VIRTUAL TECHNOLOGY FOR TEACHING ABOUT DRINKING WATER PREPARATION AND WASTEWATER TREATMENT

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Slovenia's sustainable strategy prioritises wastewater management and drinking water preparation, yet their interconnection in the light of climate change is often neglected. To address these challenges, different educational tools were prepared, using innovative technologies. Using a 360° camera, the processes at the Maribor Waterworks and Central Wastewater Treatment Plant were recorded, documenting water preparation, treatment and laboratory work. The materials were processed with H5P software to create interactive digital lessons in Moodle. These resources raise awareness about environmental health, focusing on wastewater management and safe drinking water practices. Ultimately, the educational tools enhance skills, expand knowledge, and supports efforts to protect the environment and combat climate change.

DOI
https://doi.org/10.18690/um.fkkt.1.2026.7

ISBN
978-961-299-130-2

Keywords:
drinking water,
wastewater,
digital learning materials,
360 degree camera,
virtual reality

University of Maribor Press

1 Introduction

Wastewater management and drinking water preparation are two of the priority areas of the Slovenian sustainable smart specialisation strategy (Ministrstvo za kohezijo in regionalni razvoj, 2025). However, the connection is often overlooked between wastewater treatment and an adequate drinking water supply. Due to the impact of the increasing climate change, there is an urgent need to educate students, employees and the wider population, which can be achieved successfully through the use of new technologies (e.g., extended reality) (Fauville et al., 2020; Thoma et al. 2023; Said et al., 2023).

1.1 Drinking water

Drinking water represents one of the most essential resources for human survival, public health and sustainable development. The preparation of drinking water involves a series of carefully controlled technological processes that transform raw water into safe, high-quality water suitable for consumption. These stages typically include abstraction from groundwater or surface water, aeration, coagulation and flocculation, sedimentation, sand or membrane filtration, activated carbon treatment and final disinfection. Each step plays a crucial role in reducing or eliminating microbiological risks, suspended solids, organic matter, chemical pollutants and potentially harmful trace substances (CDC, 2022).

In Slovenia, groundwater is the primary source of drinking water, which naturally provides a high level of protection, but is also increasingly vulnerable to the effects of climate change. Rising temperatures, altered precipitation patterns, agricultural runoff and extreme weather events can influence water quality and availability (NIJZ, 2023). As a result, the need for continuous monitoring, public awareness and educational initiatives has grown significantly. Virtual reality (VR) and 360° video allow learners to explore the internal structure of water facilities, observe the functioning of filtration systems, and understand better how strict procedures ensure microbiologically safe and chemically stable drinking water (Djordjević et al., 2025).

1.2 Wastewater

Wastewater treatment is a critical process that protects the environment by removing pollutants from used water before it is returned to natural ecosystems. Municipal wastewater typically contains organic materials, nutrients such as nitrogen and phosphorus, detergents, chemicals and microorganisms. Treatment begins with mechanical processes—screening, grit removal, and primary sedimentation—followed by biological treatment, where the microorganisms in activated sludge break down the organic substances. Advanced steps include tertiary treatment, nutrient removal, disinfection and sludge handling (European Environment Agency, 2023).

The Central Wastewater Treatment Plant Maribor plays a key role in maintaining water quality in the Drava River basin. With VR-supported learning, users can walk virtually through different treatment stages, observe aeration tanks, sedimentation basins, sludge dewatering units and laboratory testing areas. This immersive approach allows the learners to understand how wastewater becomes sufficiently purified for release into the natural environment, highlighting the interconnectedness of human activities, environmental protection and long-term water sustainability (Yunqin et al., 2022).

1.3 Innovative Learning Technologies

Traditional teaching materials often fail to convey the spatial complexity, scale and procedural details of water treatment systems. Innovative technologies—such as virtual reality, augmented reality, 360° recordings and H5P based interactive modules—provide an effective solution to this challenge. These tools support experiential learning by allowing the users to step inside real environments, interact with processes, and engage in self-directed exploration (Lampropoulos et al., 2025; Hamilton et al., 2021; Safitri et al., 2025).

VR enhanced learning has been shown to improve motivation, cognitive engagement, and long-term knowledge retention, especially in science and engineering education (Fauville et al., 2020; Said et al., 2023). In this project, these technologies were integrated strategically, to create an immersive experience that combines visual realism, guided explanations, quizzes and interactive hotspots. The

final result enables students and professionals to understand complex water management systems in a realistic, intuitive and pedagogically rich format.

2 Methods

2.1 Literature Review on Drinking Water and Wastewater

The research began with a comprehensive literature review focused on drinking-water treatment processes, wastewater purification technologies, the importance of water quality for public health and the impacts of climate change on water resources. The reviewed materials included the World Health Organization (WHO) guidelines, scientific articles, technical reports, and national regulations governing drinking-water preparation and municipal wastewater treatment (WHO, 2022; European Environment Agency, 2023). The findings from the literature review served as the foundation for developing recording scenarios and designing interactive learning materials.

2.2 Development of the Recording Scenarios

Based on the studied sources, detailed scenarios were prepared for filming at the Maribor Waterworks and the Central Wastewater Treatment Plant Maribor. These scenarios covered key stages of both processes, including raw water abstraction, filtration, disinfection and distribution, as well as mechanical and biological wastewater treatment and laboratory analysis procedures. The objective of the scenarios was to establish a logical sequence, provide clear explanations, and incorporate interactive components that would allow the users to gain a deeper understanding of water-treatment technologies.

2.3 Video Processing and Integration of Interactive Elements

Filming was conducted using the Insta360 360-degree camera. After footage collection, the material underwent digital processing, during which H5P was used to add interactive hotspots, questions, hyperlinks and graphical representations of the processes. These interactive elements were designed to offer the users explanations of the individual treatment stages and real-time knowledge checks during the virtual tour. The final materials were also adapted for use with 3D headsets, enabling an immersive experience of the waterworks and wastewater-treatment environments.

3 Results

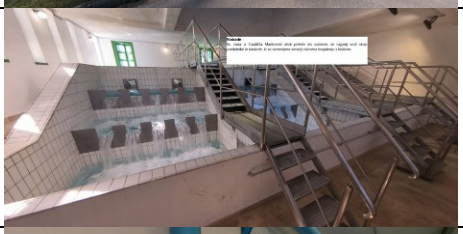
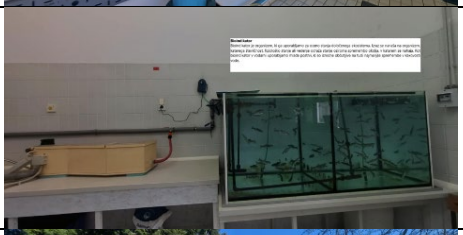
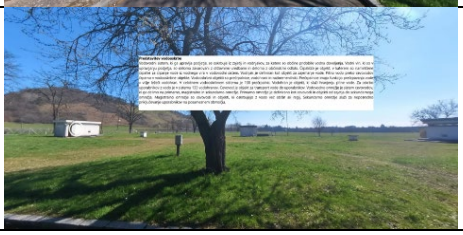
Digital interactive learning materials in the form of a virtual walk through and as learning materials for an online classroom have been prepared, with the help of which we can raise awareness among the users about the environmental determinants of health, more specifically about the importance and procedures for wastewater management and appropriate preparation and control of drinking water.

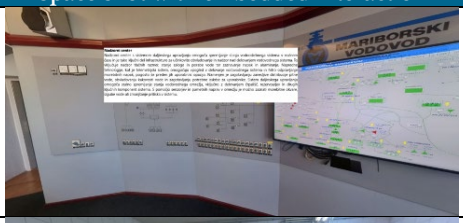
3.1 Virtual tour through the premises of Maribor Waterworks and WWTP with interactions and a quiz

A 360-degree virtual tour with embedded information allows the user to walk through the premises of the Maribor Waterworks and WWTP. This way, the user can view and obtain information about the history of the Maribor Waterworks, a presentation of the waterworks, the filling fountain, cascades, sand filters, bioindicators, pumping station, water supply, control centre, wells, and a presentation of the quality and compliance of drinking water (Table 1). The user can view each of the images freely in a 360-degree view and read the added information. The interactions about WWTP contains basic information, laboratory analyses, air purification, waste removal with coarse and fine screens, sand and grease removal, biological treatment, and treatment of waste sludge, sand and grease (Table 2).

Table 1: Virtual tour through the premises of Maribor Waterworks with interactions

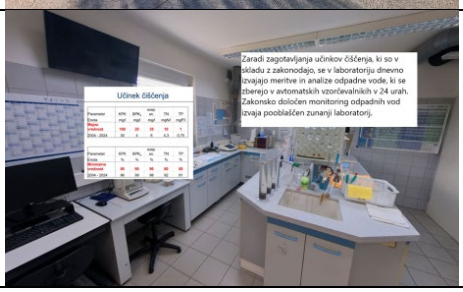
Location	Space shot with embedded interaction
Maribor Waterworks - history	
Maribor Waterworks - in numbers	

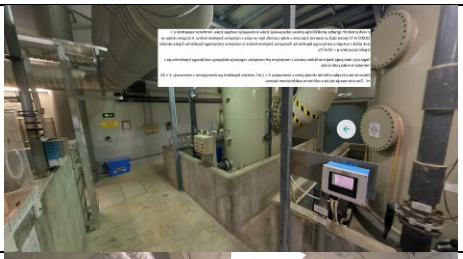
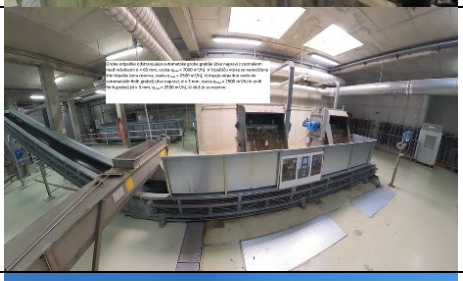
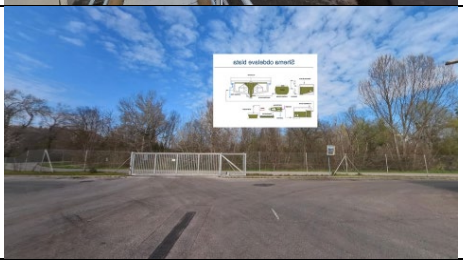
Location	Space shot with embedded interaction
Filling fountain	
Cascades	
Sand filters	
Bioindicators	
Pumping station	
Water supply	

Location	Space shot with embedded interaction
Control center	
wells	
Quality and compliance of drinking water	

Source: own

Table 2: Virtual tour through the WWTP with interactions

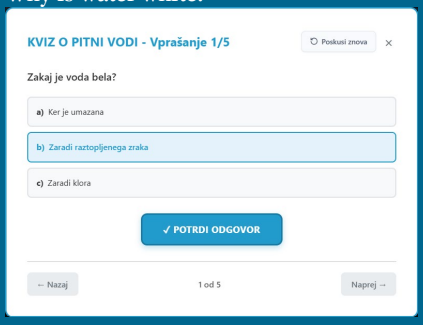
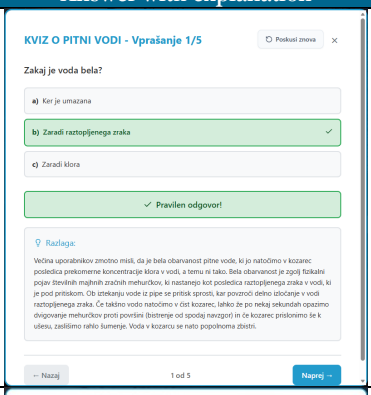
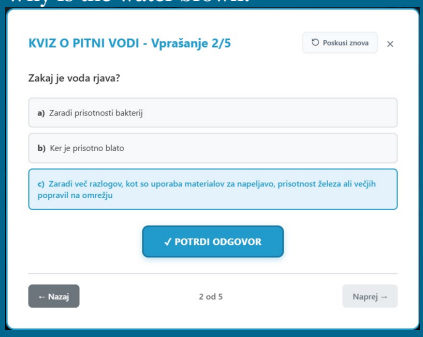
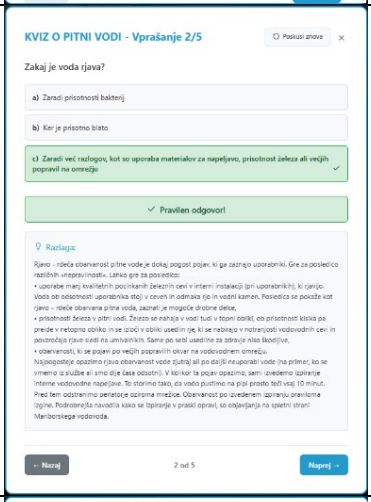
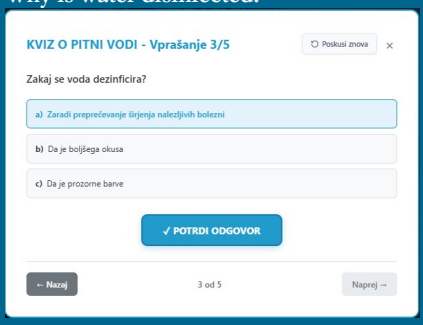
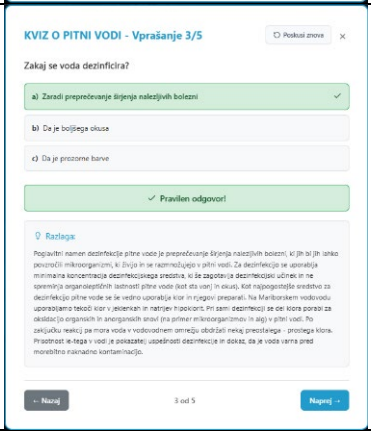
Location	Space shot with embedded interaction
basic information	
laboratory analyses	

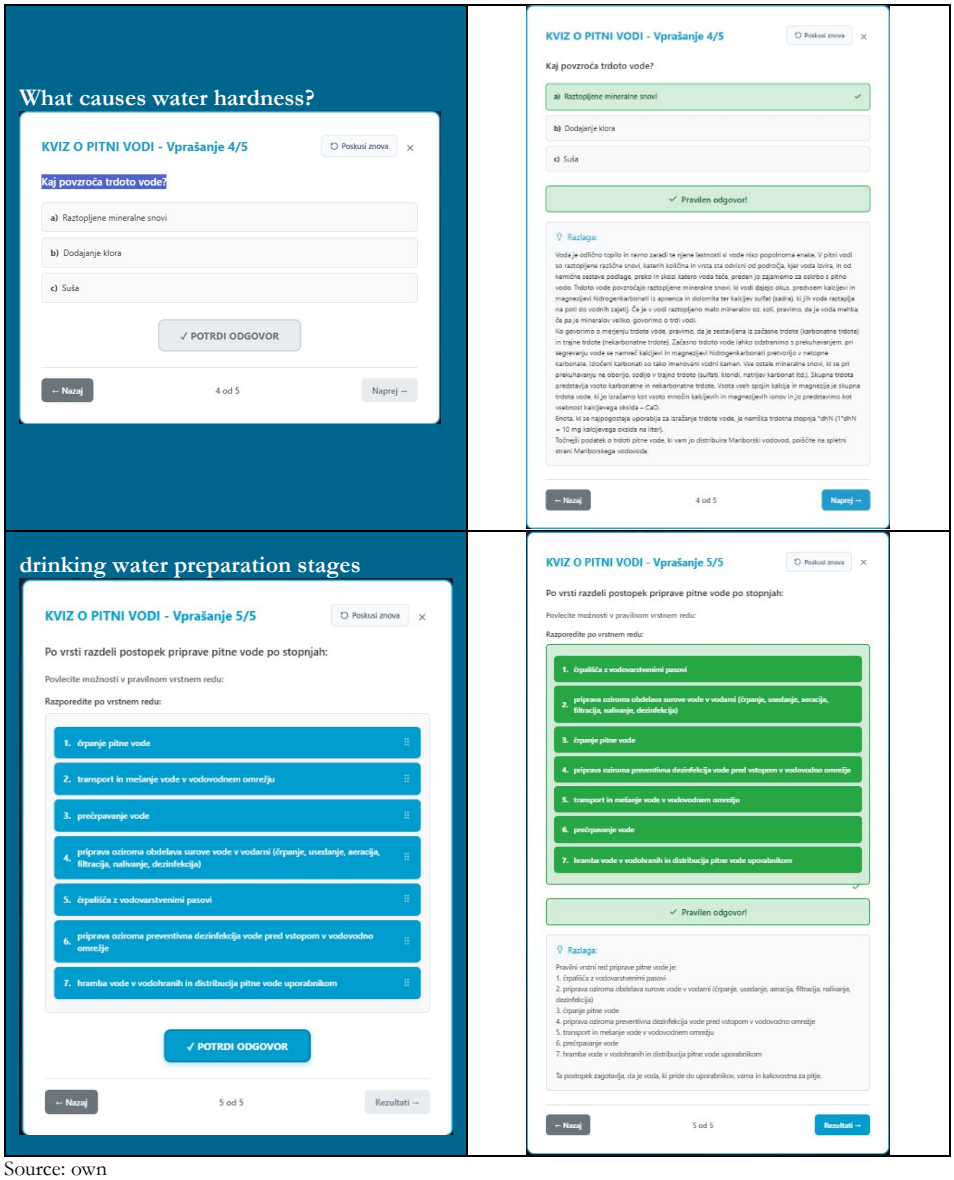
air purification	
waste removal with coarse and fine screens	
sand and grease removal	
biological treatment	
treatment of sludge from biological treatment, sand and grease treatment	

Source: own

After completing the tour, the user can take a 5-question quiz to test their knowledge about Maribor Waterworks (Table 3) or a 28-question quiz about WWTP. Each correct answer is also provided with an explanation of the answer.

Table 3: Five-question quiz about Maribor Waterworks

Question	Answer with explanation
Why is water white? 	
Why is the water brown? 	
Why is water disinfected? 	



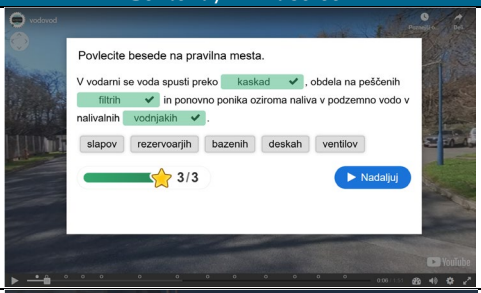
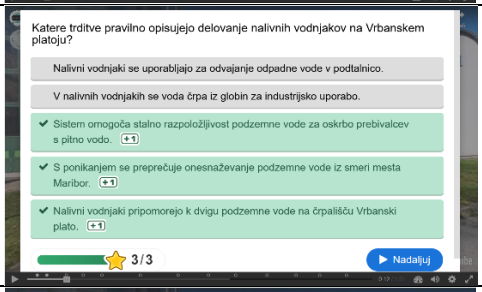
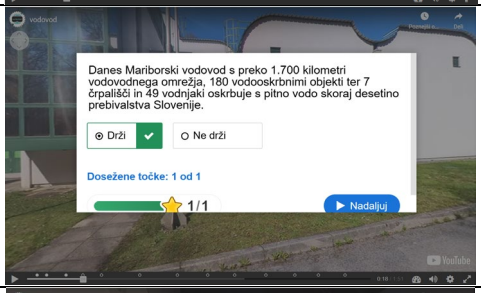
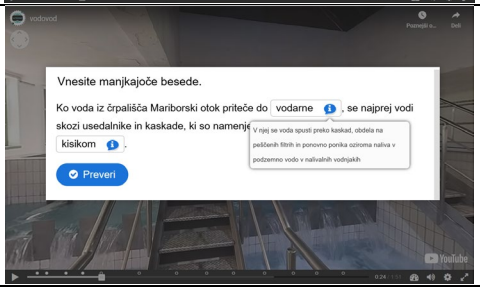
Source: own

3.2 Learning materials with knowledge testing in the online classroom

The 360-degree videos were processed with H5P, and different interactions were inserted, e.g., drag and drop a word, choosing the correct answers, correct / incorrect, fill in the missing words (Table 4,5). The learning material is designed in a

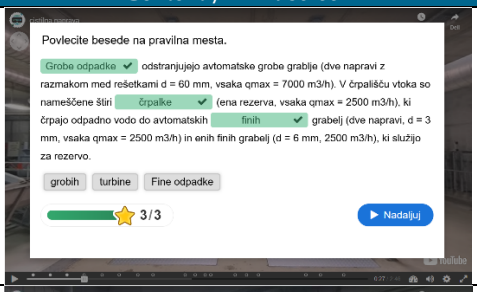
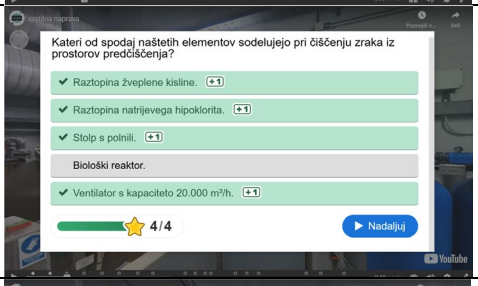
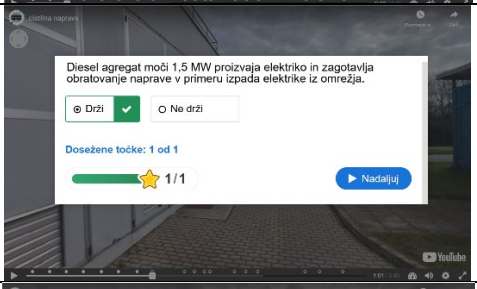
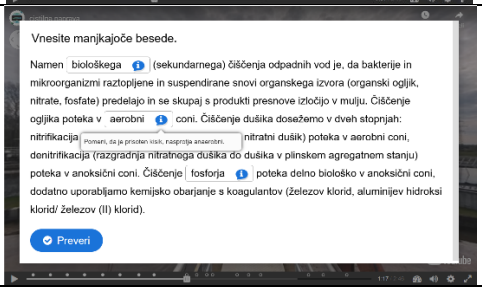
way where the user must choose all the correct answers or solve the tasks correctly in order to continue viewing. This encourages continuous learning and knowledge testing.

Table 4: Learning materials about Maribor Waterworks in the online classroom (selected interactions)

Interaction	Content / Print screen
Drag and drop a word	
Choosing the correct answers	
Correct / incorrect	
Fill in the missing words	

Source: www.um.si

Table 5: Learning materials about WWTP in the online classroom (selected interactions)

Interaction	Content / Print screen
Drag and drop a word	
Choosing the correct answers	
Correct / incorrect	
Fill in the missing words	

4 Conclusions

Innovative learning materials enable the acquisition of new skills, the upgrading of existing knowledge, as well as the verification and consolidation that is essential for maintaining a healthy environment and combating climate change effectively.

Acknowledgment

The project was implemented within the framework of the Public Tender »Problemsko učenje študentov v delovno okolje: gospodarstvo, negospodarstvo in neprofitni sektor v lokalnem/regionalnem okolju 2024-2027 (PUŠ v delovno okolje 2024-2027)«. We would like to thank all the participating students.

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