Supplementary materials for the work:

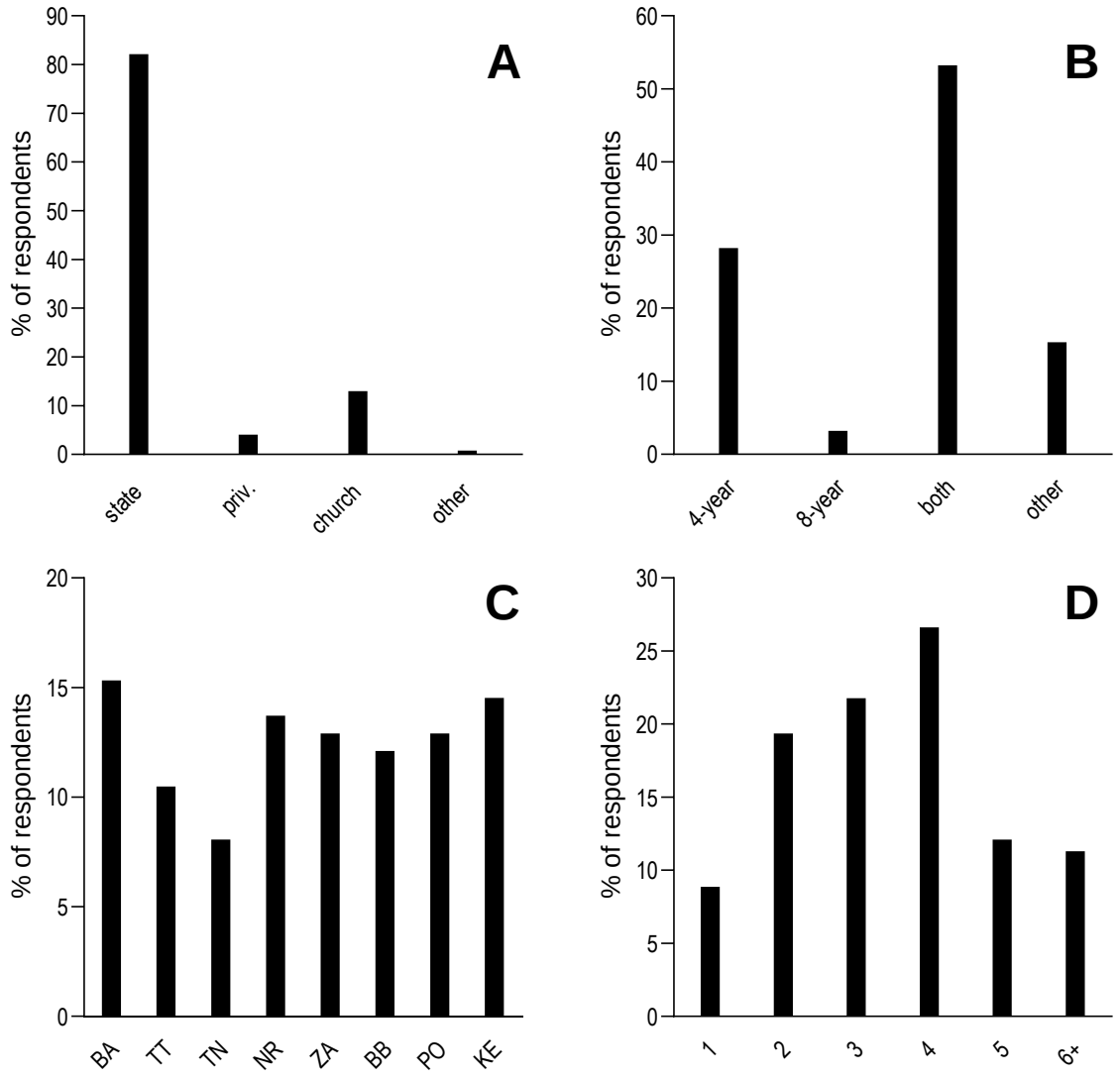
Let's Ask the Other Side: Teaching Gymnasium Plant Biology from a Teacher's Perspective

Jozef Kováčik* and Marek Vydra

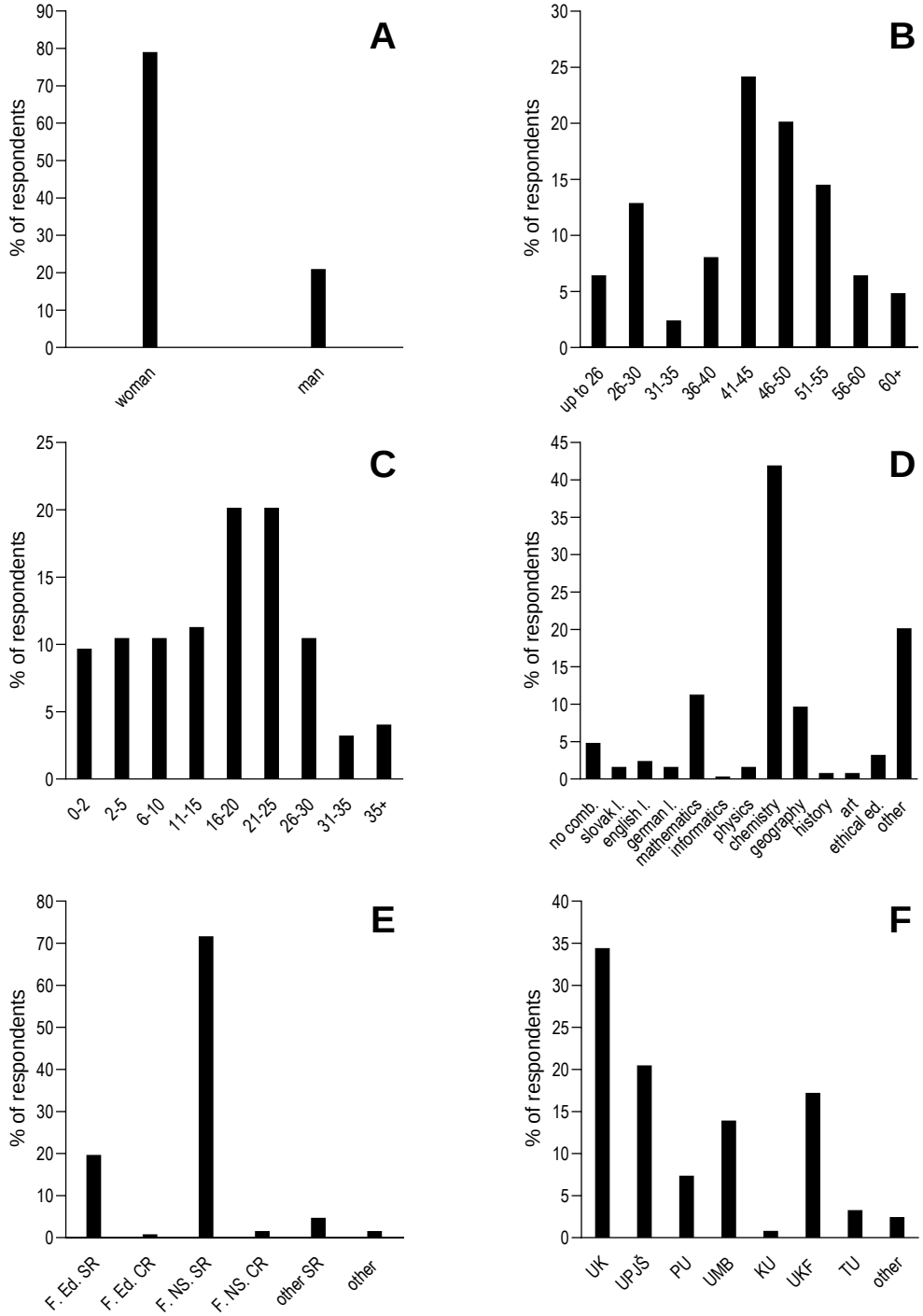
Department of Biology, Faculty of Education, University of Trnava, Priemyselná 4, 918 43 Trnava, Slovakia

* Corresponding author: jozkovacik@yahoo.com

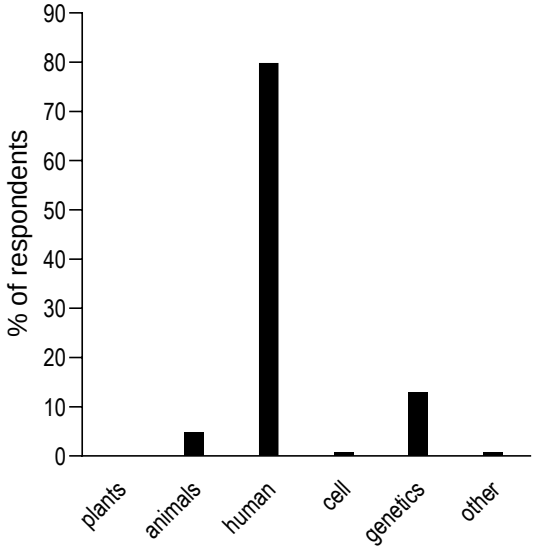
https://orcid.org/0000-0002-5701-0598



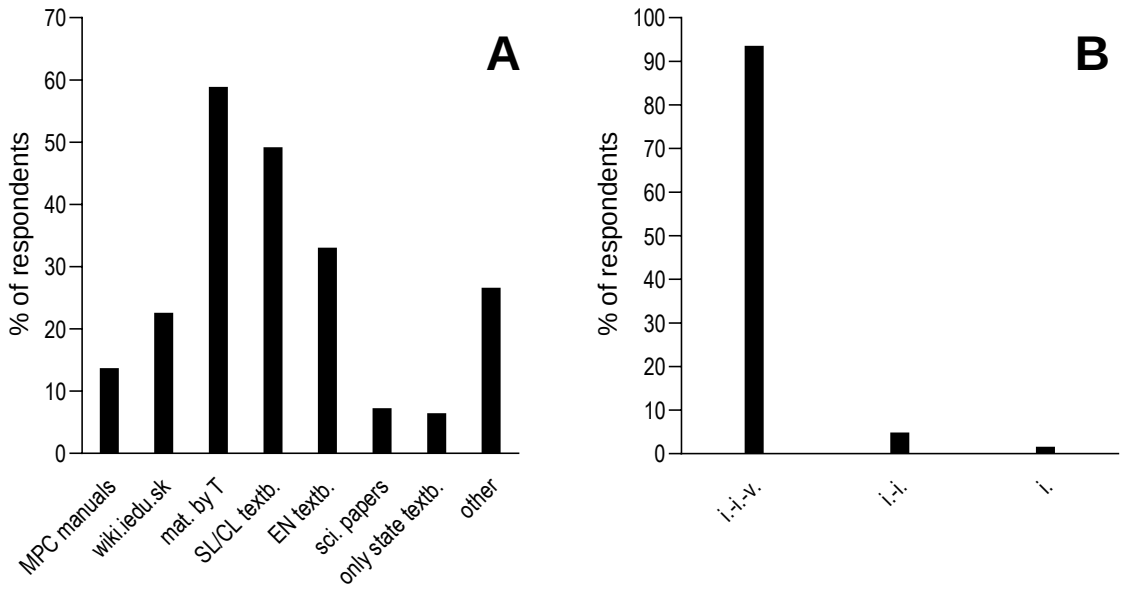
Supplementary Figure S1. Answers to questions regarding general information about the gymnasium where the respondents of this questionnaire teach: (A) founder of gymnasia (priv. = private), (B) type of gymnasia ("other" means gymnasia focused, in addition to standard curriculum, on sport or languages), (C) distribution of gymnasia within eight self-governing regions (BA = Bratislava, TT = Trnava, TN = Trenčín, NR = Nitra, ZA = Žilina, BB = Banská Bystrica, PO = Prešov, KE = Košice) and (D) number of biology teachers in gymnasia. Data are in percentage of the total number of respondents (124 teachers).



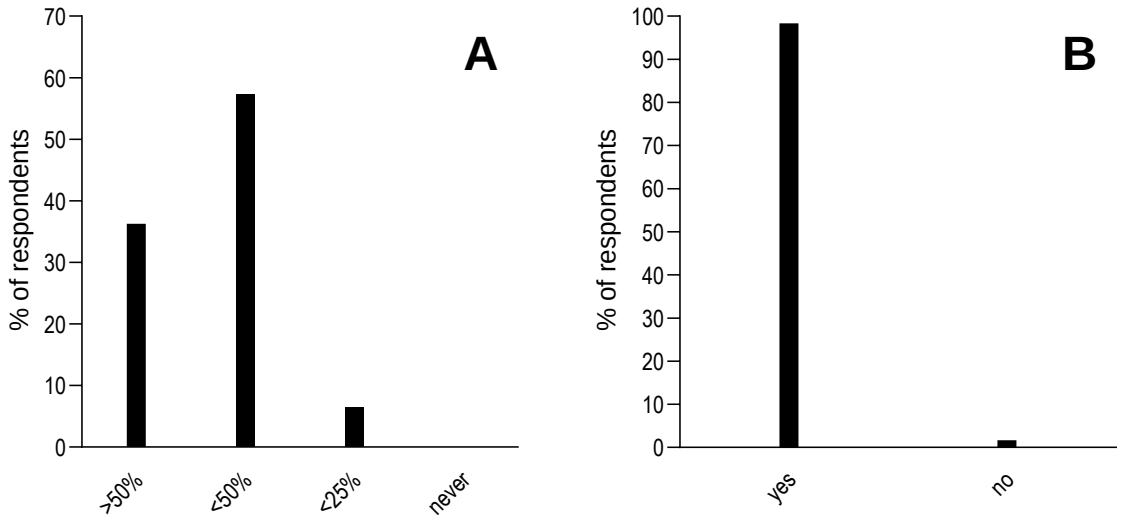
Supplementary Figure S2. Answers to questions regarding general information about the respondents: (A) gender, (B) age, (C) length of practice at gymnasium, (D) 2nd subject with biology they studied (no. comb. = only biology study, l. = language, ed. = education), (E) faculty where they studied (F. Ed. SR = faculty of education in Slovak Republic, F. Ed. CR = faculty of education in Czech Republic, F. NS. SR = faculty of natural science in Slovak Republic, F. NS. CR = faculty of natural science in Czech Republic, other SR = other study in Slovak republic), (F) Alma mater (UK = Comenius University in Bratislava, UPJŠ = P. J. Šafárik University in Košice, PU = University of Prešov, UMB = M. Bel University in Banská Bystrica, KU = Catholic University in Ružomberok, UKF = Constatine the Philosopher University in Nitra, TU = University of Trnava in Trnava). Data are in percentage of the total number of respondents (124 teachers).



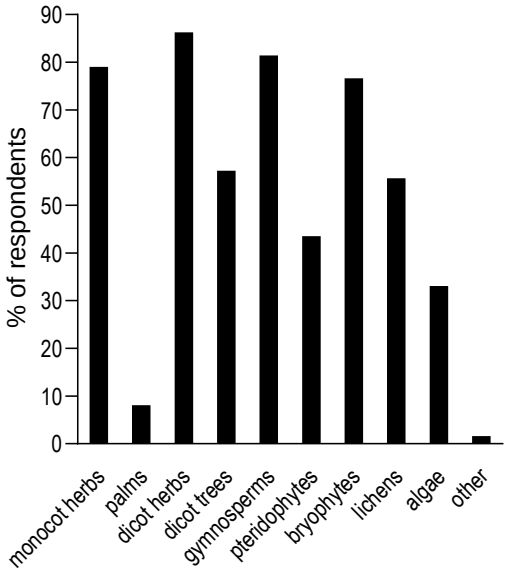
Supplementary Figure S3. Answers to question *"Which field of biology do you find most attractive for students?"* Data are in percentage of the total number of respondents (124 teachers).



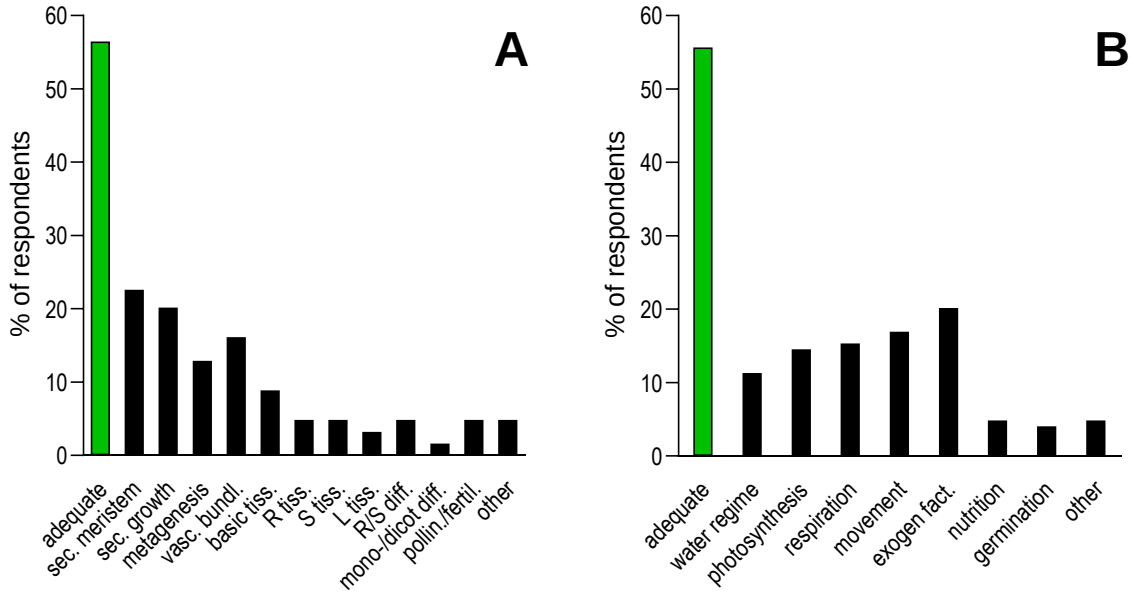
Supplementary Figure S4. Answers to questions (A) "*When preparing for teaching, you use:*" (MPC manuals = Methodological and Pedagogical Centre, mat. by T = materials created by teachers, SL/CL textb. = university textbooks in Slovak/Czech language, EN textb. = professional books/textbooks in English language, sci. papers = scientific papers in foreign journals, only state textb. = only state textbooks for gymnasia), (B) "*When teaching plant biology, you explain the subject with the use of:*" (i.-i.-v. = interpretation + images/ppt presentations + visual aids, i.-i. = interpretation + images/ppt presentations, i. = interpretation only). Data are in percentage of the total number of respondents (124 teachers). The sum of percentage in graph A is higher than 100, as the respondents could choose several answers.



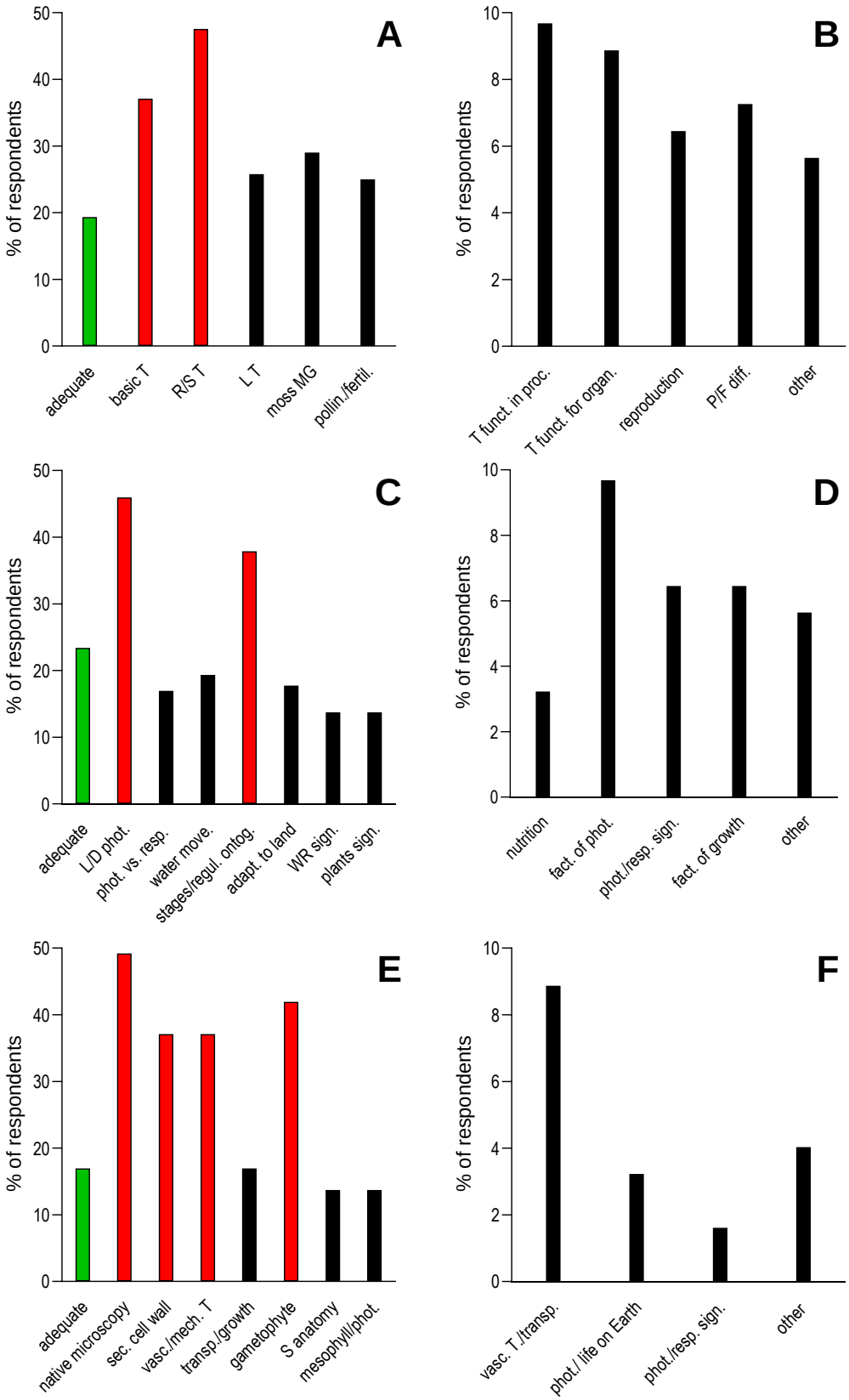
Supplementary Figure S5. Answers to questions (A) *"In how many plant biology lessons do you use visual aids?"* and (B) *"Do you use a microscope when teaching plant biology?"* Data are in percentage of the total number of respondents (124 teachers).



Supplementary Figure S6. Answers to question *"What groups of plants do you use in teaching plant biology?"*. Data are in percentage of the total number of respondents (124 teachers). The sum of percentage is higher than 100, as the respondents could choose several answers.

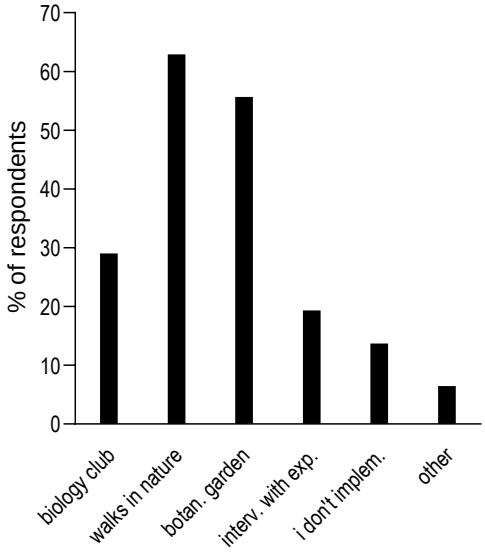


Supplementary Figure S7. Answers to questions (A) "*Do you feel a shortcoming (you as a teacher) in any of the following areas of plant anatomy beyond the gymnasium curriculum?*" (sec. meristem = secondary meristems, sec. growth = secondary growth, vasc. bundl. = types of vascular bundles, R tiss. = basic tissues of root, S tiss.= basic tissues of stem, L tiss. = basic tissues and types of leaves, R/S diff. = root/shoot differences, mono-/dicot diff = monocot/dicot differences, pollin./fertil. = flower structure, pollination and fertilization), (B) "*Do you feel a shortcoming (you as a teacher) in any of the following areas of plant physiology beyond the gymnasium curriculum?*" (exogen fact. = factors affecting plant ontogeny/growth). Data are in percentage of the total number of respondents (124 teachers). The sum of percentage is higher than 100, as the respondents could choose several answers.



Supplementary Figure S8. Answers to questions:
(A-B) *"Do you observe in teaching plant anatomy that students have difficulty with any of these topics?"* (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, T funct. in proc. = function of basic tissue in plant processes, T funct. for organ. = significance of individual tissues for the organism, reproduction = differences between sexual and asexual reproduction, P/F diff. = differences between plants and fungi).
(C-D) "*Do you observe in teaching plant physiology that students have difficulty with any of these topics?*" (L/D phot. = light/dark photosynthesis, phot. vs. resp. = differences between photosynthesis and respiration, water move. = factors affecting water movement, stages/regul. ontog. = the basic stages of ontogeny and its regulation by exogenous/endogenous factors, adapt. to land = adaptation of plants to life on land, WR sign. = significance of water regime, plants sign. = ecological, pharmacological and economic importance of plants, fungi and lichens, nutrition = plant nutrition modes, fact. of phot. = factors of photosynthesis, phot. sign. = photosynthesis and respiration significance in nature, fact. of growth = factors of plant growth).
(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?*" (native microscopy = identification of tissues on real microscopic slide compared to the drawing, 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 spore 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, vasc. T/transp. = relationship between vascular tissues and transpiration/assimilation, phot./ life on Earth = significance of photosynthesis for the life on Earth, phot./resp. sign. = significance of photosynthesis and respiration for the organisms). Data are in percentage of the total number of respondents (124 teachers). The sum of percentage is higher than 100, as the respondents could choose several answers.



Supplementary Figure S9. Answers to question *"What type of informal learning do you implement?"* (botan. garden = education in botanical garden, inter. with exp. = interview with experts, I don't implem. = I don't implement). Data are in percentage of the total number of respondents (124 teachers). The sum of percentage is higher than 100, as the respondents could choose several answers.

Table S1. Answers to question *"What are your reasons for using/not using visual aids in education?"* Data are in percentage of the total number of respondents (124 teachers). The sum of percentage is higher than 100, as the respondents could choose several answers.

Teaching aids use because:	% of respondents
students remember more of lesson	87.10
students are more interested	78.23
students themselves require the use	21.77
I explain the material better	77.42
others	1.61
Teaching aids don't use because:	
not enough time	16.13
technical equipment does not allow it	8.87
I am not experienced enough	0.80
I don't want to use teaching aids	0.80
theoretical teaching is sufficient	0.80
others	4.83

Questionnaire for teachers used in this publication

1. **The gymnasium you work at is located in the self-governing region:**

- Bratislava
- Trnava
- Trenčín
- Nitra
- Žilina
- Banská Bystrica
- Prešov
- Košice

2. **The gymnasium you work at is located in the city**:

3. **You teach at a gymnasium:**

- 4-year study
- 8-year study
- both forms
- other

4. **From the founder's point of view, your gymnasium is:**

- state
- private
- church
- other

5. **Please indicate the approximate number of your students in all grades of the 4-year and/or higher (5th-8th) grades of the 8-year gymnasium:**

6. **The number of biology teachers at your gymnasium is:**

- 1 (= only you)
- 2
- 3
- 4
- 5
- other

7. **Gender:**

- female
- male

8. **Your age is (select interval of years):**

- less than 26
- 26 – 30
- 31 – 35
- 36 – 40
- 41 – 45
- 46 – 50
- 51 – 55
- 56 – 60
- over 60

9. **Length of your teaching experience at the gymnasium (in years):**

- less than 2
- 2 – 5
- 6 – 10
- 11 – 15
- 16 – 20
- 21 – 25
- 26 – 30
- 31 – 35
- over 35

10. **You received your education in biology at:**

- faculty of education in Slovak Republic
- faculty of education in Czech Republic
- faculty of natural science in Slovak Republic
- faculty of natural science in Czech Republic
- other

11. **What combination of teaching biology with another subject have you studied?**

- I haven´t study combined teacher studies
- biology-Slovak language
- biology-English language

- biology-German language
- biology-mathematics
- biology-informatics
- biology-physics
- biology-chemistry
- biology-geography
- biology-history
- biology-art
- biology-ethical education
- other

12. If you studied biology teaching in Slovakia, please select your Alma mater

- UK in Bratislava
- UPJŠ in Košice
- PU in Prešov
- UMB in Banská Bystrica
- KU in Ružomberok
- UKF in Nitra
- TU in Trnava
- none of the above

13. Do you have a Ph.D. title?

- I don't have
- I have a degree in botany (e.g. plant physiology/ecology/genetics/biotechnology/systematics)
- I have from another biological (not botanical) field
- I have from didactics of biology
- I have from any other discipline

14. Which field of biology do you think is the most attractive for students?

- plant biology
- zoology
- human biology
- cytology
- genetics and molecular biology
- other

15. **Approximately how many teaching hours do you devote to the thematic unit anatomy/morphology and physiology of plants?**

16. **You teach plant anatomy in:**

- 1st grade
- 2nd grade
- 3rd grade
- 4th grade

17. **You teach plant physiology in:**

- 1st grade
- 2nd grade
- 3rd grade
- 4th grade

18. **You teach plant anatomy and physiology using textbooks** (several options can be chosen):

- Ušáková et al. (1999 or 2003) Biológia pre gymnáziá 1: Biológia bunky a rastlín. SPN Bratislava, ISBN 80-08-03518-8 or ISBN 80-08-02983-8
- Višňovská et al. (2012) Biológia pre 2. ročník gymnázia a 6. ročník gymnázia s osemročným štúdiom. SPN Bratislava, ISBN 978-80-10-02286-1
- both textbooks
- other

19. **When preparing for teaching, you use** (several options can be chosen, the penultimate one only separately):

- materials of Methodological and Pedagogical Centre
- portal viki.iedu.sk
- materials created by teachers (e. g. zborovna.sk)
- university textbooks in Slovak/Czech language
- professional books/textbooks in English language
- scientific papers in foreign journals
- ***only state textbooks for gymnasia***
- other

20. **The technical equipment for teaching gymnasium plant biology at your school is:**

- sufficient
- insufficient

21. **Choose the teaching aids that are available at your gymnasium** (several options can be chosen, the penultimate one only separately):

- ☐ computer with a data projector
- ☐ inadequate microscope
- ☐ quality microscope
- ☐ microscope connected to computer
- ☐ magnifying glass
- ☐ histology stains
- ☐ acrylic models (herbs, woody plants, algae, lichens, etc.)
- ☐ permanent/fixed microscope slides
- ☐ inorganic chemicals
- ☐ organic chemicals
- ☐ laboratory glassware
- ☐ laboratory plastic materials (micro and macro test tubes, Petri dishes, Pasteur pipettes, etc.)
- ☐ tweezers
- ☐ automatic pipettes
- ☐ analytical balances
- ☐ centrifuge
- ☐ spectrophotometer
- ☐ chromatograph
- ☐ cultivation device (artificial lighting for growing plants or greenhouse)
- ☐ ***none of the above***
- ☐ other

22. **When teaching plant biology, you explain the subject with the use of:**

- ○ (verbal) interpretation only
- ○ interpretation + images/ppt presentations
- ○ interpretation + images/ppt presentations + visual aids

23. **What types of teaching aids do you use in plant biology education?** (several options can be chosen, the penultimate one only separately)

- ☐ plastic/acrylic models
- ☐ fixed microscopy
- ☐ native microscopy
- ☐ macroscopic observation of live material (morphology, plant ecological adaptations, systematics)
- ☐ physiology experiments (germination, water regime, osmosis, etc.)

- [ ] data from scientific papers
- [ ] *I don't use visual aids*
- [ ] other

24. **In how many plant biology lessons do you use visual aids?**

- ○ never
- ○ less than 25% of lessons
- ○ less than 50% of lessons
- ○ more than 50% of lessons

25. **What groups of plants do you use in teaching plant biology?** (several options can be chosen)

- [ ] monocot herbs
- [ ] monocot woody plants (palms)
- [ ] dicot herbs
- [ ] dicot woody plants
- [ ] gymnosperms
- [ ] pteridophytes
- [ ] bryophytes
- [ ] lichens
- [ ] algae
- [ ] other

26. **Do you use a microscope when teaching plant biology?**

- ○ yes
- ○ no

27. **What topic do you use fixed microscopy for?** (several options can be chosen, the penultimate one only separately)

- [ ] basic tissues
- [ ] stem, root and leaf structure
- [ ] flower structure
- [ ] metagenesis
- [ ] anatomy of non-vascular plants
- [ ] *I don't use fixed microscopy*
- [ ] other

28. **What topic do you use native microscopy for?** (several options can be chosen, the penultimate one only separately)

- ☐ basic tissues
- ☐ stem, root and leaf structure
- ☐ flower structure
- ☐ metagenesis
- ☐ anatomy of non-vascular plants
- ☐ ***I don't use native microscopy***
- ☐ other

29. **What topic do you use live plant material for?** (several options can be chosen, the penultimate one only separately)

- ☐ metagenesis of non-vascular plants
- ☐ metagenesis of vascular plants
- ☐ monocot/dicot structure
- ☐ secondary growth
- ☐ ecological adaptations of plants (cacti, aquatic plants, etc.)
- ☐ flower structure (morphological and evolutionary comparison, etc.)
- ☐ fruit structure
- ☐ algae/fungi thallus structure (unicellular versus multicellular thallus)
- ☐ lichen thallus structure
- ☐ ***I don't implement these activities***
- ☐ other

30. **What topic do you use physiological experiments for?** (several options can be chosen, the penultimate one only separately)

- ☐ water regime (transpiration, etc.)
- ☐ osmosis
- ☐ germination
- ☐ photosynthesis
- ☐ respiration
- ☐ ***I don't use physiology experiments***
- ☐ other

31. **Do you use data from scientific papers when teaching plant anatomy and physiology?**

- ○ yes
- ○ no

32. **For students' work with living plant material and physiological experiments, you draw inspiration from** (several options can be chosen):

- ☐ activities from gymnasium textbooks
- ☐ MPC manuals and internet portals for teachers
- ☐ Slovak/Czech university textbooks
- ☐ foreign professional books/textbooks (especially in English)
- ☐ information from foreign websites
- ☐ own invention
- ☐ other

33. **If you carry out native microscopy or physiological experiments, please briefly give examples of activities** (e.g. starch staining with Lugol's solution in the root cap, observation of collenchyma/sclerenchyma in the stem of a plant..., cross-section of a stem/root/leaf of a plant..., movements/growth of plants in light/darkness, influence of mineral nutrition on plant growth ... etc.).

34. **Please indicate what visual aids/practical exercises you use when teaching the topic 'Ecological, pharmacological and economic importance of plants, fungi and lichens'.** *If the answer is negative, state "I do not use".*

35. **What are your reasons for using visual aids in education?** (several options can be chosen, the penultimate one only separately)?

- ☐ students remember more of lesson
- ☐ students are more interested
- ☐ students themselves require the use
- ☐ I explain the material better
- ☐ ***this question does not concern me (I do not use visual aids)***
- ☐ other

36. **What are your reasons for not using visual aids in education?** (several options can be chosen, the penultimate one only separately)

- ☐ not enough time
- ☐ technical equipment does not allow it
- ☐ I am not experienced enough
- ☐ I don't want to use teaching aids
- ☐ theoretical teaching is sufficient
- ☐ ***this question does not concern me (I use visual aids)***
- ☐ other

37. **Do you feel a shortcoming (you as a teacher) in any of the following areas of plant anatomy beyond the gymnasium curriculum?** (several options can be chosen, the penultimate one only separately)

- ☐ basic tissues
- ☐ basic tissues of root
- ☐ basic tissues of stem
- ☐ basic tissues and types of leaves
- ☐ root/shoot differences
- ☐ types of vascular bundles
- ☐ secondary meristems
- ☐ secondary growth
- ☐ monocot/dicot differences
- ☐ flower structure, pollination and fertilization
- ☐ metagenesis
- ☐ ***my knowledge and skills are adequate***
- ☐ other

38. **Do you feel a shortcoming (you as a teacher) in any of the following areas of plant physiology beyond the gymnasium curriculum?** (several options can be chosen, the penultimate one only separately)

- ☐ water regime
- ☐ nutrition of plants
- ☐ photosynthesis
- ☐ respiration
- ☐ germination
- ☐ movement
- ☐ factors affecting plant ontogeny/growth
- ☐ ***my knowledge and skills are adequate***
- ☐ other

39. **Do you observe in teaching plant anatomy that students have difficulty with any of these topics?** (several options can be chosen, the penultimate one only separately)

- ☐ basic tissues
- ☐ tissues in root and stem
- ☐ leaves by type of mesophyll
- ☐ function of basic tissue in plant processes
- ☐ significance of individual tissues for the organism

- [ ] differences between sexual and asexual reproduction
- [ ] moss metagenesis and its principle
- [ ] pollination/fertilization of seed plants
- [ ] differences between plants and fungi
- [ ] ***none of the above (students have no problem)***
- [ ] other

40. **Do you observe in teaching plant physiology that students have difficulty with any of these topics?** (several options can be chosen, the penultimate one only separately)

- [ ] plant nutrition modes
- [ ] light/dark photosynthesis
- [ ] factors of photosynthesis
- [ ] differences between photosynthesis and respiration
- [ ] photosynthesis and respiration significance in nature
- [ ] significance of water regime
- [ ] factors affecting water movement
- [ ] the basic stages of ontogeny and its regulation by exogenous/endogenous factors
- [ ] factors of plant growth
- [ ] adaptation of plants to life on land
- [ ] ecological, pharmacological and economic importance of plants, fungi and lichens
- [ ] ***none of the above (students have no problem)***
- [ ] other

41. **Do you observe in your teaching that students have a problem with some of these topics when integrating their knowledge of anatomy and physiology?** (several options can be chosen, the penultimate one only separately)

- [ ] identification of tissues on real microscopic slide compared to the drawing
- [ ] stem anatomy and relationship to mono-/dicot plants
- [ ] secondary cell wall significance for mechanical strength and plant evolution (vascular versus non-vascular plants, sclerenchyma)
- [ ] relationship between transport/mechanical tissues and mechanics of plant organs (secondary growth, collenchyma)
- [ ] relationship between vascular tissues and transpiration/assimilation
- [ ] relationship between transpiration and growth (mineral nutrition)
- [ ] relationship between leaf mesophyll and photosynthesis
- [ ] gametophyte of spore or seed plants and the reasons for its evolutionary, morphological and physiological changes

- ☐ significance of photosynthesis for the life on Earth
- ☐ significance of photosynthesis and respiration for the organisms
- ☐ ***none of the above (students have no problem)***
- ☐ other

42. **What type of informal learning do you implement?** (several options can be chosen, the penultimate one only separately)

- ☐ biology club
- ☐ walks in nature
- ☐ education in botanical garden
- ☐ interview with experts
- ☐ ***I don't implement these activities***
- ☐ other

43. **Please express your level of agreement with the following statements about the teaching of plant biology and student knowledge:**

	strongly agree	agree	don't know	disagree	strongly disagree
The gymnasium teacher has enough methodical materials for teaching plant biology					
The quality of textbooks and methodological materials for gymnasia is excellent					
I would appreciate new practical methodological materials and worksheets for teaching					
My students' knowledge of plant anatomy and physiology is mostly excellent					

My students' knowledge of plant anatomy and physiology is mostly poor					
Interpretation of plant biology should be linked to practical aids/activities as much as possible					
Plant biology is less attractive to students than other areas of biology					

44. **Only this question addresses teaching and student knowledge/interest during the COVID-19 pandemic. Please express your level of agreement with the following statements:**

	strongly agree	agree	don't know	disagree	strongly disagree
Online teaching was problematic for technical reasons (internet signal, PC equipment, etc.)					
Face-to-face teaching is better than online					
Online teaching = less interested students					
Use of teaching aids during online learning was more difficult to impossible					
Students observed plants during online education as homework					
Students' knowledge "post-online" is weaker					