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# Are attitudes towards science and technology related to critical areas in science education?

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**ABSTRACT**

**Background:** The importance of developing positive attitudes towards science and technology has been widely known, and it reflects a general interest and a strong need to define more explicitly what measures can be taken to improve student attitudes towards science. In Slovakia, in addition to a low interest in scientific jobs, there is another problem related to science: a long-term low level of science literacy. Therefore, we are interested in the ways in which a teacher can improve students' attitudes towards science, as significant studies highlight the importance of teachers.

**Purpose:** In our research, we compared attitudes towards science and technology among teachers of natural sciences with their students' attitudes. By analysing the teaching process, we sought critical areas in teaching natural sciences, and we also evaluated the relations between attitudes towards science and technology and the teaching process.

**Sample:** We explored the opinions of 498 students and 98 teachers of natural science subjects in Slovak secondary and high schools.

**Design and methods:** An e-questionnaire was used as a research tool. The processed quantitative data as well as their reliability were analysed statistically in the STATISTICA 8 (Statsoft) programme. Basic dependencies between the items were found by a correlation analysis. For comparing the collected points between individual categories and dimensions the ANOVA software was used.

**Results:** The statistical analysis showed a strong influence of the critical areas of teaching on student attitudes with respect to science. The most critical area was practical work in science, which was closely linked with inquiry-oriented activities in class.

**Conclusions:** In the conclusion, we propose further measures for improving student attitudes towards science and technology that teachers should focus on if they want to positively influence their students. The suggested measures could support the development of science literacy with the emphasis on the utilization of science in everyday life.

**KEYWORDS**
Science attitudes; science education; teaching; critical areas

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## Introduction

In Slovakia and other countries, the demand for scientifically oriented jobs is on the rise; however, the number of students with an interest in studying sciences is decreasing. Thus, there is a need to reverse this trend and encourage students to pursue science education. Research has consistently shown that individual interest in science is very important for learning science (Fančovičová and Kubiatko 2015). Furthermore, unless students are able to see the utility of science in their daily lives, they will become disinterested in science. The development of positive attitudes toward science can motivate student interest in science education and science-related careers (George 2006).

Among Slovak students, in addition to the problem of declining interest in science, there is a low level of science literacy, which is significantly lower than the average level of OECD countries (OECD 2018). The level of science literacy is dependent on the interest in science education. Therefore, it is definitively necessary to improve science literacy along with science education, by various means. Moreover, one of the key factors to succeed is to ascertain the attitudes of students.

It is especially important to examine students' attitudes towards science and technology, since their attitudes can lower or raise their performance in class (Papanastasiou and Papanastasiou 2004; Ali and Awan 2013). The measurement of student attitudes towards science is very difficult (Lederman 2007; Said et al. 2016; Losh, Wilke, and Pop 2008; Kind, Jones, and Barmby 2007; Hillman et al. 2016), and currently, there is no single construct. Research on attitudes in science education has focused on a wide range of aspects (Osborne, Simon, and Collins 2003) and has observed that students' in-class attitudes towards science appear to be shaped by factors such as the school climate, teaching, parental influence, cultural background, and level of aspiration (Hetherington et al. 2020; Toma, Greca, and Gómez 2019; George 2006).

Most literature points to teachers and teaching as being the most important factor of attitudes towards science (Hillman et al. 2016; Fraser, Aldridge, and Adolphe 2010; Osborne, Simon, and Collins 2003). Many studies (Hu, Leung, and Chen 2018; Raved and Assaraf 2010; Soltani 2020; Papanastasiou and Papanastasiou 2004; Ali and Awan 2013; George 2006) considered the correlation between attitudes and the quality of teaching to be very high, which clearly indicates the significant influence that teachers have on their students as well as on the learning process in general.

Although student attitudes towards science have been studied for decades, no significant progress has been made in terms of rendering these attitudes more positive (Pinto et al. 2014; Kind, Jones, and Barmby 2007; Denessen et al. 2015). Nevertheless, the importance of developing positive attitudes towards science has long been recognized, and widespread interest and concern has developed among researchers to more precisely define what measures can be taken to improve these attitudes among students (Sjøberg 2015; Ali and Awan 2013).

As already mentioned, several studies have observed the influence of various factors on attitudes towards science; however, we could not find a study that focussed on critical areas of education and their relationship with attitudes towards science and technology.

This is important to be explored mainly in countries with lower educational outcomes or a less developed educational system because it would be irrelevant to investigate these topics in countries where there are over-average results of science literacy. Along with Slovakia, other countries are attempting to find a way to improve science literacy and positively influence students' attitudes towards science.

These findings have helped us define our research questions (RQs), with which we investigated the opinions of teachers and students on science and technology. In class, teachers have the greatest influence on the development of their students' attitudes, and in this research, we will compare the teachers' and students' attitudes towards science. Science education in school is a vital area that needs to be addressed further to improve student attitudes towards science.

To investigate the potential influence of teachers on student attitudes towards science, we needed to know the following:

RQ1: What are the differences between science teachers' attitudes towards science and technology and their students' attitudes?

RQ2: What are the critical areas in science education resulting from students' and teachers' evaluations of the educational process?

RQ3: Is there a possible influence of the identified critical areas in science education on students' attitudes towards science and technology?

In conclusion, we outline possible measures for improving student attitudes towards science and which areas of teaching should be focused upon for teachers to positively influence these attitudes among their students.

## Slovak national curriculum

The content of the curriculum in Slovakia is specified for each grade by the educational standards in the National Educational Programmes (NEP), which set the general educational objectives and key competencies for which education should strive (NUCEM 2019; SPU 2008). A part of the NEP is an educational framework that includes a list of educational areas as well as compulsory and elective subjects.

According to the NEP of Slovakia, science subjects (physics, chemistry, and biology) belong to the educational area 'People and Nature', which contains the part of education connected to an investigation of nature. In this part, students are given the opportunity to understand nature as a dynamic system of relations and changes. Science subjects involve students in the process of understanding more in-depth phenomena in nature, on the basis of which they form their own attitudes towards science.

## Methodology

When creating a research tool for our study, an analysis of existing tools for measuring attitudes towards science was conducted (Papanastasiou and Papanastasiou 2004; Hillman et al. 2016; Oscarsson et al. 2009; Sjøberg 2015; OECD 2018). Given that we could not find a suitable research tool that would correspond to our research questions, we created our own e-questionnaire. We found the Programme for International Student

Assessment (PISA) questionnaire (OECD 2018) to be the most suitable. This questionnaire was, however, very extensive; thus, we selected only the most suitable items and adjusted them to our research goals.

Individual items in the questionnaire were valued according to a 4-point Likert scale. As a baseline, a questionnaire for teachers was created, and by adjusting several items, a questionnaire for students was created. An initial version of the teacher questionnaire was tested on some teachers of science subjects to eliminate indistinct items and wordings that were difficult to understand. From this feedback, the final versions of the teacher and student questionnaires were created. The questionnaire was distributed online to science teachers from different secondary and high schools in all regions of Slovakia at the beginning of 2020, which was before the COVID-19 pandemic was officially declared.

We asked the teachers to distribute the student questionnaires to their students. The teachers willing to include their students in this research distributed the e-questionnaire to at least one of their classes (i.e. approximately 15–20 students for each school).

The total number of respondents of our research was 596, of whom 98 were science teachers and 498 were students. Fifty-seven percent were secondary school teachers, and 43% were high school teachers. Most of these teachers were women (85% women and 15% men). We monitored the teachers' length of pedagogical experience. Our sample included teachers with the following lengths of experience: up to 2 years (5%), from 3 to 10 years (23.4%), from 11 to 20 years (31.8%), and over 20 years of pedagogical experience (39.8%).

The student questionnaire was designed for students between 15 and 18 years old; thus, it was intended for both secondary and high school students. The secondary school pupils were in their final year of studies, which means that they had completed all of the compulsory science subjects. This status implies that they were able to have an informed opinion about science as well as on teaching science subjects. The sample consisted of 63.1% secondary school pupils and 36.9% high school students.

The research sample proportionally corresponds to the real numbers of teachers and students in Slovak schools according to the following criteria by the Scientific and technical information centre of Slovak Republic (CVTI-SR 2020): school types, geographical areas (all 8 regions of Slovakia).

The introductory part of the questionnaire included items pertaining to identifying information, which were intended to help us characterize our sample more accurately. In the second part of the questionnaire, we researched the '*attitudes towards science*' *category*, which was divided into three dimensions (Tables 2 and 3). The three dimensions are *value of science to society* (7 questions), *attitudes towards school science* (5 questions), and *intrinsic motivation for science* (4 questions), and the endpoints of the scale are '*I agree*' and '*I disagree*'. For the third dimension, the individual items were adjusted and tailored for the teachers and students.

The third part of the questionnaire is the most extensive and investigates the opinions of teachers and students regarding their science lessons – category *teaching*. We asked, 'How often do the following situations occur during science lessons?' The endpoints of the scale in this category were '*very often*' and '*never or almost never*', and 33 questions were asked.

**Table 1.** Summary of the attitude towards science measures.

| Dimension | Cronbach's α Teachers | Cronbach's α Students |
|---|---|---|
| **Attitude towards science** (AS = VSS+ASS+MO) | 0.808 | 0.785 |
| Value of science to society (VSS) | 0.748 | 0.651 |
| Attitude towards school science (ASS) | 0.856 | 0.634 |
| Intrinsic motivation for science (MO) | 0.544 | 0.780 |
| **Teaching** (TEACH = BE+IBLE+PW+CE+TA) | 0.877 | 0.868 |
| Basic elements of active teaching (BE) | 0.529 | 0.597 |
| Inquiry-based learning elements (IBLE) | 0.657 | 0.651 |
| Practical work in science (PW) | 0.742 | 0.718 |
| Class environment (CE) | 0.816 | 0.647 |
| Teacher assessment (TA) | 0.895 | 0.843 |

The processed quantitative data as well as the reliability of the questionnaire were analysed statistically in STATISTICA 8 (Statsoft). We used a correlation analysis to find basic dependencies between the items. When we compared the collected points between individual categories, we used ANOVA. When finding the mean value for a particular attitude measure, the collected responses for each item were coded numerically (*4 = agree, 3 = somewhat agree, 2 = somewhat disagree* and *1 = disagree*; these ranks

**Table 2.** Teachers' quantified opinions about science compared with their students' opinions on the same statements. The list is ranked according to the teacher means in descending order (the maximum value is 4) with their respective standard deviations (SD).

| Statements | Teachers (N = 98) Mean SD | Students (N = 498) Mean SD |
|---|---|---|
| Value of science to society (VSS) | | |
| Science and technology are important for society | 3.75<br>0.438 | 3.49<br>0.532 |
| Science and technology can solve various global issues | 3.75<br>0.459 | 3.58<br>0.543 |
| A country needs science to develop | 3.62<br>0.53 | 3.51<br>0.554 |
| Science and technology will help find cures for serious diseases | 3.55<br>0.520 | 3.35<br>0.631 |
| Science and technology are the causes of environmental issues | 3.35<br>0.561 | 3.27<br>0.639 |
| Science will provide better opportunities for future generations | 3.16<br>0.620 | 2.82<br>0.691 |
| Benefits of science are greater than its potential harmful effects | 2.50<br>0.803 | 2.37<br>0.729 |
| Attitudes towards school science (ASS) | | |
| Science teaching is currently up to date | 3.40<br>0.622 | 3.09<br>0.637 |
| Science teaching prepares students for everyday life | 3.36<br>0.662 | 2.9<br>0.808 |
| Science teaching provides students with a comprehensive education | 3.34<br>0.642 | 2.89<br>0.801 |
| Science teaching prepares students for future work | 3.26<br>0.662 | 2.92<br>0.751 |
| Science teaching can increase one's chances to land jobs | 3.18<br>0.647 | 2.81<br>0.799 |

**Table 3.** 'Intrinsic motivation' in terms of teachers' and students' mean responses, where the maximum value is 4.

| Intrinsic Motivation (MO) | Teachers (N = 98) | | Students (N = 498) |
|---|---|---|---|
| Statements | Mean SD | Statements | Mean SD |
| Research is an important tool for professional teachers | 3.17 0.70 | I enjoy science topics | 3.04 0.655 |
| During my studies (professional teacher preparation), I pursued inquiry-based activities | 2.76 0.838 | I like to read about science | 2.57 0.805 |
| Currently, I attend (am interested in) trainings with the topic of innovation in science (new scientific knowledge) | 2.83 0.760 | I enjoy solving tasks from the area of sciences | 2.59 0.738 |
| Currently, I attend (am interested in) trainings with the topic of innovations in education | 3.16 0.728 | I am interested in novel knowledge from the area of sciences | 3.04 0.695 |

were reversed for negatively worded items). The reliability of the questionnaire was tested with Cronbach's alpha (Table 1). The total alpha for teachers was 0.914, and the comparable total for students was 0.882.

## Results and discussion

### *RQ1: What are the differences between science teachers' attitudes towards science and technology and their students' attitudes?*

We investigated the attitudes towards science in three dimensions: '*value of science to society*', '*attitude towards school science*', and '*intrinsic motivation for science*'.

From the data in Table 2, one can conclude that teachers and students rate *the value of science to society* and *attitudes towards school science* in the range between 2.37 and 3.75 (mean score), with a maximum value on the scale of 4. Questions pertaining to external motivation (the motivation focused on the expected future value and the usability of science subjects in employment) were also evaluated positively, which reflects the degree of student interest in sciences on the ground of their use in a future professional life. Students are aware of the importance of studying sciences in connection with their employment possibilities.

The next step (the third dimension) in this analysis was to examine the *intrinsic motivation* of teachers and students for conducting scientific research and how they pursue it. The questions we asked are shown separately in Table 3. The teachers were monitored for their current professional scientific development, and the students were monitored for their interest in new scientific knowledge.

In our research (Table 3), most teachers claim that research is an important tool for professional teachers. In addition, most teachers claim that they still educate themselves today, and this education is mainly in the field of pedagogical practice but also in professional scientific preparation.

We researched the intrinsic motivations of students by asking if they were interested in science. As seen from the mean values in Table 3, most students enjoy science topics and are interested in new scientific findings.

When comparing all three of the monitored dimensions (Figure 1), it is clear that the strongest figure corresponds to the evaluated *value of science to society*; then, we have *attitudes towards school science*, and the weakest dimension is *intrinsic motivation* in both target groups. We can also state that all three dimensions are valued significantly more negatively among students than among teachers (p = 0.0000 for VSS, p = 0.0000 for ASS and p = 0.0047 for MO). The causes of this phenomenon are varied. As already mentioned, attitudes towards science are influenced by many different factors (Oscarsson et al. 2009). Hence, in the following questions, we will try to find the relationships among our dimensions in the category *Teaching*, and we will monitor the direct impact of teaching on attitudes towards science.

## *RQ2: What are the critical areas in science education resulting from students' and teachers' evaluation of the educational process?*

To identify the critical areas, we needed to investigate the opinions of our respondents on the teaching process, and subsequently, based on the responses' analysis of teachers and students, we identified the critical areas.

In 33 questions of the questionnaire, we monitored the opinions of the teachers and their students on various aspects of teaching. Naturally, the questions were grammatically adapted to the target group; hence, the tables use the passive voice. Because there were many items, we divided the questions into several dimensions, which facilitated our

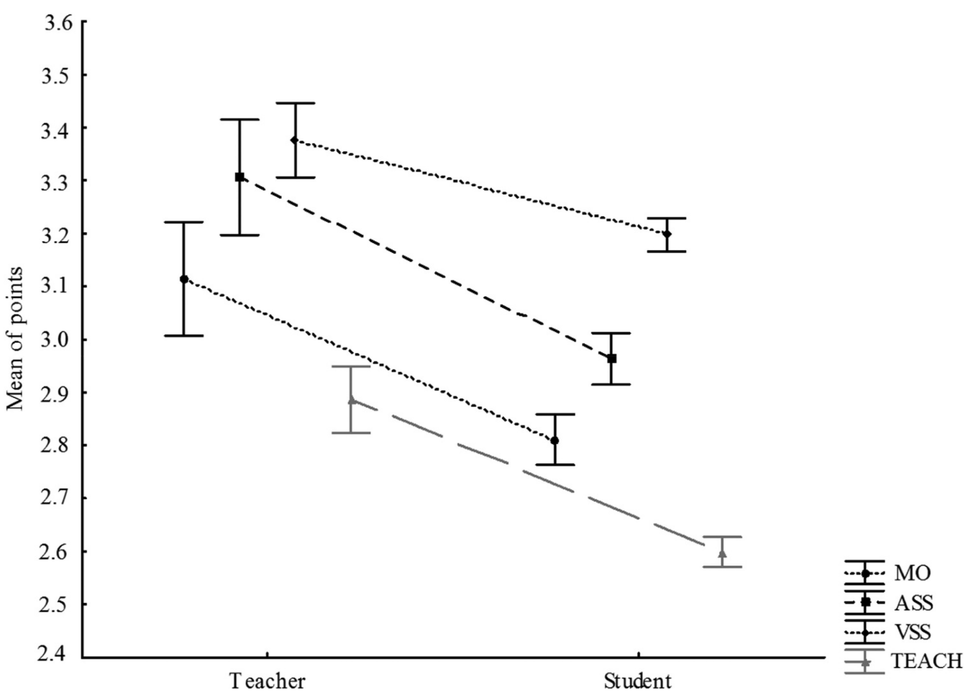


Figure 1. Comparison of the mean values of the obtained points between teachers and students for the *value of science to society* (VSS), *attitude towards school science* (ASS), *intrinsic motivation* (MO) and *teaching* (TEACH).

statistical analysis. Then, we focused on finding more detailed correlations. We determined the dimensions according to our criteria, as it is difficult to assign each item to a specific dimension. Indeed, this assignment is a matter of perspective (Barmby, Kind, and Jones 2008), and we monitor which aspects of teaching indicate changes in students' attitudes.

We identified 5 dimensions in the second category, 'Teaching' (TEACH): *basic elements of active teaching* (BE, 7 questions), *inquiry-based learning elements* (IBLE, 9 questions), *practical work in science* (PW, 6 questions), *the class environment* (CE, 5 questions), and *teacher assessment* (TA, 6 questions).

When tracking the dimensions, we found only basic information. A comparison of the mean values of the results showed that *practical work* was valued as the weakest dimension in both target groups and that *the class environment* was assessed as the strongest dimension (Figure 2). In the *practical work dimension*, the relative mean value among students was 2.16, and among teachers, it was 2.44 from the maximum value on scale 4. The dimension *class environment* was assessed by teachers with a mean score of 3.01 and by students with a mean score of 2.87.

To analyse the data in depth and not only evaluate them in general, we have arranged all of the items that relate to teaching in Table 4. We sorted the results obtained from the analysis of teaching in descending order according to the mean values of the students' answers, and we compared them with the order of the mean values of the teachers' answers. For the sake of clarity, the order is given for both students and teachers. From Table 4, it is possible to derive the interesting fact that the first and last places are identically valued by the teachers and students. In the top six items, the students' and teachers' results were identical. Both target groups agree that they will learn more when they are actively involved in the teaching process and when the teacher clearly explains to them the importance of scientific knowledge in life.

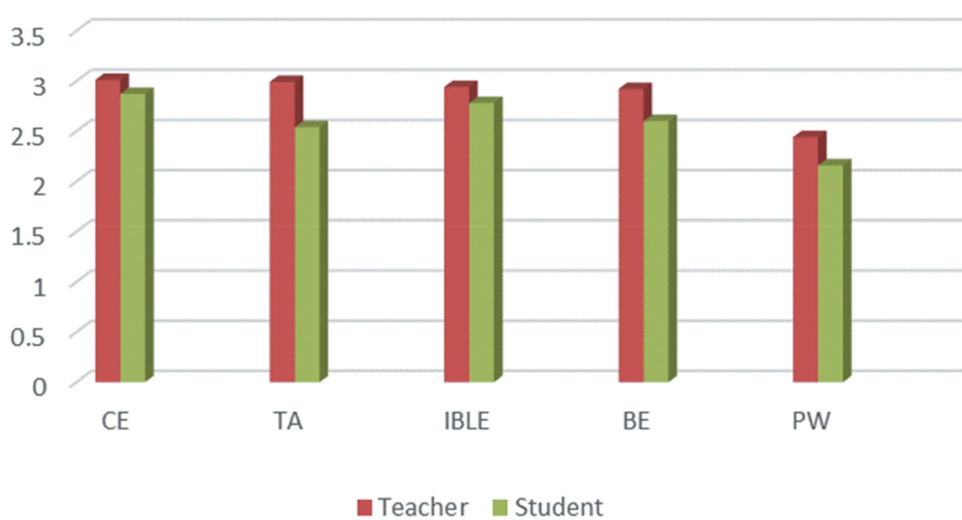


**Figure 2.** Score dimensions of teacher and student teaching (TEACH) (CE – *the class environment*, TA – *teacher assessment*, IBLE – *inquiry-based learning elements*, BE – *basic elements of active teaching*, PW – *practical work in science*).

**Table 4.** Students' mean values of researched items in descending order and their comparison with the order of teachers' mean values. Each item refers to a specific teaching dimension in parentheses *(4 = agree, 3 = somewhat agree, 2 = somewhat disagree and 1 = disagree; these ranks were reversed for negatively worded items).*

| | Students | | Teachers | | |
|---|---|---|---|---|---|
| Item (Dimension) | Mean | Order | Mean | Order | Diff. |
| Students learn more during active work methods (BE) | 3.38 | 1. | 3.28 | 1. | 0 |
| The teacher understandably explains the significance of science knowledge for life (IBLE) | 3.14 | 2. | 3.24 | 2. | 0 |
| The teacher gives additional help when students need it (TA) | 3.13 | 3. | 3.21 | 3. | 0 |
| The teacher lets us express our opinion (CE) | 3.3 | 4. | 3.15 | 6. | 2 |
| The teacher requires us to logically explain our answers (IBLE) | 3 | 5. | 3.17 | 5. | 0 |
| In class, we discuss the results of given tasks together (IBLE) | 2.99 | 6. | 3.17 | 4. | 2 |
| *The teacher gives students feedback about their strengths in science subjects (TA)* | *2.97* | *7.* | *2.81* | *23.* | *16* |
| *The students discuss the results of tasks with each other (IBLE)* | *2.96* | *8.* | *2.79* | *24.* | *16* |
| I do not understand what the teacher requires from us (CE) | 2.94 | 9. | 2.99 | 11. | 2 |
| The teacher has to wait until we quiet down (CE) | 2.88 | 10. | 2.97 | 12. | 2 |
| It is noisy and untidy in class (CE) | 2.83 | 11. | 3.12 | 7. | 4 |
| The teacher advises students how to reach their study goals (TA) | 2.79 | 12. | 2.93 | 15. | 3 |
| The teacher has an interest in students' learning process (TA) | 2.76 | 13. | 3.30 | 10. | 3 |
| The teacher prepares us for various competitions (BE) | 2.76 | 14. | 2.92 | 17. | 3 |
| *The students solve problem-based tasks that require solution proposals (IBLE)* | *2.72* | *15.* | *2.79* | *25.* | *10* |
| *After being given the task, everyone works individually (IBLE)* | *2.7* | *16.* | *2.69* | *27.* | *11* |
| The students do not listen to what the teacher says (CE) | 2.69 | 17. | 2.84 | 20. | 3 |
| The teacher requires us to remember explicitly the terms and definitions (BE) | 2.69 | 18. | 2.92 | 16. | 2 |
| *The teacher tells students how they progress in the subject (TA)* | *2.66* | *19.* | *2.63* | *29.* | *10* |
| The teacher explains scientific phenomena with demo-experiments (PW) | 2.56 | 20. | 2.85 | 19. | 1 |
| The teacher informs students of the areas in which they can (TA) | 2.54 | 21. | 2.73 | 26. | 5 |
| The teacher encourages students to bring unique solutions (IBLE) | 2.48 | 22. | 2.82 | 22. | 0 |
| We solve tasks in groups (BE) | 2.43 | 23. | 2.83 | 21. | 2 |
| *The teacher requires students to present task solutions (IBLE)* | *2.37* | *24.* | *3.40* | *9.* | *15* |
| *We understand the used academic literature (BE)* | *2.35* | *25.* | *2.95* | *14.* | *11* |
| We work in a lab where we conduct practical experiments (PW) | 2.25 | 26. | 2.43 | 30. | 4 |
| *We utilize information technology in class (BE)* | *2.23* | *27.* | *3.80* | *8.* | *19* |
| *The teacher asks us to draw conclusions from experiments (PW)* | *2.15* | *28.* | *2.95* | *13.* | *15* |
| The students solve real-life tasks (BE) | 2.14 | 29. | 2.64 | 28. | 1 |
| *The teacher lets us propose procedures for solving tasks (IBLE)* | *2.9* | *30.* | *2.89* | *18.* | *12* |
| The teacher requires us to validate our ideas with research (PW) | 1.85 | 31. | 2.15 | 33. | 2 |
| We go into nature for excursions (PW) | 1.7 | 32. | 2.17 | 32. | 0 |
| We can propose our own experiments (PW) | 1.65 | 33. | 2.24 | 31. | 2 |

* Basically identical results of teachers and students are marked in bold, and the most uneven results are marked in italics.

The data show that the weakest area is *practical work* in science. It strongly suggests that the importance of practical work in the laboratory and practical lessons in teaching science subjects is an important aspect of teaching, as the student has the opportunity to work directly with the scientific method and significantly contributes to the understanding of the principles of science (Sharpe and Abrahams 2019; Pekmez, Johnson, and Gott 2010; Gumilar and Ismail 2021). In comparison, students rate these items more unfavourably than teachers do. We found that most students cannot design their own experiments, do not venture into nature and do not go on excursions. Moreover, only a small proportion of teachers require students to validate their proposals with research. Therefore, the items in *practical work*, which are closely related to teaching science as an inquiry, are also poorly valued.

In the dimension *basic elements*, we were surprised by the opinions of both the students and the teachers. We assumed that these elements would be among the most highly rated elements, as they are commonly used activities in teaching, but they were poorly valued by both target groups. This rating applies in particular to solving tasks from everyday life, comprehensive reading, and working in groups.

When considering the other items related to teaching, we noticed different evaluations from the points of view of the students and teachers. Thus, we sought to find the largest differences in the evaluations between teachers and students. Accordingly, we found differences in the opinions on specific items, which are shown in the last column of Table 4, where we calculated the absolute value of the difference in the order among the teachers and students. The items for which we noticed a large difference (10–19) in the order bars are highlighted in italics in Table 4.

When we compared *basic elements* between teachers and students (the last column of Table 4), we found the highest differences of opinion for the item of IT use: whereas students rate this item very poorly (27th place in the ranking), teachers rate it fairly positively (8th place), a difference of 19 places. This discrepancy is probably caused by students' better orientation in this area than the teachers themselves.

A difference of 11 places was found for the item of reading comprehension/understanding. Many of the students' failures in solving complex scientific problems are caused by insufficient work with scientific text and argumentation to prove their solutions. Working with text by focusing on the proper questions to ask when formulating ideas about the whole text is a solid method for improving problem-solving skills. Many students are unable to withdraw substantial information from text and the relationships related to the problem (Bellová, Melicherčíková, and Tomčík 2018). When observing inquiry-oriented activities, we remained slightly confused because some items of the questionnaire from *inquiry-based learning elements* are in the first places from the perspectives of teachers and students (e.g. the teacher clearly explains the importance of scientific knowledge for life, the teacher requires from us a logical justification of our answers, and the class discusses the results of solving tasks), but for other *inquiry-based learning elements* items, we observe large differences in evaluation. In our opinion, this discrepancy is another critical point of teaching because the difference is as high as 10 or more points for some items (e.g. the students discuss the results of problem solving with each other, the teacher requires students to present problem solutions, and the teacher lets students suggest procedures for solving scientific tasks). We believe that this finding may be related to practical work, which we have identified as critical. When there are no *inquiry-based learning elements* in teaching, i.e. when students rarely work in the laboratory, they cannot design their own experiments, and the teacher does not require them to verify their ideas by experiments, we can conclude that the teaching is basically implicit. Explicit teaching requires students to think about what they did during an inquiry and what their actions mean for the interpretation of the results (Concannon et al. 2020), and this is only partially fulfilled. Implicit teaching is not sufficient to enable students to understand science (Lederman 2007; Baroudi and Helder 2019).

### *RQ3: Is there a possible influence of the identified critical areas in science education on students' attitudes towards science and technology?*

Quantified answers of the respondents in the dimensions *attitudes towards science* (AS) and *teaching* (TEACH) were compared in the correlation analysis, which enabled us to obtain an idea of the dependencies. The values of the correlations between the dimensions were between values 0.10 and 0.57, while all values were significant.

The correlations observed in *teaching* confirmed the connection of all of the monitored dimensions of teaching among students. Two dimensions of teaching, namely, *basic elements* (r = 0.20) and *practical work* (r = 0.15), have the strongest influence on students' *attitudes towards science*. When identifying the critical points in teaching from the teacher's point of view, the most critical dimensions are again *practical work in science* (r = 0.17) and *basic elements* (r = 0.21). All the correlations are significant.

## Summary of the analysis

When analysing the teaching and defining the critical points, we identified two groups of items that we consider to be weak points in the teaching of science subjects. The first group consists of areas that were valued by both target groups as the weakest; this group clearly covers the whole dimension of *practical work* and some items from the dimension *basic elements of active teaching*, which should be commonly used teaching activities (examples include solving real-life tasks, group work, and independent problem solving, reading comprehension/understanding). Despite practical work being a major part of school science, teachers do not always implement it in teaching, which was also confirmed by our analysis. Many studies have confirmed students' interest in practical work (Sharpe and Abrahams 2019; Pekmez, Johnson, and Gott 2010), however, our research revealed an insufficiency of practical activities in teaching.

The second group consisted of items with the largest difference in evaluation, as the teachers and students expressed differences of opinion on specific items. These items were mostly *inquiry-based learning elements* (IBLE) items, but some items from *basic elements* (BE) were included. The correlation analysis showed the strongest influence among students on their attitudes towards science in *practical work* (PW) and BE, which confirmed that these critical points significantly affect students' *attitudes towards science*.

In the overall evaluation of the teaching dimensions, both target groups rated *the class environment* (CE) the most positively, but the correlation analysis did not confirm a significant impact on the formation of students' *attitudes towards science* with this dimension.

## Measures to improve students' attitudes towards science

Based on the areas that we have identified as critical in teaching science subjects, we propose the following measures to improve students' attitudes towards science. Science education should clearly lead to utilizing the natural way of knowing the world in the research process, and it is based on curiosity, the creation of questions and hypotheses and their subsequent verification in a reasonably appropriate way (Gott and Duggan 2007). Thus, traditional scientific research enters the educational environment, which aims to solve the problem of motivation and the problem of the quality of education as well as the development of skills to work scientifically (Hellgren and Lindberg 2017; Bellová, Melicherčíková, and Tomčík 2018).

Our results indicate that the curriculum of science subjects should be strengthened by practical activities that allow students to engage in inquiry processes (Čipková, Karolčík, and Scholzová 2020; Leonard, Speziale, and Penick 2001; Tomčíková 2020; Baroudi and Helder 2019).

It is essential for students' understanding of science not only to teach them about the importance of science but also to focus on the implementation of various teaching activities while teaching. These activities include laboratory activities, videos, reading assignments, interactive presentations of scientific content, and solving tasks in the context of scientific knowledge (Wilson et al. 2010; Bellová, Melicherčíková, and Tomčík 2018).

We propose that teachers should understand experiments not only as isolated stimulating experiences for students that they could present in their lessons but also as part of a broader purpose, namely, as a component of the concept of research-focused science education. It is important that those inquiry-oriented activities occurring in the classroom are explicitly connected to scientific inquiry (Capps and Crawford 2013; Kruit et al. 2018; Cincera et al. 2017; Baroudi and Helder 2019). We believe that in scientific research, because it is important that students understand the principles of scientific processes, it is necessary to achieve a deeper understanding that leads to effective education.

While implementing active teaching, teachers should not forget to utilize important practical elements of teaching, such as solving real-life tasks, group work, and independent problem solving, which we also identified as critical points.

For the improvement of students' attitudes towards science, it is not only important what they learn but also mainly how they learn. Teaching activities and educational elements that the teacher includes in the teaching process are essential. The content of subjects usually cannot reflect new knowledge as quickly as the media, but the pace of innovations in science education and their implementation should (in our opinion) be much faster. As it has been confirmed to us that teachers follow new scientific knowledge, they should also make time while teaching to comment on current events at home and worldwide so that they can connect the curriculum with everyday life (as both teachers and students valued low the item 'The students solve real-life tasks'). In this way, they can increase the motivation of students, as the motivation for studying science is low according to our findings.

Group work and individual work have justifications in inquiry-oriented activities (Forbes, Forbes, Neumann, and Schiepe-Tiska 2020; Owen et al. 2008; Gumilar and Ismail 2021). In our opinion, the creation of situations in which students learn from each other should be part of teaching. A list of situations and creations is as follows: questions (including both student-to-teacher questions and questions between students); discussions with teachers and between students; the formulation of opinions; and these opinions' subsequent presentation, defence, and support with arguments (Gott and Duggan 2007).

Another important objective of learning is to develop reading literacy based on work with scientific texts. Students should understand these texts and use the information to complete specific tasks (Bellová, Melicherčíková, and Tomčík 2018). The results of the survey showed that teachers learn constantly and that their interest in new scientific knowledge is significant, but they should probably also focus on improving the pedagogical process in the field of IT. The appropriate use of modern digital technologies is one of the most important factors that can increase the efficiency of education, but its implementation requires a teacher who knows how to use these technologies (Williams and Otrel-Cass 2017).

## Conclusion

In our research, we examined students' and teachers' attitudes to see how teachers can positively influence students' attitudes towards science. The results showed that students evaluate the category '*attitudes towards science*' (including the three dimensions VSS, ASS, and MO) and the category of *teaching* (TEACH) more negatively than teachers do (Figure 1).

Based on our proposed recommendations for the teaching of science subjects, teachers could positively influencing students' attitudes towards science. Osborne, Simon, and Collins (2003) argued that for science subjects in general, the research evidence clearly shows that teacher variables are the most important determinants of attitude rather than curriculum variables. The above results indicate that we can take the view of several pedagogical studies that have shown that science teachers can have a positive effect on students' attitudes towards science. We can emphasize the importance of teachers in general and the way in which they present the science content and organize their work in particular (Hillman et al. 2016; Fraser, Aldridge, and Adolphe 2010; Osborne and Collins 2001). In addition, we highlight how teachers provide information on the use of inquiry-oriented activities that are most beneficial for science (Forbes, Neumann, and Schiepe-Tiska 2020; Wilson et al. 2010; Kruit et al. 2018).

Thus, because we have statistically found that these critical areas significantly affect students' attitudes towards science, the teacher can improve the given circumstances by removing or at least mitigating the identified critical areas in teaching. The recommended measures could support the development of science literacy with an emphasis on the actual use of science in everyday life.

We do not claim that our results are 100% reliable because only a few possible features that can influence students' attitudes towards science were observed, especially in the learning process. Given that we collected a great number of responses and the questionnaire reliability was satisfactory, we believe that we obtained a sufficiently clear representation of the situation in the context of our research questions. Based on Cronbach's alpha, one can assume that our attempt was successful.

There are certainly many other factors that can be further explored. The limitation is that our sample is selected only among Slovak teachers and students who adhere to the established standards for Slovak schools (NUCEM 2019).

We believe that our recommendations could be beneficial in general, also for other countries that attempt to improve the level of education, taking into account individual specifications of each country's educational system. It would be worth considering extending our research by individual personal interviews with teachers and students, which would supplement our results with qualitative data.

It could be beneficial to compare our study of the Slovak educational system with an educational system of another country with a similar level of science literacy.

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