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Introduction of Hydrosphere Environmental Problems in Lower Secondary School Chemistry Lessons

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Abstract: The 2030 Agenda for Sustainable Development focuses on ensuring a healthy environment for present and future generations by avoiding risks associated with consumption, exploitation of natural resources and pollution. Maintaining an environmentally aware society to address hydrosphere environmental problems requires environmental literacy, which should be continuously improved through environmental education. The study aimed to evaluate the effectiveness of integrating hydrosphere environmental problems into chemistry lessons through an online workshop, comparing students' achievements and their situational and individual interest before and after participating in the workshop. Altogether, 145 students from seven Slovenian lower secondary schools participated in the study. Three-tier achievement tests assessed students' knowledge about hydrosphere environmental problems before and after the workshop, while 15-item and 10-item questionnaires measured individual and situational interest. Results showed that 42.1% of students achieved more than half of the points on the preliminary achievement test, while following the workshop, 61.5% of students achieved better results on the achievement post-test. Students struggled to understand the chemical structures of pollutants and their effects on the hydrosphere. No significant differences in results on the post-test and delayed achievement test were identified, but high individual and situational interest positively influenced students' results on all achievement tests.

Keywords: hydrosphere environmental problems; lower secondary school; chemistry education; interest

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1. Introduction

The hydrosphere consists of the total amount of water on our planet. It covers approximately 1.39 billion cubic kilometers of its surface, which represents three quarters of the entire Earth's surface (Ibanez et al., 2007). A total of 96.5% of the hydrosphere is represented by oceans, seas and bays, 1.7% by glaciers and polar snow, 1.7% by underground water, lakes, rivers and streams, and a very small proportion of water vapor in the atmosphere (NASA Earth Observatory, n.d.). It can be concluded that approximately 97.3% of the entire hydrosphere is salt water and the other 2.7% is fresh water, but in most cases, fresh water is frozen in glaciers or polar ice. Consequently, less than 1% of fresh water, or less than 0.1% of the entire hydrosphere, is available for human usage (Kajfež-Bogataj, 2014; Reid et al., 2018; Dudgeon et al., 2006). Due to the increase in population, economic growth, technological and industrial progress, natural sources of drinking water are becoming alarmingly rare and polluted (Kajfež-Bogataj, 2014; Reid et al., 2018; Dudgeon et al., 2006; Albert et al., 2021; Ahmed et al., 2011; Goleman, 2011). Four billion people are experiencing fresh water scarcity, with two-thirds of the human population facing severe fresh water scarcity for at least part of the year, especially in densely populated areas or in areas with agricultural irrigation systems (Mekonnen & Hoekstra, 2016).

For over ten years, studies have focused on analyzing different pollutants, with the emerging group of contaminants mainly comprising those from personal care industries (Mishra et al., 2023), plastic waste (Jambeck et al., 2015), oil spills (Dave & Ghaly, 2011; Doshi et al., 2018), fertilizers (J. Chen et al., 2018; Ward et al., 2018), pharmaceutical products (Kanakaraju et al., 2018), and emissions of toxic gases (Alves et al., 2014). Some substances do not change the value of physical parameters such as color or odor, thus making water contamination barely recognizable (Ibanez et al., 2007; Kajfež-Bogataj, 2014; Kanakaraju et al., 2018). Without a well-functioning water treatment system, various problems can occur, including the contamination of drinking water with harmful pathogens and chemicals. This can lead to the spread of infectious diseases, which are, in some cases, deadly (Ibanez et al., 2007; Kajfež-Bogataj, 2014). In addition, untreated water released into the environment can disrupt ecosystems, harm aquatic life and contribute to the degradation of water bodies, leading to further ecological imbalances. Well-balanced ecosystems contain complex webs of interactions among microorganisms, fungi, plants, animals and humans. If any of these organisms are affected by toxic substances, it creates a chain effect, imperiling the entire ecosystem (Albert et al., 2021). As an example, recent studies (Auta et al., 2017; Barboza et al., 2018; Leslie et al., 2022; Vethaak & Legler, 2021) have shown that plastic pollution creates a harmful chain effect in the environment by accumulating in natural habitats, after plastic debris degrades into smaller microplastics due to different circumstances. Microplastics are small plastic pieces that measure less than five millimeters (Auta et al., 2017), becoming easily digestible by smaller organisms like plankton, which introduces toxins into the food chain (Leslie et al., 2022). These toxins then accumulate in higher concentrations as they move across the food chain, affecting fish, birds, and ultimately humans (Barboza et al., 2018; Leslie et al., 2022; Vethaak & Legler, 2021). Digested microplastics could cause DNA damage, metabolic disturbance, oxidative stress, carcinogenic effects, reproductive deficiency and more (Leslie et al., 2022; Vethaak & Legler, 2021).

The 2030 Agenda for Sustainable Development (United Nations, 2015) focuses on ensuring opportunities for present and future generations to live in a healthy environment, which is both a prerequisite and a foundation for human health, well-being and economic prosperity. Society should be oriented towards sustainable development to avoid the risks associated with consumption, the exploitation of natural resources and environmental pollution. Future generations must be prepared to respond to a rapidly changing environment faced with such challenges to be able to make thoughtful decisions that promote human health and well-being (Boon, 2024). The 17 Sustainable Development Goals (SDGs) were adopted by the United Nations in 2015 as a call to end poverty, protect the planet, and ensure that by 2030, all people enjoy peace and prosperity. The sixth Sustainable Development Goal, Clean Water and Sanitation, focuses on ensuring availability and sustainable management of water and sanitation for all by 2030. Therefore, the pollution of the hydrosphere should be recognized as a serious public concern, requiring drastic measures at local, regional, and global levels to ensure its prevention (United Nations, 2015).

Building a sustainable and environmentally aware society capable of tackling the challenges of hydrosphere pollution requires the development of environmental literacy. Environmental literacy can be achieved through effective implementation of environmental content in the education system to raise awareness of environmental issues at all levels of education (Šömen Joksić, 2011; Wardani et al., 2018; McBride et al., 2013). An environmentally literate individual is motivated to address and avoid imbalances and threats to the environment while fostering a positive relationship and responsibility towards the environment (Šömen Joksić, 2011; Wardani et al., 2018). In addition to environmental knowledge, such individuals are also able to develop social and technological competencies, understand the interconnectedness of natural, economic, social and political systems and consciously face the future environmental challenges of humanity (Šömen Joksić, 2011; McBride et al., 2013; Cotič & Medved Udovič, 2011).

The fourth SDG (United Nations, 2015) ensures inclusive education and promotes lifelong learning opportunities for all learners, thus placing a social and educational responsibility on schools to contribute to the education of critical citizens who are committed to solving global environmental problems and building a more sustainable world. Education for sustainable development begins with the intrapersonal dimension, focusing on the cultivation of ethical and moral values that enable students to understand their impact on sustainability through reflective processes that involve creativity. Creativity fosters critical thinking and innovation, essential skills for addressing sustainable challenges, and requires transforming classrooms into safe environments that encourage participation and creative self-efficacy (López et al., 2024; Dittrich et al., 2024).

Teachers play a central role, as they must be motivated and professionally trained to design, implement and evaluate activities that empower students to develop responsibility and engagement by seeing themselves as global citizens. It is important for teachers to ensure that their students are well informed and prepared to respond to matters that affect them in all areas of life by providing opportunities to develop their own ideas and possible solutions, in particular, to protect marine and fresh water ecosystems, biodiversity, and to prevent and eliminate pollution for a sustainable future (Boon, 2024; Booth Sweeney & Sterman, 2007). Schools that emphasize creativity and sustainable innovation through research, experimentation and risk taking prepare students to adapt and overcome current and future sustainability challenges. For example, Green Schools (also known as eco-schools) were developed by international organizations and national programs all around the globe by focusing on implementing a whole-school approach to environmental education, which would encourage students to develop eco-thinking skills and adopt environmentally friendly, sustainable behaviors. Green Schools are provided with a framework which also includes a section focusing on the water cycle, water resources and water supply management (Krnel & Naglic, 2009). Studies (Boeve-de Pauw & Van Petegem, 2013; Ozsoy et al., 2012; Kerret et al., 2014) suggest that students in Green Schools present higher environmental knowledge, pro-environmental behavior, and subjective well-being due to the influence of goal-directed environmental hope.

To effectively address the challenges regarding the hydrosphere, it is important to ensure that students not only develop environmental literacy, but also acquire accurate and comprehensive scientific knowledge, which is essential for understanding complex natural processes and tackling environmental problems such as hydrosphere pollution. Studies (Kerret et al., 2014; Ben-zvi-Assarf & Orion, 2005; Rebolj & Devetak, 2013; Dickerson & Callahan, 2004; Havu-Nuutinen et al., 2018; Iliopoulou, 2018; Koomson & Owusu-Fordjour, 2018) have reported that students' lack of scientific knowledge leads to misconceptions about natural processes in the hydrosphere and therefore affects their attitudes towards the environment. Students often employ colloquial and simplified language in their explanations of natural processes in the hydrosphere, indicating a deficiency in comprehensive scientific knowledge. Despite occasionally recalling scientific terminology and definitions from memory, they frequently struggle to apply these concepts accurately to specific situations in the hydrosphere and its pollution issues. It was also found that students exhibit the greatest deficiencies in scientific knowledge concerning processes with which they are not regularly engaged in their daily experiences (Ben-zvi-Assarf & Orion, 2005; Rebolj & Devetak, 2013; Havu-Nuutinen et al., 2018). Misconceptions as cognitive structures have a negative influence on new knowledge construction, so it is important that possible misconceptions are identified before teaching new content (Pan & Liu, 2018; Kahraman, 2019). Misconceptions can be identified by using written achievement tests, such as multiple-choice tests, multiple-tier tests, concept maps, interviews, etc. (Borghini et al., 2022; Milenković et al., 2016), where it is required that students explain their answer (Suprapto et al., 2015).

Some studies (Dickerson & Callahan, 2004; Kerret et al., 2014) argue that school learning is often determined as fragmented, without providing connections to students' daily life and societal contexts. Providing students with the inadequate visualization of natural hydrosphere processes in textbooks or other teaching materials, where they include only natural environments, such as forests, mountains, meadows and not artificial environments, such as cities, buildings, infrastructure, and other spaces intentionally designed and constructed by people, can cause additional misconceptions. Therefore, it is more difficult for students to understand the impact of hydrosphere pollution in their daily lives. Regarding describing the natural processes in the water cycle, students do not have difficulties in understanding only the importance of groundwater as a part of the water cycle (Koomson & Owusu-Fordjour, 2018) but also as a usable source for human consumption (Iliopoulou, 2018), as well as recognizing sources and consequences of water pollution during the water cycle processes (Dickerson & Callahan, 2004). Studies (Kerret et al., 2014; Iliopoulou, 2018) indicate that students have difficulties understanding the connections between natural processes occurring in hydrosphere, biosphere, atmosphere and geosphere. Considering chemical knowledge, students face difficulties explaining examples of physical changes in water's states of matter in the environment (Kerret et al., 2014; Ben-zvi-Assarf & Orion, 2005; Rebolj & Devetak, 2013; Dickerson & Callahan, 2004; Havu-Nuutinen et al., 2018; Iliopoulou, 2018). One of the studies by Koomson and Owusu-Fordjour (2018) identified that students acknowledged only two phase changes of water in nature—freezing and melting—while the study by Havu-Nuutinen et al. (2018) identified students' misconception regarding water existing in the environment only in the liquid form. These findings re-emphasized the importance of promoting students' understanding of environmental systems, as well as their ability to think systemically (Koomson & Owusu-Fordjour, 2018). Students require further opportunities to expand their knowledge and comprehension of sustainable solutions for hydrosphere pollution, as they tend to propose primarily short-term measures (Havu-Nuutinen et al., 2018).

Chemistry is, from students' point of view, often considered as a complex subject focusing on abstract chemical concepts and processes which students have difficulty understanding (Çetin-Dindar & Geban, 2011; Slapničar et al., 2020; Abdinejad et al., 2021), especially when the teaching methods are focused on memorizing and reproducing information or when the content is not directly linked to students' everyday experiences. This may contribute to a decline in student interest in science subjects, despite the fact that most students recognize the importance of scientific knowledge in their daily lives (Urbančič et al., 2018; Devetak, 2014). When learning chemistry, students need to be involved in finding, processing data and solving current life problems through observation and experimentation (Koomson & Owusu-Fordjour, 2018).

Environmental chemistry is essential for evaluating chemical pollution in the environment, thereby aiding in the preservation of ecosystems and safeguarding human health. Consequently, equipping future generations with knowledge and skills in this field is crucial for sustaining environmental protection efforts (Georgiou & Kyza, 2014). Environmental chemistry topics such as hydrosphere environmental problems could be implemented in chemistry lessons while learning different chemistry concepts (Dickerson & Callahan, 2004). Using different teaching methods to make chemistry lessons more student-centered, engaging, and applicable to real-world contexts, teachers could design activities that trigger a spontaneous and temporary situational interest (Vidmar et al., 2024; Juriševič, 2012; Marentič Požarnik, 2012). Situational interest refers to the interest activated by the immediate environment, for example, the classroom setting, which enables attention to a certain activity at that time (Ryan & Deci, 2000; Hidi, 2006). This could lead to increased attention and engagement over time, and even to the development of more sustained individual interest. Students with a high level of individual interest become more effective learners and tend to develop a positive attitude towards natural sciences, the environment, and its values (Juriševič, 2012; Marentič Požarnik, 2012; Hidi, 2006; Schraw & Lehman, 2001).

The results of the literature reviewed over the years (Ferk Savec & Mlinarec, 2021) show that it is necessary to develop teaching materials for different fields of chemistry, especially analytical, environmental and physical chemistry, for primary and secondary levels of education in order to promote sustainable development. A study by Havu-Nuutinen et al. (2018) shows that using active teaching methods, such as experimental work, group discussions, and other different technology-supported teaching methods, positively affects students learning outcomes regarding understanding hydrosphere environmental problems. A study by Avsec and Ferk Savec (2021) also highlights collaborative learning as a key factor in dealing with several sustainability challenges through the perception of consciousness raising, critical reflection, personal growth, and individuation. The following studies give some concrete examples of experimental work in the context of environmental problems of the hydrosphere, such as (1) using an android smartphone-based Digital Image Colorimeter (DIC) as a simple, accurate and environmentally friendly analytical procedure for quantitative detection of acid fuchsine dye in aqueous solutions (Khalid & Fakhre, 2023); (2) synthesis of bioplastics that are easily degradable from food waste, such as banana peels (Tsang et al., 2019); (3) removing contaminants using activated carbon through adsorption processes (Yuan et al., 2023); (4) designing a small-scale wastewater cleaning plant to demonstrate physical and chemical treatment steps (Néel et al., 2015), etc. In addition to experimental work, the study by Boon (2024) proposes a concrete example of using technology to design innovative artefacts that students can use for advertising slogans on social media blogs to raise awareness and educate different audiences about water use and pollution and the impact of population growth on drinking water supplies. Educators should be aware of students' conceptions and attitude towards the environment, to select effective and efficient teaching approaches in this field (Devetak, 2014; Iliopoulou, 2018).

Even though previous studies (Kerret et al., 2014; Ben-zvi-Assarf & Orion, 2005; Rebolj & Devetak, 2013; Dickerson & Callahan, 2004; Havu-Nuutinen et al., 2018; Iliopoulou, 2018; Koomson & Owusu-Fordjour, 2018) have shown that students have misconceptions about the processes in the hydrosphere and the impact of pollution on their daily lives, there is a lack of comprehensive research in the literature on how to effectively address these misconceptions in the context of chemistry education. These studies emphasize environmental education more broadly without making a clear link to how the subject of chemistry can provide meaningful insights and actionable solutions to such problems. Although the study by Havu-Nuutinen et al. (2018) addressed the role of situational interest in learning outcomes, there is a lack of empirical evidence linking situational and individual interest to student performance in relation to hydrosphere environmental problems. There is an increasing importance in engaging students in sustainability education and equipping them with the skills, attitudes and knowledge they need to tackle real-world environmental challenges. The research gap, therefore, lies in the less researched integration of hydrosphere environmental problems into chemistry education, particularly through innovative, student-centered teaching methods aimed at eliminating student misconceptions and fostering both situational and individual interest in sustainability issues.

The purpose of the study was to implement and evaluate the effectiveness of integrating hydrosphere environmental problems into chemistry through an online workshop, comparing students' knowledge achievements and their situational and individual interest levels before and after the educational intervention. The aim was further specified by the following research questions:

1. How does students' knowledge achievement change before and after the educational intervention?
2. Which students' misconceptions of hydrosphere can be identified before and after the educational intervention?
3. How do students' levels of individual interest influence their knowledge achievement before and after the educational intervention?
4. How do students' levels of situational interest affect their knowledge achievement after the educational intervention?

2. Materials and Methods

A quantitative non-experimental research approach with descriptive methods was used.

2.1. Participants

For this study, the sample was selected using the convenience sampling method, i.e., participants were selected based on their availability and willingness to participate. The sample included 145 ninth grade students (M = 14.2 years; IQR = 0.46 years) from seven public lower secondary schools in the central and southeastern regions of Slovenia. To recruit participants, we sent invitations to various lower secondary schools in Slovenia, specifically addressing chemistry teachers and school principals. Involving schools from different regions also provides valuable insights into how educational activities can be tailored to specific environmental issues relevant to the students' local context. The teachers who responded positively to these invitations were willing to supervise the three phases of the study in their classes. Students were included in the study if their teachers were willing to participate in and supervise the study, and if the students themselves were willing to participate in the study.

2.2. Instruments

2.2.1. Achievement Tests

For this study, three-tier achievement tests were constructed by the authors to diagnose students' knowledge about hydrosphere environmental problems. The validity of all achievement tests was assured by forming three-tier tasks based on the learning objectives and related standards of the chemistry curriculum in lower high school in Slovenia by constructing the specification tables for each achievement test. The achievement tests were later thoroughly reviewed by two independent researchers specializing in chemistry education at the University of Ljubljana, Faculty of Education. Their feedback was instrumental in ensuring the relevance and alignment of the tests with the learning objectives and related standards of the lower secondary chemistry curriculum, shown in specification tables.

The objectivity of the entire achievement test was assured by providing students with the same instructions and giving them the same time limit to finish all tasks. Students' achievements on the tests were evaluated based on the previously formed criteria.

The first tier of a three-tier achievement test contained multiple-choice questions with one correct answer to assess content knowledge. The second tier also contained multiple-choice questions with one correct answer, and it required students to explain the reason for choosing their answer in the first tier. In the third tier, students measured their confidence in given answers to the first two questions using a 6-point Likert scale: 1 (just guessing), 2 (very unconfident), 3 (unconfident), 4 (confident), 5 (very confident) and 6 (absolutely confident). Figure 1 presents an example of three-tier task number 3 on the achievement post-test and delayed achievement test.

3. You have bought a bag that has a special certificate for biodegradability. Where can you dispose of it after use?
A In the nearby river.
B In the container for plastic and plastic packaging.
C In the forest.
D In the container for organic waste.

3.1. Why did you choose the answer above in the question number 3?
A The bag is made of natural organic material.
B The bag is made of synthetic plastic material.
C There are aerobic microorganisms in the forest soil that will break down the materials of the bag.
D There are anaerobic microorganisms in the river that will break down the materials of the bag.

3.2. 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 three-tier task number 3 on the achievement post-test and delayed achievement test.

A preliminary achievement test was used in the first phase of the study to analyze students' prior knowledge about hydrosphere environmental problems. The specification table of the preliminary achievement test is shown in Table 1. An achievement post-test was used in the second phase of the study, right after completion of activities in the online workshop to measure their achievements and the effectiveness of the workshop. Two weeks after the completion of the online workshop, a delayed achievement test was used to once again measure students' achievements and analyze their memory retention. The descriptions of the tasks of the achievement post-test and delayed achievement test are listed in Table 2.

Table 1. The specification table of the preliminary achievement test.

Task Number	Description of the Task	Bloom's Cognitive of the Task Level
1.	Students select the formula of the molecule with properties similar to water molecule and explain their answer based on the distribution of electric charge in the molecule.	Application
2.	Students select the submicroscopic formula of the molecule that reduces surface tension between two substances and explain their answer based on the molecular structure.	Application
3.	Students identify the incorrect statement about the properties of synthetic polymer waste and explain their answer based on their knowledge of polymer degradation in nature.	Understanding
4.	Students select which group of organic compounds starch belongs to and explain their answer based on the molecular structure of starch.	Remembering

Table 1. *Cont.*

Task Number	Description of the Task	Bloom's Cognitive of the Task Level
5.	Students identify the most effective measure to prevent groundwater pollution and explain their answer based on reducing usage of pesticide and fertilizer agriculture.	Understanding
6.	Students identified the effect of uncontrolled releases of detergents into the aquatic ecosystems and explained their answer based on the detergent's pictogram.	Understanding
7.	Students analyze the water quality data from a table, identify the most likely range of the water sample and explain their answer based on the pollutant concentrations and their possible source.	Analyse
8.	Based on the picture of a wastewater treatment plant, students identify the primary stage of wastewater treatment and explain their answer based on the characteristics of the primary wastewater treatment.	Understanding
9.	Students predict which chemical reaction would occur if a weak base solution was added to rainwater and explain their answer based on the properties of rainwater and weak base solution.	Analyse
10.	Students selected the appropriate use of activated carbon and explained their answer based on its adsorptive capacity.	Remembering

Table 2. The specification table of the achievement post-test and delayed achievement test.

Task Number	Description of the Task	Bloom's Cognitive of the Task Level
1.	Students identify the incorrect statement regarding the effects of oil spills and explain the answer based on the properties of oil.	Remembering
2.	Students selected which material can speed up the natural microbial decomposition of oil spills and explained the answer based on the ability of surfactants to break down larger oil spills into smaller droplets.	Application
3.	Students decide where to dispose of a litter bag with special biodegradability certificate and explain the answer based on the composition of the bag.	Remembering
4.	Students select which chemical reaction occurs during the process of bioplastic production and explain their answer based on the properties of the materials.	Application
5.	Students select which pollutant causes eutrophication in lakes and explain their answer based on the composition of fertilizers.	Understanding
6.	Students select the correct statement about the impacts of atrazine on the environment and explain their answer based on the pesticide's pictograms.	Understanding
7.	Students differentiate between samples of copper sulfate solutions and explain their answer based on the mass concentration of the solution samples using the data in the diagram.	Analyse

Table 2. *Cont.*

Task Number	Description of the Task	Bloom's Cognitive of the Task Level
8.	Students select which wastewater treatment technique they would choose to remove water-soluble dyes of textile industry and explain their answer based on the properties of the dye.	Analyse
9.	Students choose which pollutant is the reason for the formation of acid rain and explain the answer based on the solubility of the pollutant in water.	Understanding
10.	Students select the function of activated carbon in the wastewater treatment process and explain their answer based on its adsorptive capacity.	Understanding

All achievement tests had ten different tasks and were constructed based on the six levels of Bloom's cognitive taxonomy. The complexity of each task was distributed equally on all three achievement tests. Discriminatory indexes for every item on the preliminary achievement test were between 0.35 and 0.57, between 0.25 and 0.65 on the achievement post-test and between 0.24 and 0.66 on the delayed achievement test. Items in the achievement tests can differentiate between capable and less capable students. Difficulty indexes for every item on the preliminary achievement test were between 0.37 and 0.73, between 0.31 and 0.76 on the achievement post-test and between 0.34 and 0.82 on the delayed achievement test. Thus, achievement tests consist of items with different ranges of difficulty.

2.2.2. Individual Interest Questionnaire

The individual interest questionnaire was formed based on the original instrument *Individual Interest Questionnaire* (Rotgans & Schmidt, 2017) and it was used to acknowledge students' individual interest in learning about environmental problems. According to the definition of individual interest, the questionnaire was used to measure at least three key components: positive attitude towards this topic, increased value for the topic and willingness to reengage with the topic. To measure these key components, fifteen items were formed focusing on the topic of environmental problems (e.g., "*I am very interested in learning about environmental problems*"). All items were scored on a 5-point Likert scale: 1 (not true at all), 2 (not true for me), 3 (neutral), 4 (true for me), and 5 (very true for me). The questionnaire also included two essay questions. The essay questions were as follows: (1) "*Which part of the environmental topic do you find most intriguing?*" and (2) "*Which part of the environmental topic do you find the least intriguing?*". The internal consistency (Cronbach's α) of the instrument is 0.930.

2.2.3. Situational Interest Questionnaire

Based on the original instrument *Situational Interest Scale* (A. Chen et al., 2001), the situational interest questionnaire was formed to acknowledge whether the online workshop worked as a motivational situation to increase students' interest in learning about environmental problems. To measure the situational interest, ten items were formed focusing on the topic of the online workshop (e.g., "*The topic of the online workshop is very interesting*"). All items were scored on a 5-point Likert scale: 1 (not true at all), 2 (not true for me), 3 (neutral), 4 (true for me), and 5 (very true for me). The questionnaire also included one essay question. The essay question was "*Which three activities from the online workshop were most interesting for you?*". The internal consistency (Cronbach's α) of the instrument is 0.812.

2.3. Research Design

2.3.1. Description of the Intervention

The intervention of the study was designed in the form of a 90 min online workshop, and it took place in the second part of the study. An Arnes website was set up for participation in the online workshop and data collection, to which the materials were uploaded, including five interactive videos and a memory game. The online workshop focused on four main topics of hydrosphere pollution—industry pollution, agriculture pollution, oil spill pollution and plastic waste pollution. The industry pollution, oil spill pollution and plastic waste pollution topics were presented in one interactive video, while the agriculture pollution topic contained two interactive videos. The interactive videos were created using digital tools, such as Microsoft PowerPoint 2016, Canva (online version 2022), Adobe Premiere Pro 2020 (version 15.4), ChemSketch (version 2021.1) and H5P (online version 2022). An asynchronous teaching approach has been used to facilitate personalization and differentiation of the learning process so that students can progress at their own pace and have a flexible, tailored learning experience that caters to different learning styles. When creating the interactive videos, the recommendations and findings of the reviewed literature (Dickerson & Callahan, 2004; Havu-Nuutinen et al., 2018; Iliopoulou, 2018; Koomson & Owusu-Fordjour, 2018; Pan & Liu, 2018; Kahraman, 2019) were considered. Mayer's cognitive theory of multimedia learning (Mayer, 2024), particularly the two-channel assumption, states that information is processed via two separate channels. The visual channel processes visual information (e.g., photos, sketches, animations, videos of experiments), while the auditory channel processes auditory information (e.g., personal audio recordings). By engaging both channels simultaneously, the cognitive load on each channel is reduced. Therefore, video content should be designed to optimize both the visual and auditory channels for more effective learning. The interactive videos of the online workshop included videos of experiments, animations, simulations, hyperlinks to various databases, quizzes and discussion questions as well as voice explanations that reduced cognitive overload on the visual or auditory channel.

The interactive design of the first section aimed to deepen students' understanding of the environmental impact of industrial pollution while encouraging critical thinking and engagement through simulations, experiments and interactive tasks. The first part introduced the concept of the hydrosphere and its composition, followed by an overview of the main chemical concepts: the molecular structure of water, states of matter, phase transitions, the water cycle and the solubility of substances in water. These topics were illustrated on a macroscopic (e.g., photos of water in different states of matter), submicroscopic (e.g., PhET simulations of water particle movements in a specific state of matter) and symbolic level (e.g., symbolic formulas of water in different states of matter). In chemistry lessons, it is important to combine these three levels, as the triple nature of chemical concepts promotes the understanding of complex concepts and processes (Slapničar et al., 2020). The animation of the water cycle included not only processes in nature, but also anthropogenic influences such as industrial gas emissions which react with water droplets to form acid rain. Five interactive H5P tasks (e.g., fill in the blanks, one correct answer questions, etc.) were provided to reinforce the first part of the interactive video (Wehling et al., 2021). The second part focused on understanding the effect of using activated carbon in the treatment of wastewater from the textile industry. In this part, the results of an experiment on the removal of dyes, such as methylene blue (Mikro+Polo, Maribor, Slovenia) from water using activated carbon (Sanolabor, Ljubljana, Slovenia) at different time intervals (after 1 h, after 24 h) were presented (Royal Society of Chemistry, n.d.-b; Yuan et al., 2023). This part was organized in smaller sections, including an introduction, objectives, safety protocols, materials, experimental procedure, results, discussion, key findings and interactive H5P tasks (e.g., short answer questions, drag and drop, etc.) that provided hints and solutions. The discussion encouraged students to critically evaluate the effectiveness of activated carbon in wastewater treatment.

The second section of the online workshop enabled students to gain a comprehensive understanding of the chemical principles behind agricultural practices and their impact on the environment. The first interactive video introduced the use of fertilizers and pesticides in agriculture and explained their chemical composition, physical properties and environmental effects. The students investigated the chemical structure of atrazine, a compound found in herbicides. By clicking on the hyperlink to access the PubChem database, they identified the hazard labels for atrazine and analyzed its potential impact on the aquatic environment and human health by completing interactive H5P tasks (e.g., one correct answer questions). The second interactive video was divided into two experimental parts. Both experimental activities were divided into smaller sections that included the introduction, objectives, safety protocols, materials, experimental procedure, results, discussion, and interactive H5P tasks (e.g., short answer questions, fill in the blanks, etc.). In the first part, an experiment to measure the mass concentration of a copper(II) sulfate pentahydrate solution (Mikro+Polo, Maribor, Slovenia) using the ColorGrab mobile app (version 3.9.2) was presented (Khalid & Fakhre, 2023). Students collected H-values (hues) of solutions with known mass concentrations and used these data to create a calibration curve in Microsoft Office Excel 2021. The concentration of the sample solution was then determined graphically and calculated using the linear equation derived from the curve (Montangero et al., 2015). In the second part of the experiment, the students investigated the effectiveness of precipitation reactions as a chemical method for removing metal ions, e.g., copper ions, from aqueous solutions (Royal Society of Chemistry, n.d.-a). Observations were documented at the macroscopic level, e.g., the formation of visible precipitates, while conclusions were drawn at the submicroscopic and symbolic level. The results were organized in tables and supplemented with interactive symbols that provided hints and solutions to guide the students. In both cases, interactive H5P tasks were included to encourage critical thinking and reasoning.

The third section of the online workshop presented plastic pollution. As an introduction to this topic, the students examined a well-known commercial about water packaged in plastic bottles and critically reflected on the possibility of consumer deception. Using animations, the students learned about the chemical reaction of polymerization and the difference between the chemical terms monomer and polymer. The students learned about the most used polymers for the manufacture of plastic products on a macroscopic, submicroscopic and symbolic level. For example, students filled in the blank spaces of the interactive H5P task with their guesses about how long it takes for plastic products to decompose in nature. The students were provided with interactive symbols with hints, as it was pointed out that synthetic plastic waste decomposes very slowly in the environment and therefore has alarming consequences for animals and humans. The experimental part of the interactive video focused on the synthesis of biodegradable plastic from potato starch (Mikro+Polo, Maribor, Slovenia), tap water, glycine (Mikro+Polo, Maribor, Slovenia) and acetic acid (Mikro+Polo, Maribor, Slovenia) (Tsang et al., 2019; Buckley, n.d.). This part was divided into smaller sections, including an introduction, objectives, safety protocols, materials, experimental procedures, results, discussion with interactive H5P hints and tasks (e.g., true or false statements, short answer questions, etc.). The discussion encouraged students to critically compare the properties of synthetic and biodegradable plastics and give concrete examples of how they can reduce the use of plastic products in their everyday lives.

The interactive video in the fourth section of the online workshop focused on presenting some examples of oil spills and encouraged the students to reflect on the practical application of the cleaning methods and their impact on the environment. The video began with a hyperlink to an article about an example of a recent oil spill. After reading the article, students learned about the use of oil, its chemical composition and its physical properties. They learned about the chemical structures of hydrocarbon molecules commonly found in oil mixtures and participated in an interactive task where they wrote down the molecular formulas of selected hydrocarbons. Based on the physical properties of oil presented, students drew conclusions about the solubility of oil in water by answering a true or false interactive question. The experimental part of the video focused on simulating mechanical (e.g., using a pipette), physical (e.g., activated carbon, absorbent cotton (Sanolabor, Ljubljana, Slovenia) and sawdust) and chemical methods (e.g., surfactants (Sanolabor, Ljubljana, Slovenia)) used to remove oil (Sanolabor, Ljubljana, Slovenia) spills from the water. This part was divided into smaller sections including an introduction, objectives, safety protocols, materials, experimental procedures, results, discussion with interactive H5P hints and tasks like those mentioned above. The results of the experiment were presented in tables that included observations at the macroscopic level and conclusions at the submicroscopic and symbolic levels. The discussion focused on critically evaluating the benefits and challenges of using these methods to clean up oil spills. The tables included interactive symbols with hints and solutions to assist students in their observations and conclusions.

Finally, a memory game was developed in which the students had to find the corresponding pairs within a given time, e.g., the source of pollution and its consequences (e.g., fertilizer–eutrophication).

2.3.2. Data Collection

Questionnaires and achievement tests were formed in the online tool 1nka. Before the study started, approval from school authorities was obtained. Data were collected anonymously and teachers gathered signed consent forms from parents or legal guardians. Participants were informed about the study and could withdraw at any time. Ethical research guidelines were followed at all stages. This study was reviewed and approved by the Ethics Commission of the Faculty of Education of the University of Ljubljana.

The online workshop and data collection were conducted in computer classrooms in schools where teachers played an active role in monitoring student participation. Teachers monitored students' engagement with the interactive content and ensured that they completed the tasks within the given timeframe. Their guidance and supervision were essential in supporting students throughout the workshop and ensuring accurate data collection.

We designed a web page for the purpose of uploading all necessary materials (e.g., instructions, links to questionnaires and tests, interactive videos, etc.); it was divided into four web tabs. The first web tab contained an interactive video to invite students to participate in this study and explain the importance of their involvement. To enlighten students about circumstances of hydrosphere pollution, an infographic was designed.

Data collection took place in three parts. In the second web tab, students could access all instructions regarding the first part of the study. In the first part of data collection, students (n = 145) filled in the Individual Interest Questionnaire and completed the preliminary achievement test under standard conditions that were the same for all students. The purpose of the first part was to indicate their prior knowledge and individual interest in learning about hydrosphere environmental problems. This part took up to 40 min, one week before the second part of the study. In the third web tab, students could access the online workshop with interactive videos, interactive games and instructions regarding the second part of the study. In the second part of data collection, students (n = 96) filled in the

Situational Interest Questionnaire and completed the achievement post-test. The purpose of the second part was to acknowledge the effectiveness of the workshop. Students needed approximately 90 min to finish the activities (20 min for each interactive video and 10 min for the memory game) in the workshop and 40 min to fill in the questionnaire and complete the achievement test. The fourth web tab included instructions for the third part of the study. The third part of data collection was carried out two weeks after participating in the online workshop. The purpose of the third part of the study was to indicate students' memory retention; therefore, students (n = 65) solved the delayed achievement test. The third part of data collection took up to 30 min.

2.3.3. Data Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS), version 21. For statistical analysis, students were divided into three groups based on one variable.

As mentioned above, the Individual Interest Questionnaire consisted of fifteen items, which students scored using the 5-point Likert scale. Therefore, the maximum points collected for each student on this questionnaire totaled 75, and the minimum was 15 (M = 44.8; SD = 11.9). The Kolmogorov–Smirnov test showed a normal distribution of data collected from Individual Interest Questionnaires (p = 0.200). The classifications of students into three groups regarding their collected points on the Individual Interest Questionnaires were performed according to the statistical equations. Into Group 1 (low level of individual interest) were classified students who scored less than $M - 1\ SD$ points, into Group 2 (medium level of individual interest) those who scored less than $M - 1\ SD$ and $M + 1\ SD$ points, and into Group 3 (high level of individual interest) students who scored above $M + 1\ SD$ points on Individual Interest Questionnaires. Therefore, students in Group 1 collected 15 to 32 points on the questionnaire (M = 27.7; SD = 5.6), students in Group 2 collected 33 to 56 points on the questionnaire (M = 45.2; SD = 6.4) and students in Group 3 collected 57 to 75 points on the questionnaire (M = 62.1; SD = 4.5).

The Situational Interest Questionnaire consisted of ten items, which students scored using the 5-point Likert scale. Therefore, the maximum points collected for each student on this questionnaire totaled 50, and the minimum was 10 (M = 35.7; SD = 5.1). The Kolmogorov–Smirnov test showed a normal distribution of data collected from the Situational Interest Questionnaire (p = 0.143). The classifications of students into three groups regarding their collected points on the Situational Interest Questionnaire were performed according to the statistical equations. Into Group 1 (low level of situational interest) were classified students who scored less than $M - 1\ SD$ points, into Group 2 (medium level of situational interest) those who scored less than $M - 1\ SD$ and $M + 1\ SD$ points, and into Group 3 (high level of situational interest) students who scored above $M + 1\ SD$ points on the Situational Interest Questionnaire. Therefore, students in Group 1 have collected 10 to 30 points on the questionnaire (M = 27.9; SD = 3.0), students in Group 2 have collected 31 to 40 points on the questionnaire (M = 35.9; SD = 2.4) and students in Group 3 have collected 41 to 50 points on the questionnaire (M = 43.8; SD = 2.9).

The Kolmogorov–Smirnov test showed non-normal distribution of data collected from all three achievement tests; therefore, non-parametric tests were used. The non-parametric Wilcoxon Ranks Test was used to determine significant differences comparing students' achievements on preliminary achievement test, achievement post-test and delayed achievement test. The non-parametric Kruskal–Wallis Test was used to determine significant differences comparing students' achievements on preliminary achievement test, achievement post-test and delayed achievement test based on their level of individual interest or level of situational interest. The Games–Howell Post Hoc Test was used to compare combinations of groups of students, formed based on their level of interest, and their learning achievements on different achievement tests.

3. Results

3.1. Evaluation of Students' Knowledge Achievements Before and After Educational Intervention

Research question 1 focused on students' knowledge achievements before and after participating in the educational intervention. For this purpose, the preliminary achievement test, the achievement post-test, and the delayed achievement test were used to assess students' knowledge. All three-tier achievement tests consisted of ten different tasks, which content is shown in Tables 1 and 2. Correctly solved tasks in the first and second tier items of a task were scored with one point, so that the maximum possible score for the entire achievement test was 20 points. The Kolmogorov–Smirnov test showed a non-normal distribution of data collected on the preliminary achievement test ($p = 0.000$), achievement post-test ($p = 0.039$) and delayed achievement test ($p = 0.000$). The results show that students scored significantly less points on the preliminary achievement test ($Me = 8.0$; $IQR = 4.0$) than on the achievement post-test ($Me = 11.0$; $IQR = 4.0$) and delayed achievement test ($Me = 10.0$; $IQR = 5.0$). It can also be seen from the data in Figure 2 that more than half of all students scored at least 50% of all possible points on the achievement post-test and delayed test.

The results shown in Figure 3 represent the percentage of students' total scored points on achievement tests. Most of the students scored between 8 points (13.8%) and 7 points (12.4%) out of 20 possible points on the preliminary achievement test. Only 1.4% of the students scored 19 points, which was the highest achieved score on the preliminary achievement test. A total of 1.4% of the students achieved 2 points, which was the lowest score. On the achievement post-test, most students scored between 11 points (15.6%) and 12 points (12.5%) out of 20 possible points. A total of 2.1% of the students scored 17 points, which was the highest achieved score, and 1.0% of students achieved 5 points, which was the lowest achieved score on the achievement post-test. On the delayed achievement test, most students scored between 10 points (16.9%) and 9 points (15.4%) out of 20 possible points. A total of 1.5% of students scored 18 points, which was the highest achieved score, and 6.2% of students scored 6 points, which was the lowest score on the delayed achievement test.

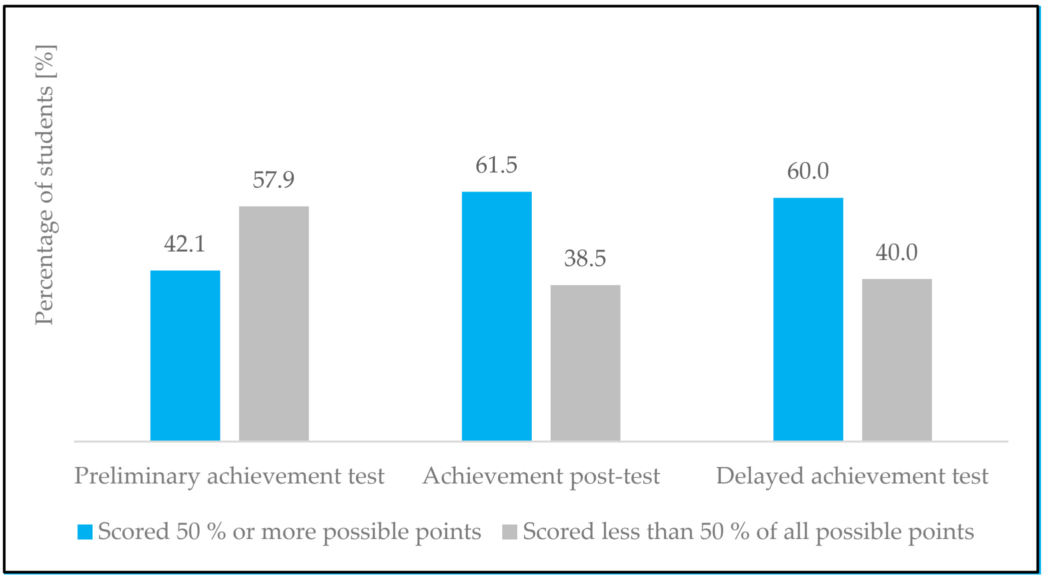


Figure 2. Percentage of students who scored more or less than 50% of all possible points on achievement tests.

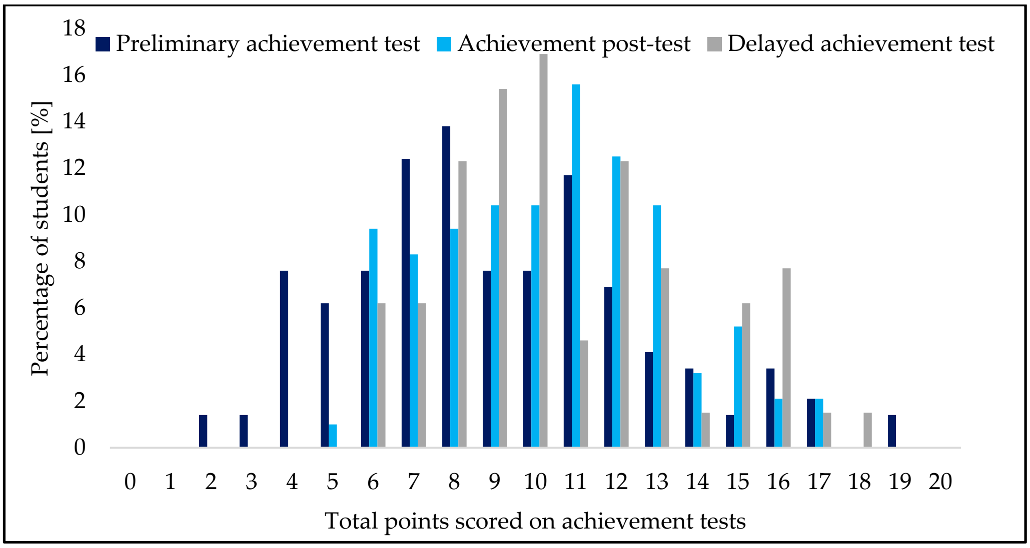


Figure 3. Percentage of students' total scored points on achievement tests.

The non-parametric Wilcoxon Ranks Test showed significant differences between students' results on the preliminary achievement test and students' results on the achievement post-test ($Z = -4.42$; $p = 0.000$). It also showed significant differences between students' results on the preliminary achievement test and students' results on the delayed achievement test ($Z = -3.44$; $p = 0.001$). Students' knowledge about hydrosphere environmental problems has improved after participation in the online workshop. A total of 68.8% of students have achieved a better score on the achievement post-test in comparison with the achieved score on the preliminary achievement test. A total of 69.2% of students have achieved a better score on the delayed achievement test in comparison with the achieved score on the preliminary achievement test. Based on this result, we can conclude that the participation in the online course has positively affected students' memory retention. The non-parametric Wilcoxon Ranks Test has not shown significant differences between students' results on the achievement post-test and students' results on the delayed achievement test ($Z = -0.70$; $p = 0.486$). Therefore, trouble with memory recall has not been identified.

3.2. Identification of Students' Misconceptions of Hydrosphere Before and After the Educational Intervention

Research question 2 focused on identifying students' misconceptions of the hydrosphere before and after the educational intervention. On the preliminary achievement test, most students had problems solving tasks no. 2, 4 and 8. Task number 2 focused on identifying the chemical structure of a surfactant and explaining why such compounds have a negative effect on the hydrosphere. A total of 23.4% of students successfully completed the first and second tier task no. 2. Task no. 4 examined students' understanding of the molecular structure of starch as a polysaccharide and understanding of the use of polysaccharides as ingredients in the process of biodegradable plastic synthesis. A total of 20.0% of students successfully completed the first and second tier question of task no. 4. The least successfully solved task of the preliminary achievement test was task no. 8, where only a minority of students (4.1%) correctly identified the primary phase of the wastewater treatment process from the given figure and gave a precise explanation for this phase. Since the students were very confident or absolutely confident in their given (incorrect) answers in task no. 8, misconceptions were identified. On the preliminary achievement test, misconceptions were also identified in task no. 1 and no. 10 and are presented in Table 3. On the other hand, students had less problems solving tasks no. 5 and no. 6. In task no. 5, about half of the students (51.7%) correctly stated that reducing the use of pesticides and fertilizers is one of the most effective measures to prevent water pollution in the agriculture area, as these substances enter the groundwater through precipitation due to their chemical and physical properties. More than half of the students (64.8%) successfully completed task number 6, in which they correctly recognized the pictogram for environmental hazards on detergent packaging and explained the consequences of an uncontrolled release of such substances into the environment.

On the achievement post-test, most students had problems solving task no. 2 and no. 4, which required students to understand complex chemical structures and processes in the hydrosphere. Only 13.5% of students completed the first and second tier of task no. 2 correctly. Almost half of the students (43.8%) correctly identified that surfactants are used to accelerate the natural microbiological degradation of oil stains, but only 16.7% of the students gave the correct explanation for why they chose the answer in the first tier of the task, namely, to break down larger oil spills into small droplets. A total of 18.9% of the students solved the first and second tier of task no. 4 completely correctly. Most students had difficulty understanding the change in the chemical structure and properties of the starch molecule due to the effect of heat during the synthesis process of biodegradable plastic. Although task no. 5 was not one of the least successfully solved tasks of the achievement post-test, misconceptions regarding possible sources of eutrophication were still identified and are shown in Table 3. Students were most successful in solving task no. 3 (70.8%) of the achievement post-test, in which they select the appropriate container for biodegradable waste disposal based on the composition of the waste. Students were also successful in solving task no. 1 (67.7%), where they correctly identified the incorrect statement about the effects of oil spills in the first tier and explained the answer based on the properties of oil in the second tier.

Compared to students' results on the achievement post-test, students had difficulties solving task no. 8 and no. 10 on the delayed achievement test. Only 23.1% of the students showed understanding by correctly identifying adsorption as one of the processes of the wastewater treatment plant on the first and second tier of task no. 8. Only 24.6% of students correctly recognized activated carbon as one of the adsorbents for adsorbing organic pollutant molecules from wastewater on its surface. Tasks no. 1 (67.7%) and no. 3 (78.5%) were most successfully solved on the achievement post-test as well as on the delayed achievement test. Although task no. 6, which involved understanding the meaning of pictograms on pesticide packaging, was not one of the least successful tasks in the delayed achievement test, it was still found that students had misconceptions, as they were very certain or absolutely certain of the accuracy of their answers.

Table 3. Identified misconceptions of students regarding hydrosphere environmental problems on all achievement tests.

Achievement Test	Task Number	Misconception Statement	f % of Students with Misconceptions
Preliminary achievement test	1.	The oxygen molecule, like the water molecule, is non-polar, as the electric charge is unequally distributed in both molecules.	10.3
	8.	Primary treatment is the first phase of wastewater treatment at a treatment plant. In this process, a mechanical barrier screen is used to retain larger solid particles.	11.7
	10.	Activated carbon tablets are used in medicine for increased gastric acid secretion, as activated carbon neutralizes excess gastric acid due to its alkaline properties.	10.3

Table 3. *Cont.*

Achievement Test	Task Number	Misconception Statement	f % of Students with Misconceptions
Achievement post-test	5.	The eutrophication of lakes is a consequence of the excessive use of pesticides in agriculture, as the toxic degradation products of pesticides cause the death of algae and higher plants.	17.7
Delayed achievement test	6.	The pictograms on the packaging of the pesticide atrazine show a dead fish and warn the user to exercise caution with an exclamation mark.	12.4

3.3. Impact of Students' Level of Individual Interest on Their Knowledge Achievement Before and After the Educational Intervention

Research question 3 focused on how students' levels of individual interest influence their knowledge achievement before and after the educational intervention. Table 4 shows the results of students' collected points when rating items of the Individual Interest Questionnaire using a 5-point Likert scale.

Table 4. The results of students' collected points when rating items of the Individual Interest Questionnaire using a 5-point Likert scale.

Items of the Individual Interest Questionnaire	*M*	*SD*
1. I am interested in learning about environmental problems.	3.1	1.2
2. The content about environmental problems is not too difficult for me.	3.2	1.1
3. I enjoy looking into problems related to environmental content.	2.9	1.1
4. I look forward to the lessons when we cover the content about the environmental problems.	2.8	1.1
5. I stay focused while learning environmental content.	3.1	1.2
6. I get high marks on the content of the environmental problems.	3.5	1.2
7. I learn more about the environment problems than is required at school.	2.4	1.1
8. I learn about environmental problems quite quickly.	3.2	1.0
9. I like experiments related to environmental content.	3.2	1.2
10. Learning about environmental problems is interesting for me.	3.1	1.2
11. In my free time, I also deal with environmental problems.	2.4	1.1
12. I am good at learning about environmental content.	3.2	1.0
13. Everything that has to do with environmental issues attracts my attention.	2.7	1.1
14. I like to take part in lessons when environmental problems are discussed.	2.9	1.1
15. When solving tasks that relate to environmental problems, I keep at it until I have fully understood them.	2.8	1.1
SUM	44.8	11.9

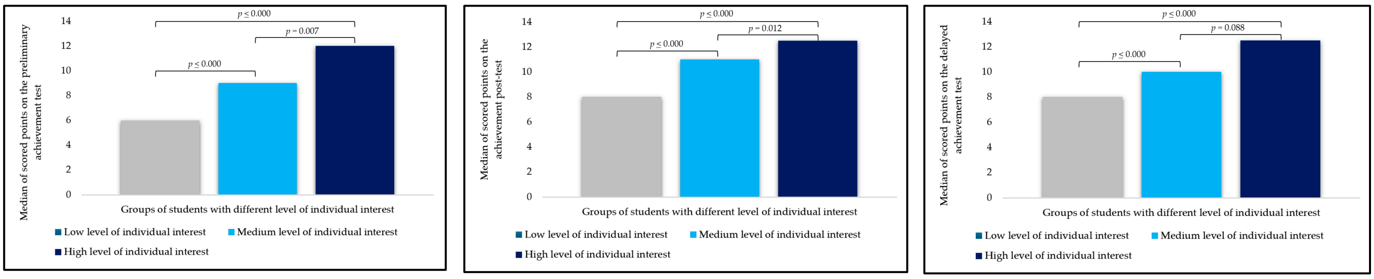
The students were divided into three groups based on the points collected on the Individual Interest Questionnaire according to the statistical equations described in subheading Data analysis. The Kolmogorov–Smirnov test showed a non-normal distribution of data collected on the preliminary achievement test ($p = 0.000$), achievement post-test ($p = 0.039$) and delayed achievement test ($p = 0.000$).

The Kruskal–Wallis test showed significant differences between students' results on the preliminary achievement test ($H = 29.13$; $g = 2$; $p = 0.000$), achievement post-test ($H = 21.61$; $g = 2$; $p = 0.000$) and delayed achievement test ($H = 14.97$; $g = 2$; $p = 0.001$) based on their level of individual interest.

The Games–Howell post hoc test showed statistically significant differences in results on the preliminary achievement test between students with a low level of individual interest and students with a medium level of individual interest ($p = 0.000$), between students with a low level of individual interest and students with a high level of individual interest ($p = 0.000$) and between students with a medium level of individual interest and students with a high level of individual interest ($p = 0.007$). Students with a high level of individual interest achieved the highest score on the preliminary achievement test ($Me = 12.0$; $IQR = 3.0$) in comparison to students with a medium level ($Me = 9.0$; $IQR = 4.0$) and low level of individual interest ($Me = 6.0$; $IQR = 3.0$).

Regarding the result on the achievement post-test, the Games–Howell post hoc test showed statistically significant differences between students with a low level of individual interest and students with a medium level of individual interest ($p = 0.000$), between students with a low level of individual interest and students with a high level of individual interest ($p = 0.000$) and between students with a medium level of individual interest and students with a high level of individual interest ($p = 0.012$). Students with a high level of individual interest achieved the highest score on the achievement post-test ($Me = 12.5$; $IQR = 4.0$) in comparison to students with a medium level of individual interest ($Me = 11.0$; $IQR = 3.0$) and a low level of individual interest ($Me = 8.0$; $IQR = 2.8$).

The Games–Howell post hoc test showed statistically significant differences in results on the delayed achievement test between students with a low level of individual interest and students with a medium level individual interest ($p = 0.000$) and between students with a low level of individual interest and students with a high individual interest ($p = 0.000$). There are no statistically significant differences between students with a medium level of individual interest and students with a high level of individual interest ($p = 0.088$). Students with a high level of individual interest achieved the highest score on the delayed achievement test ($Me = 12.5$; $IQR = 6.0$) in comparison to students with a medium level ($Me = 10.0$; $IQR = 3.0$) and a low level of individual interest ($Me = 8.0$; $IQR = 3.0$). Statistical differences in results on the achievement tests between students with different levels of individual interest are presented in Figure 4.



(**a**) (**b**) (**c**)

Figure 4. Statistical differences between students with different levels of individual interest in results on the preliminary achievement test (**a**), achievement post-test (**b**) and delayed achievement test (**c**).

3.4. Impact of Students' Level of Situational Interest on Their Knowledge Achievement After the Educational Intervention

Research question 4 focused on how students' levels of situational interest affect their knowledge achievement after the educational intervention. Table 5 shows the results of students' collected points when rating items of the Situational Interest Questionnaire using a 5-point Likert scale.

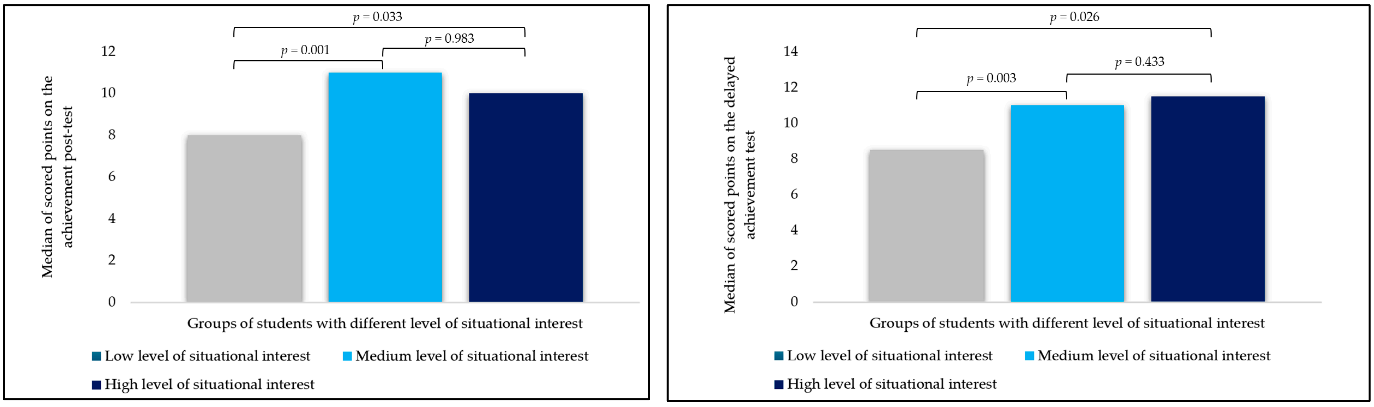
Table 5. The results of students' collected points when rating items of the Situational Interest Questionnaire using a 5-point Likert scale.

Items of the Situational Interest Questionnaire	*M*	*SD*
1. The online workshop was interesting for me.	4.0	0.8
2. The content of the online workshop was difficult for me.	3.5	0.9
3. I stayed focused while participating in the online workshop.	3.6	0.8
4. I enjoyed participating in the online workshop.	3.8	0.8
5. I clearly understood what was discussed in the online workshop.	3.5	0.8
6. Participating in the online workshop was fun.	3.6	0.7
7. The online workshop contained a lot of different activities.	3.5	0.8
8. I paid attention during the online workshop from beginning to the end.	3.5	0.9
9. The content of the online workshop encouraged me to solving tasks.	3.5	0.9
10. I want to delve into the details of the content presented in the online workshop.	3.3	0.8
SUM	35.7	5.1

The students were divided into three groups based on the points collected on the Situational Interest Questionnaire according to the statistical equations described in subheading Data analysis. The Kolmogorov–Smirnov test showed a non-normal distribution of data collected on the preliminary achievement test ($p = 0.000$), achievement post-test ($p = 0.039$) and delayed achievement test ($p = 0.000$).

The Games–Howell Post Hoc test showed statistically significant differences in results on the knowledge post-test between students with low and medium levels of situational interest ($p = 0.001$). Meanwhile, between students with a medium and high level of situational interest ($p = 0.983$) and between students with a low and high level of situational interest ($p = 0.063$), there were no statistically significant differences shown in the achieved results on the achievement post-test. Students with a medium level of situational interest (*Me* = 11.0; *IQR* = 4.0) achieved better results on the achievement post-test compared to students with a high level of situational interest (*Me* = 10.0; *IQR* = 4.0) and students with a low level of situational interest (*Me* = 8.0; *IQR* = 2.8).

The Games–Howell Post Hoc test showed statistically significant differences in results on the delayed achievement test between students with a low and medium level of situational interest ($p = 0.003$) and between students with a low and high level of situational interest ($p = 0.026$). Between students with a medium level and a high level of situational interest ($p = 0.433$), it showed no statistically significant differences in achieved results on the delayed achievement test. Students with a high level of situational interest (*Me* = 11.5; *IQR* = 6.0) achieved a better result on the delayed achievement test compared to students with a medium level of situational interest (*Me* = 10.0; *IQR* = 4.0) and students with a low level of situational interest (*Me* = 8.5; *IQR* = 3.0). Statistical differences in results on the achievement tests between students with different levels of situational interest are presented in Figure 5.



(**a**) (**b**)

Figure 5. Statistical differences between students with different levels of situational interest in results on the achievement post-test (**a**) and delayed achievement test (**b**).

4. Discussion

The study aimed to evaluate the effectiveness of integrating hydrosphere environmental problems into chemistry lessons through an online workshop, comparing students' achievements and their situational and individual interests before and after participating in the workshop. Research questions 1 and 2 focused on comparing students' knowledge achievements on the preliminary achievement test, achievement post-test and the delayed achievement test, as well as identifying students' hydrosphere misconceptions on all achievement tests. The results show that after actively participating in the online workshop with topics focusing on hydrosphere environmental problems, students performed significantly better on the achievement post-test and delayed achievement test than on the preliminary achievement test, which assessed their prior knowledge of understanding these environmental issues. Similar to our findings, another study by Havu-Nuutinen et al. (2018) conducted science, technology and society lessons based on different technological tools and successfully evaluated this intervention by comparing students' conceptual change processes in relation to water-related concepts. Therefore, these results highlight that employing modern teaching approaches, tailored to students' abilities, needs, and interests, significantly enhances learning outcomes.

Although students did occasionally recall scientific concepts and definitions correctly, they had difficulties applying these concepts to specific situations of the hydrosphere processes, its pollution and sustainable solutions. Students were also found to have the greatest deficits in scientific knowledge of processes that they do not regularly encounter in their daily experience. On the preliminary achievement test, due to the lack of scientific knowledge, students had difficulty identifying the chemical structure of surfactants (e.g., detergents) and explaining the negative effects caused by uncontrolled release into the environment. Students also had difficulty identifying the chemical structure of a starch molecule as a polysaccharide molecule and explaining the chemical reaction occurring during the synthesis of biodegradable plastic from starch. On the achievement post-test, due to the lack of scientific knowledge, students had difficulty selecting the appropriate source to accelerate the natural microbiological degradation of oil spills based on the knowledge of physical and chemical properties of oil. Students also had difficulties understanding the change in the chemical structure and properties of the starch molecule because of heat during the synthesis process of biodegradable plastic. On the delayed achievement test, due to the lack of scientific knowledge, students incorrectly identified properties of activated carbon as one of the adsorbents for adsorbing organic pollutant molecules from wastewater on its surface.

Since misconceptions have a negative impact on the development of new knowledge, it is important to identify them before introducing new scientific content (Borghini et al., 2022; Suprapto et al., 2015). Before participating in the online workshop, three common misconceptions of the students regarding hydrosphere environmental problems were identified using a three-tier preliminary achievement test. The first misconception was that the oxygen molecule, like the water molecule, is non-polar due to an unequal distribution of electrical charge, the second misconception was that primary wastewater treatment is a process that uses mechanical barrier screens to retain larger solid particles, and the third misconception was that activated carbon tablets neutralize stomach acid due to their alkaline properties rather than their adsorption ability. Right after students actively participated in the online workshop, one common misconception was identified using a three-tier achievement post-test, and two weeks after participation in the online workshop, one common misconception was identified using a three-tier delayed achievement test. The misconception identified on the achievement post-test was that the eutrophication of lakes is a consequence of the excessive use of pesticides in agriculture, as the toxic degradation products of pesticides cause the death of algae and higher plants. The misconception identified on the delayed achievement test was that the pictograms on the packaging of the pesticide atrazine show a dead fish and warn the user to exercise caution with an exclamation mark. Students probably had misconceptions about understanding the chemical processes involved in ocean oil spills and associated cleanup, as they either did not fully focus or skipped the fourth and final interactive video of the online workshop. This video introduced the topic of oil spills with a hyperlink to an article and explained the chemical and physical properties of oil and fossil fuels through interactive H5P tasks. It also showed an experiment to simulate mechanical (e.g., pipette), physical (e.g., activated carbon) and chemical cleaning methods (e.g., surfactants) and encouraged a critical evaluation of their benefits and challenges with interactive prompts.

The results of the study are similar to other studies (Kerret et al., 2014; Rebolj & Devetak, 2013; Havu-Nuutinen et al., 2018) where they have identified students' misconceptions regarding complex chemical concepts, such as understanding the connections between the chemical structure of pollutants and their physical and chemical properties when distributed into the environment. The same studies also highlighted that students use informal and simplified scientific terminology when explaining natural processes in the hydrosphere, although they may occasionally recall definitions of chemical concepts, but tend to incorrectly relate them to specific hydrosphere processes or pollution issues. Students' poor understanding of the water cycle processes, and of the effects of human activity upon it, seems to be a worldwide problem across levels of education (Boon, 2024). Abbott et al. (2019) in their study analyzed 464 diagrams of the water cycle from textbooks, scientific articles, teaching materials, etc., from around the world to find that only 15% of these diagrams depicted human interaction and its effect on water quality. Moreover, Mostacedo-Marasovic et al. (2023) in their study also report that when learning and discussing the water cycle, students tended to be unaware of water elements that were invisible to them, such as groundwater, aquifers, atmospheric water, water molecules, and landscapes. Before students start secondary education, they should understand the interactions of Earth's major systems: the geosphere, the hydrosphere, the atmosphere, and the biosphere. Students need to understand that these systems interact in various ways, and the possible effects upon Earth's surface, materials, and processes. Water impacting food production is an economic resource whose security and sustainability affects human livelihood (David et al., 2024). By including mayor systems, even the less visible ones, teachers can help students visualize the full extent of hydrosphere pollution sources and understand the links between human activities and water quality. Incorporating environmental issues of the hydrosphere into the chemistry classroom is crucial to raise awareness of the urgent need to protect water resources and ensure sustainable water management, as outlined in SDG 6 Clean Water and Sanitation. By educating students about the impact of pollution on the hydrosphere, we empower future generations to take informed action and advocate for the necessary measures to prevent further deterioration of water quality at local, regional and global levels (United Nations, 2015; Boon, 2024).

Studies (Ben-zvi-Assarf & Orion, 2005; Iliopoulou, 2018; Rebolj & Devetak, 2013) show that students do not tend to have difficulties understanding chemical concepts regarding processes with which they are regularly engaged in their daily experiences or are directly implemented in the school curriculum. For example, particularly in this study, students did not have difficulties recognizing the environmental hazard pictogram on detergent packaging, since this topic is commonly addressed within the learning objectives of various science subjects at the primary and secondary school levels, ensuring consistent exposure and understanding throughout their education. However, the knowledge acquired at school is often not translated into everyday habits (Amahmid et al., 2019) because students' environmental literacy is insufficient or because the constraints of an overcrowded curriculum do not allow students to delve deeper into the hydrosphere processes. During the workshop in this study, students explored how learning about environmental issues related to the hydrosphere can be translated into practical actions considering the 3R model (reduce, reuse, recycle), such as reducing plastic waste by using reusable bottles and bags, separating waste for recycling, and recognizing and rejecting consumer manipulation through advertising. These activities aimed to bridge the gap between theoretical knowledge and environmentally friendly behavior, thus promoting environmental literacy and sustainable habits.

Research questions 3 and 4 focused on differences in results on achievement tests between students with different levels of individual and situational interest before and after participating in the online workshop. The results show that students with higher levels of individual or situational interest achieved better results on achievement tests. Based on the results of the third and fourth research question, it can be verified that using different teaching approaches is needed to make chemistry lessons more student-centered, hands-on and engaging, which improves students' learning outcomes. Activities designed to capture students' attention should include elements such as personal relevance, novelty, active participation and comprehensibility, ensuring that they are both interesting and appropriately challenging. By relating activities to students' everyday lives, their interests and engaging them in role-playing or problem-solving activities that promote critical thinking, teachers can stimulate both situational and individual interest. These teaching approaches encourage deeper, sustained engagement with the activities, leading to more effective learning and a positive attitude towards science and environmental values (Tsang et al., 2019; Yuan et al., 2023; Néel et al., 2015).

Without a structured thematic form of science curricula, it is the responsibility of teachers to design and facilitate the learning process on environmental and sustainability issues. The need to update science curricula has arisen to provide numerous opportunities to teach young people about sustainable living issues. For this reason, as part of the curriculum reform currently underway in Slovenia, new curricula are being created for all subjects to provide students and teachers with skills for sustainable development (Vošnjak et al., 2024; Kapsala et al., 2022).

Due to the crucial role of teachers in achieving the fourth SDG from the 2030 Agenda for Sustainable Development, special emphasis should be given to pre- and in-service teacher education, offered ongoing professional development to achieve the competences needed to teach sustainable development as part of their subject (Erjavšek et al., 2021;

Kapsala et al., 2022). For all age groups, it is important to consider (in the context of aspects such as operational feasibility and the availability of funding) how the activities can have a lasting impact. This includes whether the activities are carried out as one-off measures or over a longer period and how they are implemented for each group (Erjavšek et al., 2021).

5. Conclusions

Educators play an important role in developing students' critical thinking about environmental hazards and encouraging them to develop their own ideas and possible solutions for a sustainable future. Therefore, they must select appropriate teaching approaches not only to improve the quality of students' knowledge but also to support their active participation in solving environmental problems. For this purpose, an online workshop was optimized with examples of implementing hydrosphere environmental problems into chemistry considering the learning objectives and related standards of the low secondary school chemistry curriculum. Students' knowledge achievements were significantly better after participating in the online workshop. Students' higher level of individual interest and situational interest positively influenced their knowledge achievement before and after the educational intervention. Based on the results, we can conclude that teachers should use student-centered innovative teaching methods (e.g., experimental work, animations, simulations, etc.) to create a learning situation which will trigger student's attention to cooperate in discussion or other activities. Such a learning situation leads to the formation of situational interest and if students' attention is relatively stable and long-lasting, the formation of individual interest occurs. Consequently, motivated students are effective learners and further tend to develop a positive attitude towards nature and its values. This study is a critical step forward in addressing the evident challenges in students' knowledge and interest toward hydrosphere-related environmental problems. By offering evidence-based insights into how such issues can be addressed through innovative, student-centered approaches, this study enriches the existing body of literature and provides a practical framework for incorporating environmental and sustainability topics into chemistry curricula. These contributions are vital for fostering a generation of learners equipped with the knowledge, skills, and attitudes necessary to take sustainable actions in the future.

5.1. Limitations of the Study

Because the education was designed to be an online workshop, all data collection took place online, making it difficult to monitor student participation in the online workshop. The decline in student responsiveness and effectiveness was due to their absence in school during certain phases of the study, the pressure of having to complete exams, national knowledge tests, and other activities at the end of the lower secondary school year. When implementing the workshop in the chemistry classroom, a combination of online and face-to face education should be used. Face-to-face education could also be conducted using ICT in the classroom, such as tablets where students could learn new content and answer questions during evaluation. Such an approach can offer teachers more control over students' learning.

5.2. Guidelines for Further Research

In further research, it would be advisable to develop more activities based on an active learning approach. For example, the online workshop could include instructions for conducting a simple experiment at home (e.g., determining the pH of rainwater with a red cabbage indicator), allowing students to share their results with their classmates in the forum. Students should also express their opinions about which activities they find most effective and interesting. When discussing the effective implementation of educational initiatives, the focus of future studies should extend beyond cognition to include affective and behavioral outcomes. Further research could also be based on a sample of chemistry teachers to determine how often they include content about hydrosphere environmental problems in their lessons, what didactic approaches they use, and what challenges they face. Further development of the workshop and its evaluation could be accomplished by implementing artificial intelligence apps to gather relevant information for students to learn and to develop augmented reality visuals using tablets to illustrate phenomena in environmental chemistry.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data used in this study are available on request from the corresponding author. The data have been anonymized but are not publicly available because of the privacy issues related to the qualitative nature of it.

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