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Scientific paper

Assessment of the 14- and 15-Year-Old Students' Understanding of the Atmospheric Phenomena

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Abstract

The main purpose of this study was to identify understanding of atmospheric pollution phenomena such as acid rain, global warming, ozone layer depletion and photochemical smog among grade 9 lower secondary school students (aged 14 to15), in all Slovenian regions. The research involves the development of a three-tier multiple-choice diagnostic test entitled the Atmospheric Pollution Phenomena Diagnostic Test (APPDiT). APPDiT is a 15-item diagnostic test comprising items for assessing students' understanding and self-confidence of atmospheric pollution problems. The results reveal that the majority of the participants demonstrated a lack of knowledge or misconception about atmosphere pollution since the overall success rate on the APPDiT was 39.6%. In particular, only 36.7%, 5.1%, 42.7% or 19.1% of the students have adequate knowledge regarding understanding of the formation, consequences, and strategies to reduce acid rain, global warming, ozone layer depletion and photochemical smog, respectively. This shows a substantial students' knowledge deficits related to atmosphere pollution at the end of the compulsory education in Slovenia.

Keywords: Three-tier diagnostic test; atmospheric pollution; adequate knowledge; lack of knowledge; misconception; self-confidence

1. Introduction

Across the globe, both the extent and the impact of air pollution are highly variable.[1] Air pollution is induced by the presence of toxic substances in the atmosphere, mainly produced by human activities in recent years,[2] which generate a number of phenomena that affect the ecosystem and living beings. Acid rain, global warming, ozone layer depletion and photochemical smog are the major ecological phenomena of air pollution.[3] Therefore, air pollution control is vital and should be top of the priority list of governments.[4] What is even more important than control is the knowledge and understanding of the formation of air pollution and their impact on health, because with suitable environmental awareness people can significantly reduce intentional environmental damage. One way to make this happen is through education, in particular science and environmental education. In addressing environmental issues, it is imperative to begin with youngsters in order that they become more concerned about the environment and also engaged in actions to protect it, since this is contributing to sustaining the environment for generations to come.[5,6] For that reason, teachers are responsible for developing students' environmental awareness and knowledge in the classroom. All major environmental education documents and International Conferences recognize explicitly the importance of knowledge and understanding of general environmental principles.[7] Researchers are convinced that education is an effective strategy for preparing young people to learn about environmental issues. Some research reveals that disinterest toward environmental issues is due to a lack of knowledge, while those students that are well informed about environmental issues also showed interest in them.[8–10] If we want to achieve lifelong understanding of environmental phenomena, environmental learning must be included throughout the entire vertical of the curricula, as this would also encourage cross-curricula integration.[11]

Recently, it has been shown that students of all ages have many misconceptions regarding environmentally-related content, as they poorly distinguish between general environmental problems.[12,13] For example, the majority think that the "*hole*" in the ozone layer contributes to global warming by allowing greater penetration of the sun rays resulting the increase of the Earth's temperature. Recently, Yazdanparast et al.[14] identified significant misconceptions among 12 and 18 years old students regarding atmosphere composition, as 45.1% of students think that the most common gas in an unpolluted atmosphere is oxygen, while only 23.7% of respondents know that this gas is nitrogen. Valeiras et al.[15] found similar results with Argentinean students, where 87.0% of students identified that the atmosphere is composed mostly of oxygen. Sah et al.[16] reported that around 71.0% students between 12 to 15 years identify the burning of coal as the main atmospheric pollutant and around 2.0% of students identified other fossil fuels, e.g. oil, as the important atmospheric pollutants. Other studies show that most students identify industry and energy as the main causes of pollution, followed by the use of deodorants, fertilizers and pesticides.[17,18] However, Dove et al.[19] found that most students recognize industry and transport as the main sources of acid rain formation, but they are not aware of the primary pollutants such as nitride and sulphur oxides that enter the atmosphere and cause the formation of acid rain. Furthermore, students think that atmospheric phenomena such as acid rain, ozone depletion and the global warming are caused by the same pollutants.[20] Other researchers have shown that misconceptions about many environmental issues, climate change included, are not only held by students but by teachers as well.[21] Due to the complex relationship between different atmospheric phenomenon, not only teachers' but also the media and literature have referred to them in synonymous ways in spite of their entirely different meanings. This and many other misconceptions concerning the causes of atmospheric phenomenon probably affect peoples' ideas about the actions that need to be taken to alleviate them. If these misconceptions can be identified and addressed already at primary school level, students' conceptual understanding of environmental issues can be further developed. And for this reason, there has lately been significant interest in educating students about atmospheric phenomenon, so as to enable them to successfully cope with atmospheric pollution.

Common approaches to identifying misconceptions are the use of open-ended questions, multiple choice questions, multi-tier diagnostic questions (3-tier or 4-tier items), and interviews.[22] In the 3-tier format, the first tier requires a fact-based response (Tier 1; a multiple-choice answer tier). The second tier is reasoning for that response (Tier 2; a multiple-choice reason tier) and the third tier is a confidence scale (Tier 3; e.g. a six-point confidence scale) to indicate how confident respondents are in the correctness of their responses to the answer and reason tiers. The addition of a confidence scale helps to overcome some of the limitations of the 2-tier format, wherein, it is not easy to differentiate whether a correct response can be attributed to a high level of understanding or whether it is due to guessing.[23] For example, if the responses to both tiers are incorrect but confidence is high, it is an indication of a misconception. On the other hand, if the responses to both tiers are correct but confidence is low, it could mean a lack of knowledge, rather than good understanding.[22] A more detailed probing of students' concepts understanding can be executed by applying 4-tier items, but for the purposes of this study a simpler version of the 3-tier items was used. The main reason for this decision was the students' age (14-years-olds solve items more effectively when they are not too complicated) and the fact that the 3-tier items can also be valid enough to identify students' conceptions.

2. Research Problem and Research Questions

Knowledge of environmental problems and pollution-related phenomena has grown over the last two decades especially in basic schools, as the environmental crisis is the greatest threat mankind collectively has ever faced, even beyond the threat of nuclear warfare according to Pikhala et al..[24] In Slovenia, there is little attention paid to environmental education.[25,26] In the contemporary education, students do not learn much about environmental issues.[27] Although the environmental concepts are present in the primary and secondary school science curriculum, but there are usually not enough lessons to include environmental education into actual classroom activities, so that the adequate students' environmental literacy could develop.[28] In chemistry and biology, students should be taught the main causes of air, water and soil pollution and their effects on people's health and lives, but we do not have enough data to evaluate students' basic understanding of environmental issues.[29]

The aim of the present research is to identify the level of 9 grade primary school students' understanding of atmospheric phenomenon, such as acid rain, global warming, ozone layer depletion and photochemical smog. For that purpose, two research questions were formed:

(1) What is 14- and 15-year-old students' current level of knowledge regarding the atmospheric phenomena?

(2) Do students understand the reasons for atmospheric phenomenon such as acid rain, global warming, ozone layer depletion and photochemical fog?

3. Method

A cross-sectional non-experimental and descriptive research approach was used in this research.[30]

3. 1. Participants

Altogether, 1012 lower secondary school (grade 9; last year of compulsory basic education in Slovenia) students participated in this research. The sample represented 5.8% of the whole population of 9-grade students (17.475 students) in the school year 2017[31] in Slovenia. Students were from 24 schools (representing 5.3% of all 452 lower secondary schools in Slovenia). Schools were sampled from eight different regions of Slovenia; 20.8% were from Primorska, 2.5% from Notranjska, 9.7% from Dolenjska, 22.7% from Osrednjeslovenska, 24.0% from Gorenjska, 12.4% from Savinjska, 3.8% from Posavska and 4.2% from the Pomurska region. The sample consisted of 474 (46.8%) male and 538 (53.2%) female students. The students' average school grade in biology is 3.8, in chemistry 3.7 and in physics 3.5 (grades' scale from 1 to 5; 1 meaning insufficient and 5 meaning excellent).

Purposive sampling was used to select participants for this research. However, all eleven statistical regions of Slovenia were included in the sampling. The nine grade students were selected according to their expressed interest to participate in the research, and also according to the interest of students' chemistry teachers, school principals and their parents/caregivers. Before applying the instruments, students' parents/caregivers granted all necessary permissions for students' participation in the research.

3. 2. Instruments

The data was collected using two instruments: the information about participants (IP) and a diagnostic instrument entitled Atmospheric Pollution Phenomena Diagnostic Test (APPDiT) to measure students' understanding of atmospheric phenomenon as the result of the pollution because of human activities. The content validity of the instrument was confirmed by six independent experts in chemical and environmental education. Both instruments were designed specifically for this study. The full texts of the instruments can be obtained by request from the corresponding author.

The IP questionnaire comprises of general information about the participants (e.g. gender, school, region, and grades in biology, chemistry, and physics. The APPDiT comprise of 15 three-tier multiple-choice items. Each task measures students' understanding of specific environmental phenomena such as: acid rain, global warming, ozone layer depilation, and photochemical fog. Each item, as presented in Figure 1, includes three-tiers: a multiple-choice answer tier (Tier 1), a reasoning tier (Tier 2) describing an expected reason for the students' answer selected in Tier 1 and a six-point confidence scale (Tier 3) – the answers obtained in the six-point confidence scale correspond to *"1-just guessing"*, *"2-very unconfident"*, *"3-unconfident"*, *"4-confident"*, *"5-very confident"* and *"6-absolutely confident"* and expresses the students' confidence in giving the answer and the reason for it (Tiers 1 and 2). In order to simplify the discussion, the following answers from the confidence scale were merged as follows: ″Not Sure″, when students choose "*1*" or "*2*" on the confidence scale, fol-

8. Which compounds are responsible for the global warming?

A Chlorofluorocarbons.
B Sulphur dioxide.
C Carbon dioxide.
D Carbon dioxide, Methane and Chlorofluorocarbons.

8.1 Why did you choose such an answer in the above question No. 8?

A CFCs (chlorofluorocarbons or freons) that can be found in deodorants are responsible for the increase of greenhouse gases.
B Sulphur dioxide (SO_2) reacts with water droplets in the air, and the resulting precipitation affects the increases of greenhouse gases.
C Carbon dioxide (CO_2) that is generated through burning of fossil fuels is the only gas that affects the global warming.
D Gaseous molecules with at least three atoms can absorb heat and emit it back into the atmosphere, which increases the greenhouse effect.

8.2 How confident are you in the correct answer?

1	*2*	*3*	*4*	*5*	*6*
Just guessing	*Very unconfident*	*Unconfident*	*Confident*	*Very confident*	*Absolutely confident*

Figure 1. An example of the task no. 8 in APPDiT; 1st tier (8), 2nd tier (8.1); 3rd tier (8.2.); the correct answer and the correct reason are presented in bold.

lowed by ″Sure″, which corresponds to "*3*" or "*4*" and ″Very Sure″ when students pick "*5*" or "*6*" on the confidence scale. The overall response possibilities in the APPDiT (first, second, and third tiers together) resulted in the following categories: *(i)* a combination of correct (tier 1) and correct (tier 2) and very sure or sure (tier 3) answers was treated as *Adequate knowledge (ii)* a combination of incorrect (tier 1) and incorrect (tier 2) and not sure or sure (tier 3) answers was treated as *Lack of knowledge* and *(iii)* a combination of correct or incorrect (tier 1) and incorrect or correct (tier 2) and either not sure, sure or very sure (tier 3) answers was treated as *Misconception*.[32] The answer to an item was considered to be correct if both first and second tiers were correctly answered. According to Chandrasegaran et al.,[33] such decisions decrease the percentage of students that obtain a correct answer by chance. The Cronbach alpha reliability coefficient of the APPDiT was calculated to be 0.86 for tier 1 and tier 2, while 0.92 for tier 3. Thus the APPDiT is a reliable test not only in that it identifies but also differentiates 15-year old students' misconceptions from a lack of knowledge regarding the atmospheric phenomena. Students' could achieve maximum 30 points solving the tasks on APPiDT (15 for answer tier, 15 for reason tier).

3. 3. Research Design

The research was conducted in April 2017. The IP and APPDiT were applied anonymously in groups and all the participants had similar classroom conditions while fulfilling both instruments. They spent 45 minutes on completing both instruments on average. The participants were informed that the data would be used for research purposes only, and the main objective of the study was explained. School principals, teachers, students and their parents/caregivers agreed to their participation in the research. The data analysis shows normal data distribution for all items on the answer tier (Skewness is 0.34; Kurtosis is 0.02) and reason tier (Skewness is 0.44; Kurtosis is 0.16). For that reason, descriptive statistics (mean M, standard deviations SD) were applied to reveal the level of students' understanding of atmospheric phenomena and self-confidence while solving the specific tasks in APPDiT, data were analysed using SPSS Statistics. Moreover, McNemar´s test to determine if there are significant differences on a dichotomous dependent variable between two related tiers of APPiDT was applied. This statistical test was applied on the data because students were divided into four groups according to their achievements in APPiDT; incorrect answer & incorrect reason, incorrect answer & correct reason, correct answer & incorrect reason and correct answer & correct reason. Taking into account that 2×2 contingency tables can be formed for each APPDiT item this test was the most reasonable selection. The research was conducting according to ethical standards for educational research.

4. Results and Discussion

4. 1. Students' Knowledge About Atmospheric Phenomena

The answer and reason responses (i.e. tier 1 and tier 2 responses) of the APPDiT indicated low levels of students understanding of environmental pollution through the atmospheric phenomena, since the overall success rate students achieved on average was only 39.8%, i.e. 11.9 points out of 30. The answer was considered correct when both tiers of the particular item (tier 1 and tier 2) were correctly answered. McNemar´s test, which was used to determine if there are differences between students' achievements in solving two related tiers of APPiDT, shows statistically significant differences in solving tasks in most items ($p \leq 0.05$), except in items 9, 10, 11 in 15 ($p \geq 0.05$) (see Table 1).

The first three tasks in the APPDiT, the composition of the unpolluted air, air pollutants and their state of matter, referred to general knowledge on atmospheric pollution. The results show that 58.5% of the students have adequate knowledge regarding the main air pollutants, but on the other hand, almost the same percentage of students demonstrated a lack of knowledge regarding the state of matter of air pollutants. Student's knowledge about particular atmospheric phenomena such as acid rain, global warming, ozone layer depletion and photochemical smog was further tested. The average students achievements related to the specific items are presented in Table 1. 36.7% of the students responded correctly to both tier 1 and tier 2 regarding acid rain related items (4, 5 and 6), while only a small percentage of students (just between 7.4% to 22.0%) gave an incorrect reason along with the correct answer. The results imply that only 36.7% of students have adequate knowledge and understanding of acid rain formation, its consequences, and strategies to reduce it; however, all others may have learned facts without an adequate understanding, which leads either to misconceptions (11.5%) or lack of knowledge (34.0%). The highest level of lack of knowledge concerned global warming. More than a half of the whole respondents in the APPDiT did not understand the causes and consequences of global warming, while a very small percentage (5.1%) showed adequate knowledge with a level of self-confidence below 14.3%. 83.1% of students have a lack of knowledge about the actions that should be undertaken to reduce global warming, which is even more worrying as this shows a very low environmental awareness of students. Students' knowledge on the items related to ozone layer depletion (11, 12 and 13) was on the same level as those with global warming. 43.4% of students gave an incorrect response to both tier 1 and tier 2 regarding the importance of the ozone layer. Accordingly, the significant lack of knowledge was identified for these items, where 69.4% and 51.4% of students did not know either the causes of ozone layer depletion on the consequences of the reduction of the pro-

Table 1. The success of students' responses for the APPDiT diagnostic test.

The content of specific item in the APPDiT test	The first (content) and the second (reason) tiers					The third tier (students' level of confidence)				
	Incorrect answer & incorrect reason [*f*%]	Incorrect answer & correct reason [*f*%]	Correct answer & incorrect reason [*f*%]	Correct answer & correct reason [*f*%]	Mc-Nemar [X^2]	Not sure [*f*%]	Sure [*f*%]	Very sure [*f*%]	*M*	*SD*
1. Content of the nonpolluted air	31.4	17.3	21.5	29.8	0.034	23.3	49.8	26.9	3.3	1.8
2. Air pollutants	24.2	2.2	14.9	58.5	0.000	15.9	55.0	29.1	3.6	1.7
3. Physical properties of air pollutants	53.1	5.6	12.7	28.6	0.000	30.7	55.1	14.1	2.8	1.6
4. Understanding on formation of an acid rain	34.0	17.9	11.5	36.7	0.000	41.2	41.9	16.9	2.7	1.7
5. The possible effects of acid rain deposition	44.9	9.4	6.8	38.7	0.051	32.8	45.3	21.9	3.0	1.8
6. Strategies to reduce acid rain	35.5	7.7	20.3	36.7	0.000	40.3	44.4	15.3	2.7	1.7
7. Understanding the causes of global warming	61.0	12.0	22.0	5.1	0.000	37.5	48.2	14.3	2.7	1.6
8. Substances responsible for the occurrence of global warming	46.8	4.3	21.8	27.0	0.000	51.5	37.5	11.1	2.3	1.6
9. The consequences of global warming	56.3	10.8	8.2	24.7	0.071	40.6	42.0	17.4	2.7	1.8
10. Actions to reduce global warming	83.1	4.4	4.5	7.8	1.00	37.4	43.0	19.7	2.9	1.8
11. The importance of the ozone layer	43.4	4.4	7.4	42.7	0.447	38.1	35.7	26.3	3.0	2.0
12. Causes of the ozone layer depletion	69.4	5.4	12.4	12.8	0.000	51.7	35.5	12.8	2.4	1.7
13. Consequences of the reduction of protective ozone layer	51.4	4.0	7.4	37.3	0.001	41.5	38.6	19.9	2.8	1.8
14. Factors impact ground-level ozone development	46.4	12.8	21.5	19.1	0.000	52.1	37.6	10.3	2.3	1.6
15. Action to reduce photochemical smog	49.4	10.8	8.1	31.9	0.060	48.6	38.9	12.5	2.4	1.6

tective ozone layer. Items 14 and 15 dealt with the tropospheric ozone, which is associated with photochemical smog. Here, students were expected to understand the importance of the stratospheric ozone to human health, e.g. lung and heart diseases with chronic patients, etc. and other environmental problems e.g. damaging plants, diminishing crops produce, etc. However, only 19.1% of the students have adequate knowledge regarding the stratospheric ozone, while 46.4% or 49.4% of students choose incorrect tier 1 and incorrect tier 2 combinations for items 14 and 15, respectively, which again shows a lack of knowledge. All-in-all, the mean values of tier 3, which measures the students' level of confidence, were between 2.3 – 3.6 out of 6, indicating a low level of student confidence when answering questions in APPDiT.

Based on the low level of confidence and low achievements in APPDiT, we might conclude that students had difficulties understanding the basic concepts regarding pollution of the atmosphere, its effects and consequences. As students should learn about these phenomena, the curriculums for the following subjects were analysed: learning about the environment (1st to 3rd grade), science and technology (4th and 5th grade), natural sciences (6th and 7th) and biology (8th and 9th). We anticipated that curriculum analysis could shed some light on the problems we found from the APPDiT (Table 2). Analysis revealed that students are acquainted with pollution concepts in the first grade of compulsory education already, when discussing environmental education.[28] In the third grade of lower secondary school, students deal with the pollution of air, water and soil that is caused by traffic. For the first time they get to know the exhaust gases and the formation of acid rain. Science and technology curriculum for 5th grade includes knowledge about air, the atmosphere and the composition of unpolluted air, the causes of air pollution and actions to reduce the effects of air pollution. After, we found that in the science curriculum for 7th grade, content such as unpolluted air, global warming, ozone depletion, acid rain and photochemical smog, are explained. Moreover, according to the curriculum, students also need to recognise the consequences and propose action on the aforementioned causes of air pollution. However, in che-

Table 2. Curricula analysis of subjects in compulsory education in Slovenia and learning content connected with the environmental pollution

School Subject	Hours per year	Learning themes	Learning themes related to the environmental pollution	Grade	Learning content related to environmental pollution
Environmental studies	105	Time, Space, States of Matter, Force and Motion, Natural Phenomena, Living things, Human, Community, Relationships, Traffic, Environmental education	Traffic, Environmental education	1st	Environmental pollution
				2nd	Consequences of pollution for living beings
				3rd	The impact of traffic on the environment Water, soil and air pollutants
Science and technology	105	States of matter, Force and Motion, Natural Phenomena, Human, Living things,	States of matter	4th	/
				5th	Air and water pollution Actions for cleaner air
Science	70	States of Matter, Energy, Living Nature, Human impact on the environment	Human impact on the environment	6th	Atmospheric pollution Thermal water pollution
	105			7th	/
Biology	52	Introduction to Biology, Research and Experiments, Cell, Human Body Structure	/	8th	/
	64	Introduction to Biology and Society, Research and Experiments, Chemistry of living systems, Genetics, Biotechnology, Evolution, Biodiversity, Biomes and Biosphere, Human impact on the environment	Human impact on the environment	9th	Global warming Ozone depletion
Chemistry	70	Introduction to Chemistry, Atoms, Chemical Bonds, Chemical Reactions, Periodic Table, Acids/Bases/ Salts, Hydrocarbons, Oxygen and Nitrogen Organic Compounds	Hydrocarbons	8th	/
	64			9th	Impact of hydrocarbons on the environment
Physics	70	Introduction to Physics, Light, Space, Motion, Forces, Pressure and Buoyancy, Newtons' laws, Work and Energy, Heat, Electrical current, Magnetic Forces, Physics and Environment	Physics and Environment	8th	/
	64			9th	Ecology

mistry curriculum for 8th and 9th grade we did not find any direct connection with the atmospheric phenomena as the result of pollution. Instead, we found content such as acids/bases/salts, the products that are formed as a consequence of complete and incomplete burning of hydrocarbons, impact of hydrocarbons and their derivatives on the environment and action to reduce them. Since there is no direct connection to the environmental problems proposed by the chemistry curriculum in 8th and 9th grade (13–15-years olds) of lower secondary school in Slovenia, it is a responsibility of the teachers to connect this specific content from science and technology and chemistry curriculums as mentioned above. Hence, it can be assumed that the lack of knowledge we found in APPDiT (Table 1) in 8th and 9th grade is most probably a consequence of confusion acquired in lower grades on atmospheric phenomenon. Simply put, students lose the connections between concepts learned from 5th up to 9th grade of lower secondary school about atmospheric pollution and teachers are responsible for linking these specific concepts so that students acquire a broader picture of these problems in the environment. Therefore, the question is why teachers do not upgrade student knowledge on atmospheric phenomenon from lower grades. Is the problem in the curriculum or do teachers themselves need to acquire a better and deeper understanding of the subject. Some studies have indicated that teachers hold prevalent misconceptions on these particular topics, similar to students' misconceptions.[30] In order for teachers to be able to teach students properly about climate change and not to pass their own misconceptions to students, they themselves should acquire a deeper understanding of the subject. It is also important to emphasise that pre-service chemistry teachers have a course Fundamentals of Environmental Chemistry in Slovenia, but obviously they do not integrate these topics into their teaching. Is also reasonable to suggest, that additional professional development courses in environmental chemistry should be available for in-service chemistry, biology and physics teachers.

It can be concluded that the average Slovenian 9th grade student does not recognize or understand the reasons for atmospheric phenomenon, such as acid rain, global warming, ozone layer depletion and photochemical fog since their score on the APPDiT was insufficient and demonstrated low level of confidence. Hence, more emphasis should be placed on developing on understanding of particular atmospheric pollution factors, as the main misconceptions and lack of knowledge were connected with global warming and ozone layer depletion. Since we found specific environmental topics about air composition and pollution already in the curricula for 5th and 7th grades but not in later grades, it is reasonable to assume that students tend to forget basic concepts on this topic. It is also important to emphasize that teachers should present global warming more clearly to their students, as this phenomenon is the most important one in the last decade, and student's knowledge about it, the weakest. However, it should also be stressed that textbooks used by students while learning specific concepts should be developed in a way that stimulate learning with understanding and that textual and pictorial material would be presented in a way that enables adequate learning processes.[34]

5. Conclusions

The purpose of this study was to determine whether Slovenian 14- and 15-year-old students have sufficient knowledge about pollution of the atmosphere, its effects and consequences (both on the environment and on people). The 3-tier APPDiT instrument was used to obtain information about their understanding of the composition of the atmosphere and of basic atmospheric phenomenon such as acid rain, global warming, ozone layer depletion and photochemical smog at the basic school level. An additional instrument to gather students' background information was also used. It can be concluded that only a small percentage of students, 36.7%, 5.1%, 42.8% and 19.1% recognise and understand the reasons of acid rain, global warming, ozone layer depletion and photochemical smog formation, respectively. Moreover, only 33.0% of students know appropriate actions that should be undertaken in order to diminish the consequences of air pollution and, surprisingly, while only 7.8% of students know about the actions to diminish global warming. From here, it is clear that students' overall knowledge of particular atmospheric phenomenon is very low with the lowest level of concerning understanding on global warming.

The present research highlights important issues in current basic school curricula and points to directions in further research into the content of atmospheric pollution phenomena. We must be aware that it is too late if one starts tackling these problems and seeking solutions only when they become obvious. Therefore, it is essential to include environmental topics about acid rain, global warming, ozone layer depletion and photochemical smog into the school curriculum in the upper grades, which, however, would require a change at the national level. The introduction of such changes may be chaotic at the beginning and thus demand high level of cooperation among all the stakeholders involved, however it would lead to a number of positive impacts such as enhancing students' critical thinking skills, developing personal growth or life-building skills, including confidence, autonomy, and leadership.[35]

There are some limitations of this research. The first one can be found in the analysis of the students' responses on all three tiers identifying the proportion of specific misconceptions about atmospheric phenomena at the end of the contemporary education in Slovenia. The more in-depth analysis will be done and submitted for publication later on. The second limitation lies in the fact that the APPDiT as applied only at one level of education and it can be also implemented at the end of secondary education as well as at the beginning or/and at the end of university teacher education. These data can provide more detailed picture of students' and teachers' understanding of specific environmental issues. Taking into account the limitation of this research some further research on this topic can be conducted. For instance, the analyse of the correlations between answer, reason and confidence tier need to be provided. The level of teachers' environmental literacy, how they apply environmental issues in their teaching even when the specific curriculum aim is suggested can be studied. More detailed textbooks analysis regarding environmental issues is necessary to interpret the data in more detail. The bottom-up approach of teaching and learning modules development to present science concepts in the environmental context is obligatory and their research-based implementation is necessary.

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Povzetek

Članek predstavlja rezultate raziskave, ki je med slovenskimi osmo- in devetošolci ugotavljala razumevanje atmosferskih pojavov kot so kisle padavine, globalno segrevanje, zmanjševanje koncentracije stratosferskega ozona in fotokemični smog. Raziskava vključuje razvoj tristopenjskega diagnostičnega inštrumenta sestavljenega iz petnajstih vprašanj z naslovom Diagnostično preverjanje poznavanja pojavov onesnaženja atmosfere (APPDiT). V raziskavi je sodelovalo skupno 1012 učencev iz vse Slovenije. Podatki pridobljeni z APPDiT so omogočili proučevanje razumevanja in prepričanosti učencev o vzrokih in posledicah onesnaževanja atmosfere. Rezultati kažejo, da učenci 8. in 9. razreda osnovne šole sicer poznajo nekatere osnovne pojme atmosferskih pojavov, medtem ko imajo precejšnje pomanjkanje znanja v zvezi z onesnaževanjem in pojavi, ki nastanejo kot posledica onesnaževanja atmosfere. V povprečju so učenci dosegli le 39 % vseh točk na APPDiT. 42,7 % učencev ima ustrezno razumevanje pojmov povezanih z zmanjševanjem stratosferskega ozona. Razumevanje pojavov povezanih s kislimi padavinami ima le 36,7 %, fotokemični smog razume le 19,1 %, kar pa je najbolj presenetljivo le 5,1 % učencev razume nastanek in pomen globalnega segrevanja. Iz rezultatov je mogoče sklepati, da imajo učenci ob koncu osnovne šole velike težave z razumevanjem pojavov v ozračju, saj več kot polovica učencev atmosferskih pojavov, ki so posledica onesnaženja, bodisi ne pozna ali pa napačno razume.