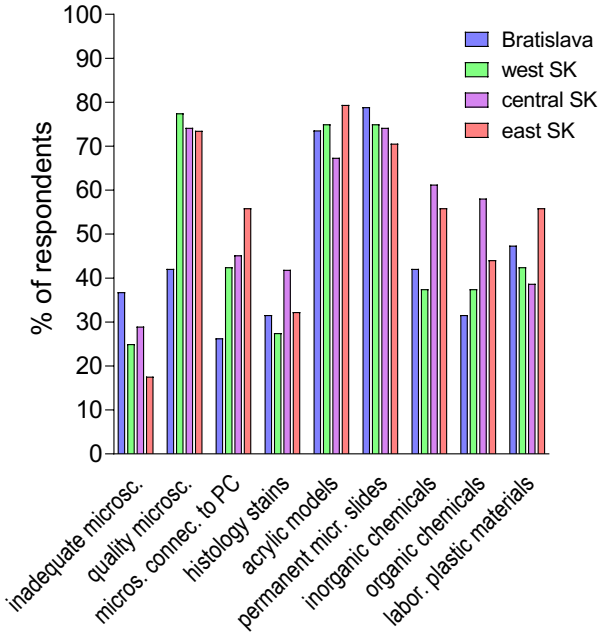

Figure 1. Teaching aids available to gymnasium teachers (inadequate microsc. = inadequate microscope, quality microsc. = quality microscope, micros. connect. to PC = microscope connected to PC, labor. plastic materials = laboratory plastic materials). Data are in percentage of the total number of respondents in every region. The sum of percentage is higher than 100, as the respondents could choose several answers.

Since botany is the science of plants, it is necessary and desirable that students come into direct contact with plants. Strgar (2007) found that students who worked and researched plants during the teacher's lecture (e.g., underground growth stages of *Arachis hypogaea*, how *Mimosa pudica* leaves close, or sticky exudate on *Drosera aliciae* leaves) showed more interest in some of these plants after the lesson. The use of living organisms in teaching develops students' awareness and interest and, consequently, students' appreciation of living organisms (Tomažič 2011). However, the use of some living organisms in teaching can cause students to feel fear and disgust (Polák et al. 2020), which is mainly associated with animals, but plants do not normally cause such emotions. This is also one of the reasons why plants (2.91 of maximum score 5) are used more often in teaching compared to animals (2.33 of maximum score 5) or microorganisms (2.06 of maximum score 5) as reported by Krell and Schmidt (2020). Slovak gymnasium teachers also use individual plant taxa to a high extent in their teaching (Fig 2B). They most often use gymnosperms, monocotyledonous herbs, dicotyledonous herbs and woody plants. On the contrary, teachers use less palms (monocotyledonous woody plants) i.e. plants that do not occur in the wild in our country. Also, teachers use less often algae and ferns in their lessons.

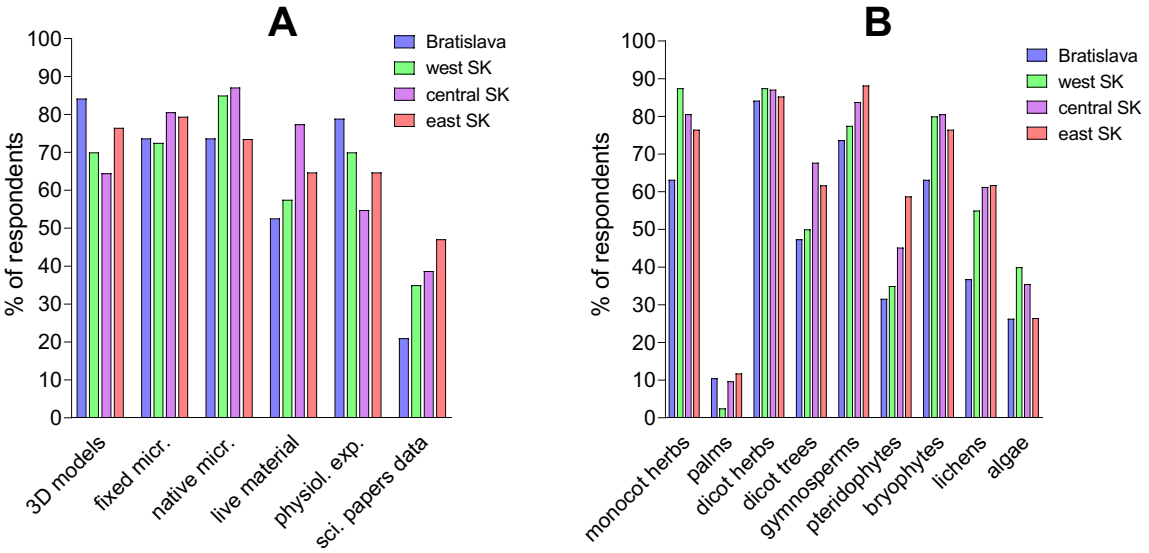

Figure 2. Answers to questions (A) "*What types of teaching aids do you use in plant biology education?*" (3D models = plastic/acrylic models, fixed micr. = fixed microscopy, native micr. = native microscopy, physiol. exp. = physiology experiments, live material = macroscopic observation of live material, sci. papers data = data from scientific papers), (B) "*Which plant taxa do you use in teaching plant biology*?" Data are in percentage of the total number of respondents in every region. The sum of percentage is higher than 100, as the respondents could choose several answers.

Since teaching aids in teaching are important, we ask teachers what teaching aids they use in certain lessons (Fig. 3A-D). It is worrying that fixed and native microscopy is not used in the teaching of flower structure and anatomy of non-vascular plants (Fig. 3A-B). At the same time, the structure of flowers and the processes related to this structure are unclear to pupils/students. Helldén (2000) found that pupils aged 10-15 do not realize the importance of flowers in the reproduction of plants. Also, Topsakal and Oversby (2012) found, that 31 of the 65 elementary science and technology teacher students and all the elementary teacher students (n = 51) mentioned that all flowers consist of the same flowering parts. Most of those students also mentioned that the parts of a flower are the same, but the size, shape and colour can differ according to the species, the climate, and the area in which they live. Chattopadhyay (2005) found that almost 15% of students (16-18 years old) thought that plants reproduce only asexually. Therefore, it is surprising that only 6% of teachers in our research think that it is a problematic task for students to define the differences between sexual and asexual reproduction. In this context, the theatre performance about plant reproduction had a positive effect on the student's knowledge of reproduction, even six weeks after the performance (Stagg and Verde 2018). Such activities can have a positive effect especially on younger grades, on the contrary, high school students are expected to have a certain professional level and such activities are not suitable for them. The level of use of macroscopic observation by Slovak teachers is shown in Fig. 3C. To a lesser extent, teachers use macroscopic observation of live material when teaching the structure of the algae/fungi thallus and the structure of lichens thallus. At the same time, up to 50% of students aged 11-14 think that fungi are plants (Barman et al. 2006). The level of use of physiology experiments is shown in Fig. 3D. Teachers use physiological experiments less often when teaching photosynthesis and respiration. This is surprising because the activities on these topics are carried out in various research. Hofeld (2021) proposed practical exercises in which students observed the production of air in small leaf cuttings from a leaf as evidence of photosynthesis, the production of carbon dioxide by living organisms (yeast) in the process of cellular respiration, and the change in pH via an indicator in an aquatic plant (a plant in the dark with only respiration) as evidence of respiration in plants. Mitra et al. (2020) proposed practical exercises with the green alga *Chlamydomonas reinhardtii*, while the activity is focused on changing colours (through a pH indicator) over time when the algae are exposed to darkness or light.

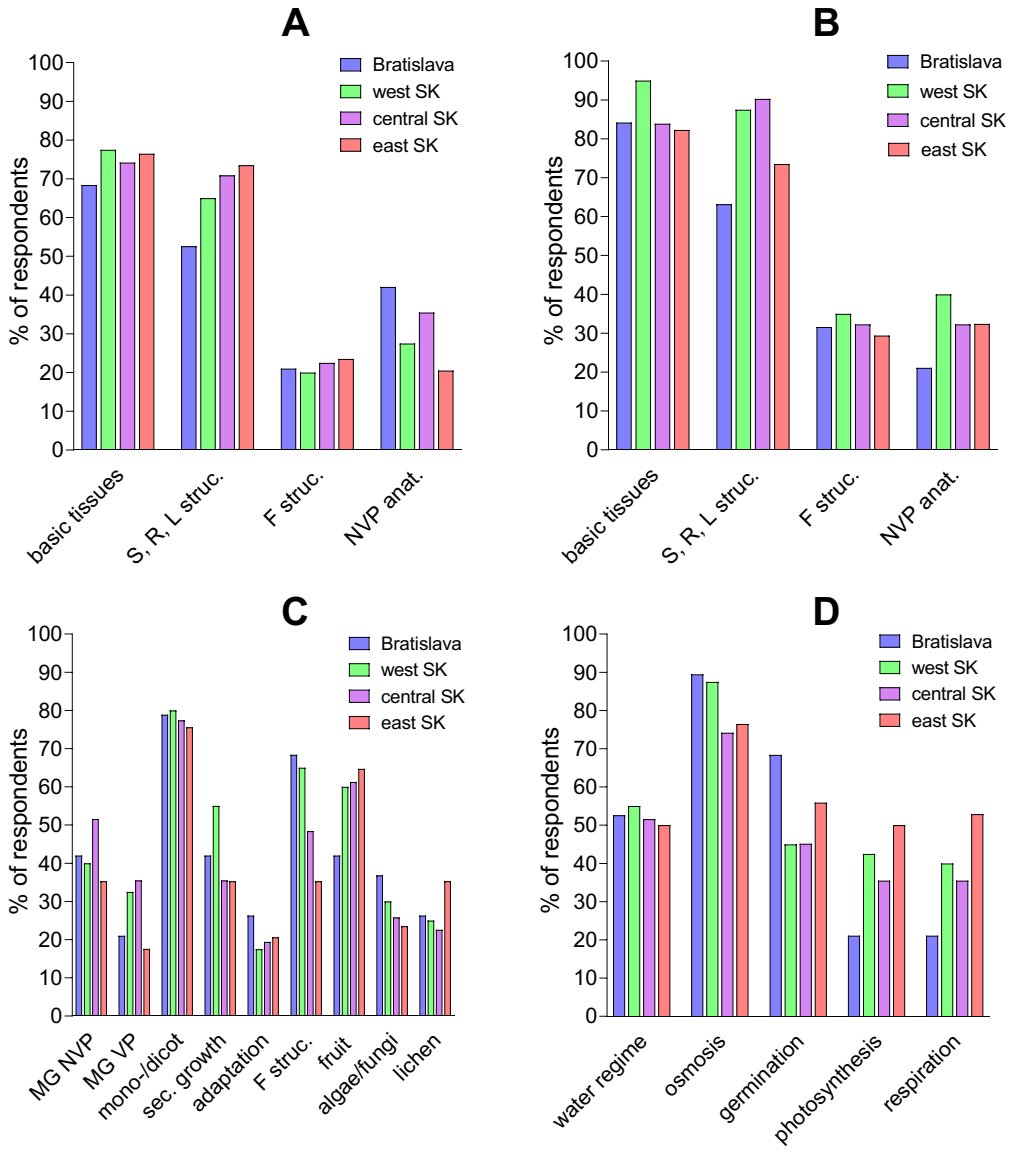

Figure 3. (A) "*What topic do you use fixed microscopy for?*" (S, R, L struc. = stem, root and leaf structure, F struc. = flower structure, NVP anat. = anatomy of non-vascular plants), (B) "*What topic do you use native microscopy for?*" (S, R, L struc. = stem, root and leaf structure, F struc. = flower 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 in percentage of the total number of respondents in every region. The sum of percentage is higher than 100, as the respondents could choose several answers.

Johnston et al. (2013) propose an experiment using the column chromatography method in which students will gain practical experience with the processing of plant material (spinach) for the isolation and identification of pigments (*β*-carotene, xanthophylls and chlorophyll *a*) using hexane and acetone solvents. As we mentioned above, insufficient equipment is the reason for the less frequent implementation of practical exercises, therefore we investigated the correlation between the number of aids and equipment that teachers have at their disposal and the number of activities they implement in

teaching (derived from Fig. 2A-B and Fig. 3A-D). A positive significant correlation indicates that teachers who have more aids and equipment at their disposal are more active in teaching (Fig. 6A).

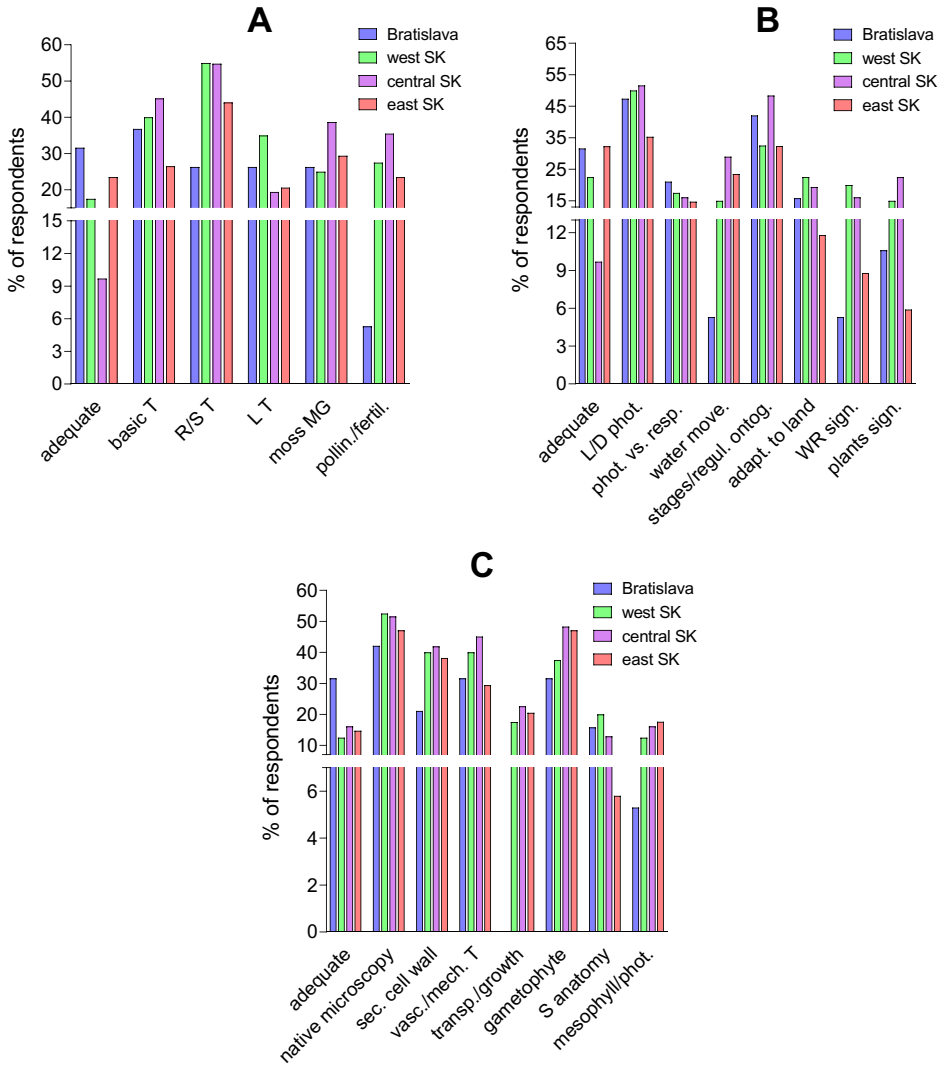

Figure 4. Answers to questions: (A) "*Which area, according to you, makes students problems in plant anatomy?*" (basic T = basic tissues, R/S T = tissues in root and stem, L T = leaves by type of mesophyll, moss MG = moss metagenesis and its principle, pollin./fertil. = pollination/fertilization of seed plants), (B) "*Which area, according to you, makes students problems in plant physiology?*" (L/D phot. = light/dark photosynthesis, phot. vs. resp. = photosynthesis and respiration opposites, water move. = water movement, stages/regul. ontog. = the basic stages of ontogeny and its regulation by exogenous/endogenous factors, adapt. to land = embryophytes adaptations to life on land, WR sign. = water regime significance for plant, plants sign. = ecological, pharmacological and economic importance of plants, fungi and lichens), (C) "*Which area, according to you, makes students problems in knowledge integration between plant anatomy and physiology?*" (native microscopy = organs tissues on real slide under microscope, sec. cell wall = secondary cell wall significance for mechanical strength and plant evolution, vasc./mech. T = relationship between transport/mechanical tissues and mechanics of plant organs, transp./growth = relationship between transpiration and growth, gametophyte = gametophyte of cryptogamae and seed plants and the reasons for its evolutionary, morphological and physiological changes, S anatomy = stem anatomy and relationship to mono-/dicot plants, mesophyll/phot. = relationship between leaf mesophyll and photosynthesis). The sum of percentage is higher than 100, as the respondents could choose several answers.

We also investigated which areas of plant anatomy and physiology and linking information between these areas are problematic for students. Most teachers identified several areas which were problematic for students (Fig. 4A-C). Only a small percentage of teachers did not identify any gaps in students' knowledge of plant anatomy (9.7 – 31.6% of teachers), plant physiology (9.7 – 32.3% of teachers) and information linking (12.5 – 31.6% of teachers). Surprisingly, the teachers did not identify the biggest deficiencies in plant reproduction, but in the area of the basic tissues and tissues of the root and stem (Fig. 4A). It was just plant reproduction and life cycle where most shortcomings have been identified in other research. For example, Lampert et al. (2019) observed that only 7.46% of pupils/students aged 10-18 were aware that "*Pollen leads to fertilization*" and 4.82% of pupils/students were aware that "*Pollen leads to the development of seeds/fruits*". He also found that only 35.53% of pupils/students were aware that "*A seed leads to development of a new plant*". Lin (2004) found that students aged 15-16 do not understand the basic phase of the life cycle (13.5% of these students described the life cycle as follows: "*Seeds germinate. The seedlings increase in volumes and mass. Their tissues and organs develop. There is not necessary having flowers and later fruits and new seeds form; old leaves drop. Life cycles end and turn again.*") and they are also not aware of the origin of fruit (36.5% of students).

Within plant physiology, most teachers identified deficiencies of students in the field of photosynthesis, specifically light/dark photosynthesis, but also in the field of the basic stages of ontogenesis and its regulation by exogenous/endogenous factors (Fig. 4B). According to teachers, the difference between photosynthesis and respiration is less problematic for students compared to the light and dark phases of photosynthesis. The area of photosynthesis is also problematic for pupils/students in other countries. For example, Sánchez and Ortega (2022) identified various gaps in students' knowledge. With the claim: "*Plants do photosynthesis during the daytime and breathe at night*" agreed 61.76% of students 17-18 aged and with the claim: "*Photosynthesis equals animal respiration*" agreed 50.57% of students aged 16-17 years. Barman et al. (2006) found that up to 64% of students aged 11-14 years think that plants need oxygen to grow and up to 23% of these students think that plants do not need carbon dioxide to grow. Also, up to 19% of these students think that a light bulb is necessary for plant growth. Also, Nanni and Plakitsi (2013) identified several misconceptions in this area among 10-year-old students, for example: "*There is no gas exchange between plants and the environment*". According to the teachers, the biggest problem for students when connecting information between the anatomy and physiology of plants is the identification of tissue under a microscope (Fig 4C). It is surprising since a high percentage of teachers use fixed and native microscopes in their teaching (Fig. 3A-B). However, the problem will probably be the textbooks themselves, which mainly contain drawings and not photos of real microscopic preparations. For example, in the chapter focused on plant anatomy in a textbook commonly used in Slovak gymnasiums, there is only one photo of a real microscopic preparation while the rest of the images are drawings of microscopic preparations. According to our information, research that would detect students' deficiencies in the ability to identify tissues on a microscopic preparation have not been carried out. However, according to the teachers, students also have problems in other areas: secondary cell wall significance for mechanical strength and plant evolution, the relationship between transport/mechanical tissues and mechanics of plant organs, or gametophyte of cryptogam and seed plants and the reasons for its evolutionary, morphological and physiological changes (Fig 4C). Linking information is not only a problem within the anatomy and physiology of plants, but also within the entire science education. In our country, a long-term decline in the level of science literacy is observed, while we lag OECD countries (MESRS-SR 2019). At the same time, more and more people in the Slovak Republic believe in conspiracy theories, which is also confirmed by the level of the conspiracy index (UCM FMK 2022), and Slovakia reached higher values than Turkey, Nigeria, or South Africa (Cordonier et al. 2021). Of course, this does not mean that lower levels of scientific literacy cause more belief in conspiracy theories, as such a claim would require a deeper and more extensive analysis that goes beyond the scope of this article. We also found a negative correlation (Fig. 6B) between the amount of teaching activities (derived from Fig. 2 A-B and Fig. 3A-D) that teachers carry out in class and the amount of students' deficiencies in plant biology (derived from Fig. 4 A-C). This means that teachers who use more aids identified fewer deficiencies, which shows the importance of visual aids in teaching plant biology.

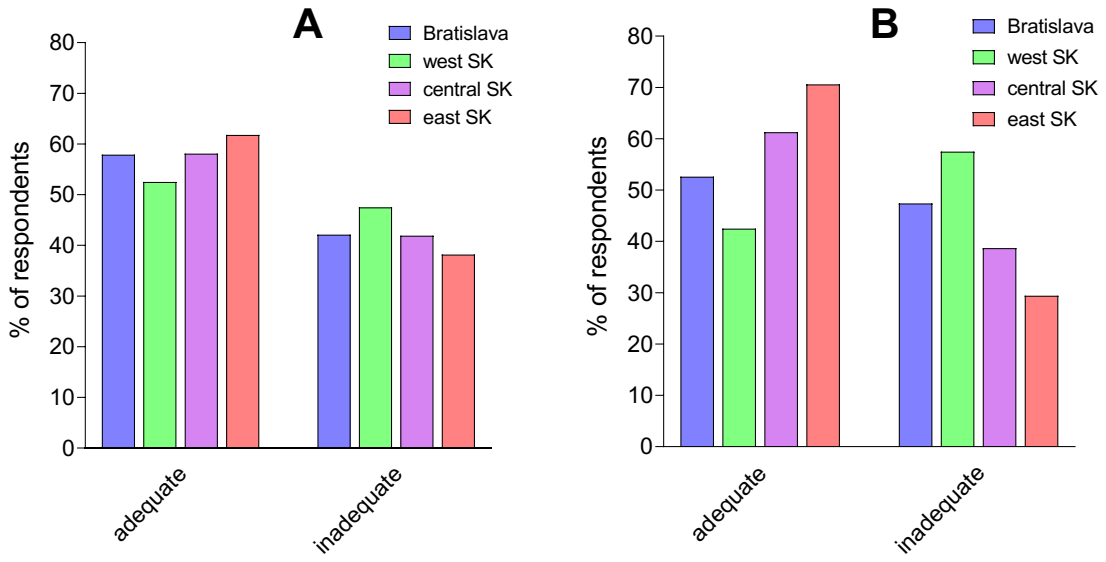

Figure 5. Teachers' deficiencies in plant anatomy (A) and plant physiology (B). Columns adequate means that teachers consider their own knowledge in the offered areas to be sufficient. The individual areas in which teachers perceive deficiencies are not listed in the chart for clarity. Data are in percentage of the total number of respondents in every region.

We also asked the teachers themselves if they felt deficiencies in some areas. Such survey has only rarely been carried out and one of previous studies by Bebbington et al. (2005) found that up to 29% of teachers could not name more than 3 photos of plants out of 10. A high percentage of teachers (29.4% – 57.5%) admitted deficiencies in some area of plant anatomy/physiology (Fig 5A-B). In terms of plant anatomy, the teachers most often admitted deficiencies (15 – 30% of teachers) in the areas of secondary meristems and secondary growth, metagenesis and types of vascular bundles. In plant physiology, teachers admit the most frequent deficiencies (10 – 25% of teachers) in the areas: factors affecting plant ontogeny/growth, plant movement, plant respiration and photosynthesis. Yates and Marek (2014) conducted research in which they found that students can have more accurate ideas about the subject itself than their teachers: according to the cited paper, this clearly indicates that the source of students' misconceptions can also be the teachers themselves. This was partially confirmed by the positive significant correlation (Fig. 6C) between the number of teacher deficiencies and the number of student deficiencies. Teachers with more deficiencies are likely to be aware of their own deficiencies and therefore have identified more deficiencies of their students.

4. CONCLUSION

In our research, we investigated the opinions of high school biology teachers about teaching and the problems they encounter during the teaching of plant biology, a not very attractive field for students. We greatly appreciate that up to 124 respondents filled out the questionnaire, as their opinions are a starting point for solving the problems they must face. Most teachers also self-critically admitted deficiencies in their knowledge of plant anatomy and physiology, which are new data that were not detected in other surveys. We also found correlations that emphasize the importance of basic equipment and aids in biology classrooms, and the importance of using these equipment and aids in the teaching process.

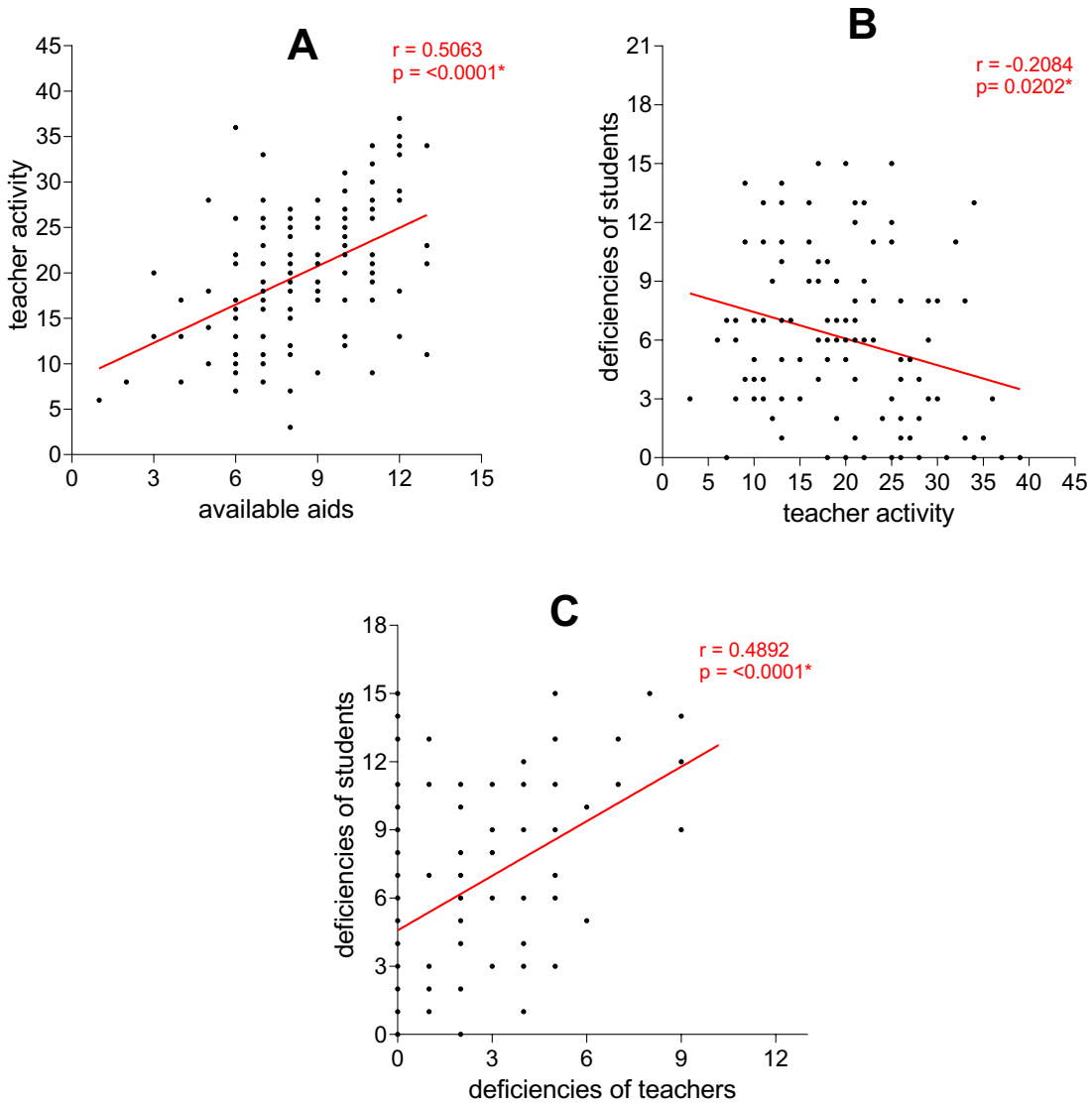

Figure 6. Graphs from Spearman's correlation analysis of the teachers' responses on selected areas: (A) teacher activity (derived from Fig. 2A-B+Fig. 3 A-D), available aids (derived from Fig. 1), (B) deficiencies of students (derived from Fig. 4A-C), teacher activity (derived from Fig. 2A-B+Fig. 3 A-D), (C) deficiencies of students (derived from Fig. 4A-C), deficiencies of teachers (derived from Fig 5A-B). * The corresponding correlation in R is considered significant as an off-diagonal element of P was smaller than the significance level of 0.05.

REFERENCES

Barman, CR Stein, M McNair, S Barman, NS 2006, 'Students' ideas about plants & plant growth', *The American Biology Teacher,* vol. 68, no. 2, pp. 73-79.

Bebbington, A 2005, 'The ability of A-level students to name plants', *Journal of Biological Education,* vol. 39, no. 2, pp. 63-67.

Chattopadhyay, A 2005, 'Understanding of genetic information in higher secondary students in northeast India and the implications for genetics education', *Cell Biology Education,* vol. 4, no. 1, pp. 97-104.

Chavan, RL 2016, 'Difficulties in teaching biology concepts by science teachers at upper primary level', *Aayushi International Interdisciplinary Research Journal,* vol. 3, no. 3, pp. 10-18.

Cordonier, L Cafiero, F Bronner, G 2021, 'Why are conspiracy theories more successful in some countries than in others? An exploratory study on Internet users from 22 Western and non-Western countries', *Social Science Information,* vol. 60, no. 3, pp. 436-456.

Dan-Ologe, IA & Shittu, AO 2012, 'Improving the standard of teaching and learning of practicals in our secondary schools: emphasis on biology and chemistry practicals', *Journal of Qualitative Education,* vol. 8, no. 1, viewed 29 June 2023, <https://globalacademicgroup.com/journals/qualitative%20education/Dan-Ologe1.pdf>.

Effiong, OE & Igiri, CE 2015, 'Impact of instructional materials in teaching and learning of biology in senior secondary schools in Yakurr LG A', *International Letters of Social and Humanistic Sciences,* vol. 62, pp. 27-33.

Helldén, G 2000, 'A longitudinal study of pupils' conceptualisation of the role of the flower in plant reproduction', *The Second Conference of European Researchers in Didaktik of Biology*, pp. 47-59, viewed 29 June 2023, <http://www.diva-portal.org/smash/get/diva2:320112/FULLTEXT01.pdf>.

Hofeld, JF 2021, 'Using modeling to develop a deep understanding of photosynthesis & cellular respiration as chemical processes', *The American Biology Teacher,* vol. 83, no. 6, pp. 382-386.

Holstermann, N & Bögeholz, S 2007, 'Interesse von jungen und mädchen an naturwissenschaftlichen themen am ende der sekundarstufe I', *Zeitschrift für Didaktik der Naturwissenschaften,* vol. 13, pp. 71-86.

Johnston, A Scaggs, J Mallory, C Haskett, A Warner, D Brown, E Hammond, K McCormick, MM McDougal, OM 2013, 'A green approach to separate spinach pigments by column chromatography.' *Journal of Chemical Education,* vol. 90, no. 6, pp. 796-798.

Kletečki, N Hruševar, D Mitić, B Šorgo, A 2023, 'Plants are not boring, school botany is', *Education Science,* vol. 13, no. 489.

Krell, M & Schmidt, J 2020, 'Biology teachers' views towards using living organisms in biology education', *Journal of Biological Education,* vol. 56, no. 3, pp. 353-364.

Lampert, P Scheuch, M Pany, P Müllner, B Kiehn, M 2019, 'Understanding students' conceptions of plant reproduction to better teach plant biology in schools', *Plants People Planet,* vol. 1, no. 3, pp. 1-13.

Lin. S 2004, 'Development and application of a two-tier diagnostic test for high school students' understanding of flowering plant growth and development', *International Journal of Science and Mathematics Education,* vol. 2, no. 2, pp. 175-199.

Lyimi, NS Too, JK Kipng'etich, KJ 2017, 'Perception of teachers on availability of instructional materials and physical facilities in secondary schools of Arusha District, Tanzania', *International Journal of Educational Policy Research and Review,* vol. 4, no. 5, pp. 103-112.

Mak, SY Yip, DY Chung, CM 1999, 'Alternative conceptions in biology-related topics of integrated science teachers and implications for teacher education', *Journal of Science Education and Technology, vol. 8, no.* 2, pp. 161-170.

MESRS-SR 2019, 'Ministry of education, science, research and sport of the Slovak republic (supplement no. 2 a 3)', viewed 29 June 2023, <https://www.minedu.sk/zverejnenie-vysledkov-slovenskych-ziakov-v-medzinarodnej-studii-oecd-pisa-2018/>.

Mitra, M Broom, SM Pinto, K Wellons, SMD Roberts, AD 2020, 'Engaging inexpensive hands-on activities using *Chlamydomonas reinhardtii* (a green micro-alga) beads to teach the interplay of photosynthesis and cellular respiration to K4–K16 Biology students', *PeerJ,* vol. 8, no 9817.

Nanni, E Plakitsi, K 2013, 'Investigating new paths in the teaching of plant processes in elementary schools', *World Journal of Education,* vol. 3, no. 4, pp. 52-70.

Polák, J Rádlová, S Janovcová, M Flegr, J Landová, E Frynta, D 2020, 'Scary and nasty beasts: Self-reported fear and disgust of common phobic animals', *British Journal of Psychology,* vol. 111, no. 2, pp. 297-321.

Ruščić, M Vidović, A Kovačević, G Sirovina, D 2018, 'The use of microscope in school biology teaching', *Resolution and Discovery,* vol. 3, no. 1, pp. 13-16.

Sánchez, IA & Ortega, JGM 2022, 'Teaching vegetable nutrition: from the problem to the proposal', *Journal of Biological Education,* vol. 56, no. 4, pp. 417-431.

Sayan, H Mertoglu, H 2020, 'Equipment use in biology teaching', *Journal of Educational Issues,* vol. 6, no. 1, pp. 357-371.

Shabiralyani, G Hasan, KS Hamad, N Iqbal, N 2015, 'Impact of visual aids in enhancing the learning process case research: district Dera Ghazi Khan', *Journal of Education and Practice,* vol. 6, no. 19, pp. 226-234.

Stagg, BC & Verde, MF 2018, 'Story of a Seed: educational theatre improves students' comprehension of plant reproduction and attitudes to plants in primary science education', *Research in Science & Technological Education,* vol. 37, no. 1, pp. 15-35.

Strgar, J 2007, 'Increasing the interest of students in plants', *Journal of Biological Education,* vol. 42, no. 1, pp. 19-23.

Stroud, S Fennell, M Mitchley, J Lydon, S Peacock, J Bacon, KL 2022, 'The botanical education extinction and the fall of plant awareness', *Ecology and Evolution,* vol. 12(7), no. 9019.

Tomažič, I 2011, 'Pre-Service biology teachers' attitude, fear and disgust toward animals and direct experience of live animals', *TOJNED: The Online Journal Of New Horizons In Education,* vol. 1, no. 1, pp. 32-39.

Topsakal, UU Oversby, J 2012, 'Turkish student teachers' ideas about diagrams of a flower and a plant cell', *Journal of Biological Education,* vol. 46, no. 2, pp. 81-92.

Treichler, DG 1967, 'Are you missing the boat in training aid?' *Film AV Commun*., vol. 1, pp. 14-16.

UCM FMK 2022, 'Najviac veria konšpiráciám Slováci, ukázal prieskum realizovaný UCM', <https://fmk.sk/konspiracny-index-na-slovensku/>.

Uitto, A 2013 'Interest, attitudes and self-efficacy beliefs explaining upper-secondary school students' orientation towards biology-related careers', *International Journal of Science and Mathematics Education,* vol. 12, no. 6, pp. 1425-1444.

Yates, TB & Marek, EA 2014, 'Teachers teaching misconceptions: a study of factors contributing to high school biology students' acquisition of biological evolution-related misconceptions', *Evolution: Education and Outreach,* vol. 7(1), no. 7.

Yürük, N Selví, M Yakişan, M 2011, 'The effect of metaconceptual teaching activities on pre-service biology teachers' conceptual understanding about seed plants', *Educational Sciences: Theory and Practice,* vol. 11, no. 1, pp. 459-464.