# Fostering interdisciplinarity through technology enhanced learning of transpiration

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**Abstract**

Technology enhanced interdisciplinary learning unit on ecological role of plant transpiration was tested in this study to explore its effectiveness. The students worked with pc programmed usb sensors for humidity and air temperature and evaluated graphically the data. They were asked to explain the results of the outdoor measurement by known concepts obtained theoretically during biology and physics lessons. An impact of education on the improvement of students' knowledge of ecological role of plant transpiration based on the understanding of physical principles was tested via a pre-test /post-test. Based on the findings of this study, discussion and recommendations are provided.

**Key words: Interdisciplinary education, transpirations, air- conditioning, vegetation**

## INTRODUCTION

Recent studies highlighted the necessity of interdisciplinary approach in teaching science (You, 2017; Shandas & Brown, 2016; Riordain, Johnston & Walshe, 2015). According to You, (2017), „*the complexity of the natural system and its corresponding scientific problems necessitate interdisciplinary understanding informed by multiple disciplinary backgrounds*", therefore „*the best way to learn and perceive natural phenomena of the real world in science should be based on an effective interdisciplinary teaching*" (You, 2017, p.66). Interdisciplinary approach is frequently used mainly for problem solving tasks (You, 2017; Shandas & Brown, 2016).

One of the serious problems in recent science teaching is underestimated and poorly understood role of plant function in our climate (Ryplova & Pokorny, 2019; 2018) resulting from the general phenomenon of so called "plant blindness", i.e. human ignorance to plants and their impact in our environment (Uno, 2009; Wandersee & Schussler, 1999).

Opposite to low awareness of plants, students' favour to use modern technologies is widely known as well as prevailingly positive impact of technology enhanced education on students' achievement in science (Higgins & Spitulnik, 2008; Lee et al., 2010).

From all these reasons a technology enhanced interdisciplinary teaching unit on double air-conditioning effect of vegetation in our climate was developed and tested in education at basic school.

### Interdisciplinarity in double air conditioning effect of vegetation

Plants cool themselves by evaporation of water via small valves in leaves (stomata). The majority of solar energy reaching the vegetation surface is used for water vapour – transpiration. Via transpiration plants control also the water balance in their root zone. Transpiration can transfer several hundred watts of solar energy per $m^2$. Phase transition from liquid into vapour is associated with changes of volume (18 mL of liquid forms 22,400 mL of vapour) and consumption of energy (0.68 kWh, 2.45 MJ $kg^{-1}$ at 20°C), which is cooling environment (Pokorný, 2019). Due to high water heat capacity, its transformation between liquid and vapour aggregate state involves exchange of energy. In cold places the water vapour condensate (e.g. via formation of fog or dew). The consumption of heat through water vapour in hot environment and the release of heat through condensation (e.g. via formation of fog or dew) in cold environment thus equalizes temperature differences in time between day and night or between spaces. (Pokorný, 2019; Schneider & Sagan, 2005). or release

To understand this „double air-conditioning effect" of vegetation on our climate at the level of basic school a knowledge obtained in physics (heat transfer, solar energy, vaporisation, condensation), biology (water vapour from plant leaves via stomata) and geography (solar energy distribution on the Earth, vegetation on the Earth) in interdisciplinary relations is necessary.

### Recent level of students' knowledge

Previous research discovered low students' knowledge of plant transpiration (Ryplova & Pokorny, 2019, Behar & Polat, 2007; Wang, 2004; Barker, 1998) as well as low ability to understand interdisciplinary relations between physical concepts and plant biology (Ryplova & Pokorny, 2019; 2018). This illiteracy is highly alarming, because knowledge of such core processes is necessary for proper understanding of ecological function of vegetation in retaining water in our environment.

## METHODS

Interdisciplinary teaching unit on double air- conditioning effect of vegetation based on the combined teaching in physics as well as biology lessons was developed and tested at basic school. In a total 29 nine grade students (14 male, 15 females, in an average 15.1 years old) were faced to this education following didactic survey of the impact of absolved education. A pre-test/ post-test design was used to test if this teaching a) improve students understanding of the double air conditioning effect of the vegetation, b) foster interdisciplinary relation between individual science disciplines. The students underwent the pre-test one day before and post-test one day after the last lesson. The results of the tests were statistically evaluated by using STATISTICA 12 PC package (StatSoft Inc.) and the differences between pre and post - test were compared by using Wilcoxon test.

## Design of the interdisciplinary science education

The teaching unit has interdisciplinary character, uses outdoor education and modern measuring devices (USB sensors for measuring air temperature and relative air humidity). The teaching started in biology outdoor lesson in school garden at the beginning of September, during sunny days but with relatively low night temperatures. The teacher discussed with students the evaporation of water from leaves via stomata and its ecological role in our climate and ware cycle in the landscape. To document this process, students were asked to place plastic bag on some branch of the tree and to leave it there for a few days. The teaching continue further during physics lessons, were students were remained about the measurement of air temperature and relative air humidity, heat conversion via evaporation and condensation. The students worked in groups, programmed on their own by using tablets simple USB sensors for measuring air temperature and relative air humidity and have learned to read graphs obtained from the sensors. The sensors were then placed on two different places: a) into the school garden with high density of vegetation, under the trees and b) on the school training court with no vegetation and water source in the area. The education continued next day during biology lesson. Students download the data from the sensors of both measuring sides into the tablets, discussed the obtained graph with a teacher. The students were asked to explain higher temperatures and lower air humidity during the day hours on the training court compared to school garden and lower differences between the day / night temperatures in the garden compared to training court. The final conclusions were done in a discussion with a teacher. As an evidence for the heat conversion via plant transpiration the water in the plastic bag removed from the tree in school garden was used.

## Didactic survey

An impact of the teaching was tested by using short questionnaire as pre/post-tests. The questions were based on the foregoing research (Ryplova & Poorly, 2019; 2019). Maximum amount of 9 points was possible to be reached:

1) *„What is happened with the majority of the solar energy reaching the tropical rain forest? "* (open type question, 1 point, as a correct any answer containing the use of solar energy for

water vapour from the vegetation was considered. Answers mentioning just photosynthesis or higher solar energy absorption due to leaf density were not considered as correct)

2) *„Imagine yourself: There is a late summer and you decided to overnight outside in a tent. The night temperatures are supposed to be quite low. You have a choice between two campsites where to stay overnight. The first one is open area campsite on the cut meadow with no trees, near of the small town. The second one is a campsite in a forest, under the trees and near of the pond. Which one do you prefer? Why do you thing, the night temperatures will be higher in this campsite? ",* (2 points, 1 for right choice of forest camp, 1 for explanation containing higher air humidity in forest air warming the air).

3) The question testing understanding of the double air conditioning effect of vegetation, ability to understand heat transfer via evaporation and condensation, ability to read and understand graphs. Students were faced to graphs describing the day/night course of air temperatures and relative air humidity in a) desert and b) tropical rain forest. They were asked:
    - to read from the graphs the highest day temperatures and lowest night temperatures in both areas (1 point for each correct answer, max. 4 points)
    - to count average day and night humidity (day time from 6:00 to 18:00, night time from 18:00 to 6:00) 2 points
    - to compare the day and night differences in both areas. Where are the differences bigger? – (right answer desert, 1 point)
    - to explain why were the differences bigger in chosen area (open type question, as correct any answer containing the role of transpiration in heat transfer in relation to the air humidity was considered – 2 points, answers mentioning just water vapour and condensation without plant transpiration were awarded by 1 point only)

In post-test students were asked as well, if they have enjoyed this education and if they would like to repeat similar kind of education again. They were asked to rate using the Likert scale how they enjoyed the work with USB sensors and how they liked to work on one topic during physics and biology lessons together.

## RESULTS AND DISCUSSION

The mean total score reached in pre-test was just 3.24 (±1.59 St. Dev.) points (Fig.1). In agreement with our previous research done among university – level students (Ryplova & Pokorny, 2019; 2018), also the data obtained from this research at basic school showed low students' knowledge about the solar energy distribution on the Earth as well as nearly no knowledge about the heat conversion via plant transpiration and condensation of vaporised water. Poor students' knowledge of plant transpiration was discovered also by several previous foreign studies (Vitharana, 2015; Wang, 2004; Barker, 1998). Students had also difficulties in reading and understanding graphs in question requiring students' decision based on the information obtained from graphs. The problems of working with graphs in biological context were already described by multiple previous works (Glaser, 2011; Maltese et al., 2015).

The results of post-test showed statistically significant improvement in total mean score 5.75 (±1.74 St. Dev.) points (Fig.1). The detail analysis of individual questions (data not shown because of the limited extend of the contribution) showed also improvement in using graphs and understanding of physical concepts relating to plant transpiration.

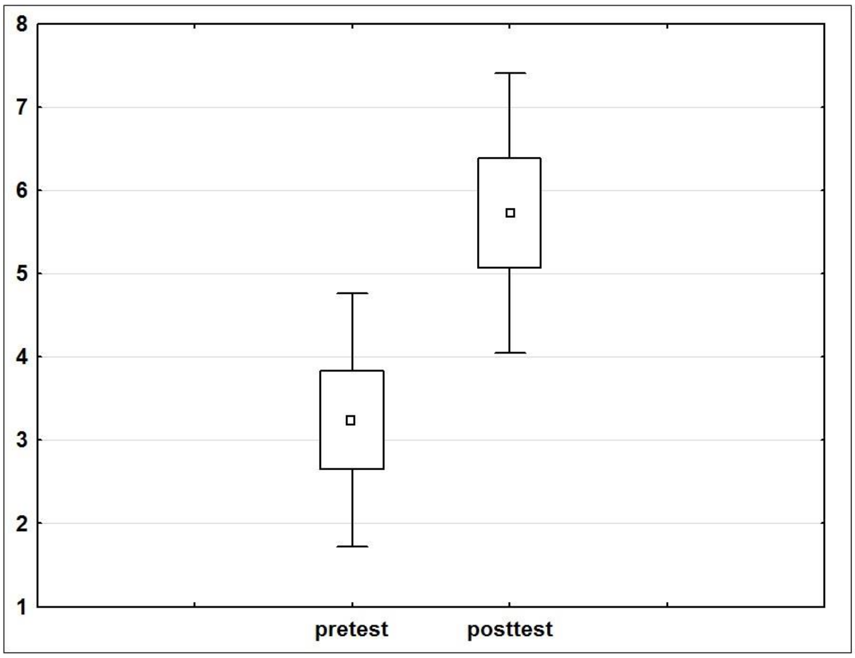


**Fig. 1 Mean test score reached by students in pre-test/post-test. Small squares represent mean values, boxes mean value± 2*std. dev., line segments mean value± 0.95*std. dev. N=29. Wilcoxon test, Z= 4.009130, p=0,00006USB sensors. Grade1= I did not enjoy, grade 5 = I enjoyed it very much**

The students were prevailingly enthusiastic during the learning and majority of them liked this kind of learning (82%) and would like to absolve similar learning again (74%). As follows from the analysis of the students rating, most of them enjoyed the use of modern USB sensors in education (median =4, Fig.2) and were also involved in interdisciplinary education (median =3, Fig.3).

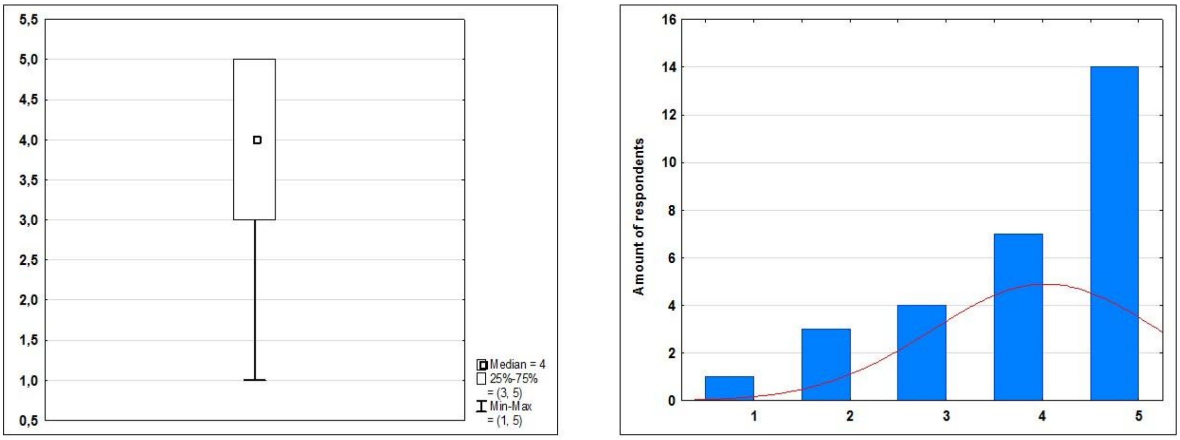


**Fig. 2 Statistic evaluation of the answers on the question "How did you enjoy the work with USB sensors". Grade 1= I did not enjoy such lessons, grade 5 = I liked it very much**

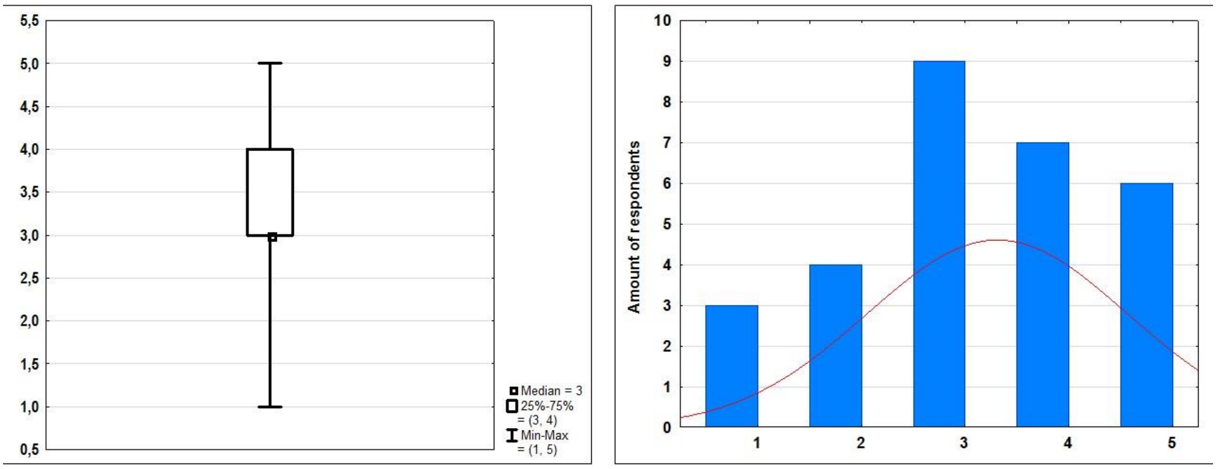


**Fig. 3 Statistic evaluation of the students' involvement of interdisciplinary education: Rate on the scale, how did you enjoy to learn the same topic in physic as well as in biology lessons? Grade1= I did not enjoy such lessons, grade 5 = I liked it very much**

## CONCLUSION

- The tested teaching unit improved students' understanding of the double conditioning effect of plant transpiration in the landscape
- The teaching helped students to understand physical principles in interdisciplinary relations to biology – heat transfer, evaporation, condensation
- The teaching improved the ability of students to use graphs in biological context

- This kind of interdisciplinary education required good time management and tight co-operation among biology and physics teachers

## ACKNOWLEDGEMENT

This work was supported by the project TACR TL 01000294 and GAJU 129/2019/S

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