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Educating Professionals to Develop Nature-Based Solutions (NBS) as Infrastructure for Water Pollution Control: A Course Proposal

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Abstract: The objective of this study was to design a university-level course focused on Nature-Based Solutions (NBS) for water pollution control. The work unfolded in three phases: the initial planning, course delivery, and assessment of learning outcomes. In the planning phase, a set of competencies was outlined using the Developing a Curriculum Method (DACUM), resulting in defined learning outcomes and a structured course outline. Subsequently, the course was conducted over a two-week period, employing a hybrid format including both online and in-person sessions. The assessments of the learning outcomes included one test, an assignment, a satisfaction survey, and the post-course feedback. As a result of the planning phase, four competencies, seven learning outcomes and four course units were defined. The participant cohort encompassed a diverse group of 50 individuals, including undergraduate and postgraduate students, professionals working in industry and institutions, and professors. The assessment of the learning outcomes showed good results. However, issues regarding the mathematical calculations and field-trip experience were noted, suggesting areas for course enhancement. The participants expressed high satisfaction levels across the various course components. Notably, 70% of the participants indicated the application of the acquired knowledge in their professional endeavors. These findings underscore the successful implementation of the course, establishing it as a pioneering university-level program in NBS for water pollution control.

Keywords: Chile; DACUM; nature-based solutions; wastewater treatment; water quality; water pollution control

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1. Introduction

Nature-Based Solutions (NBS) have been defined recently as "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits" [1]. This broad definition of NBS finds relevance in various contexts, including water management, where addressing water pollution stands as a critical objective. Presently, over 80% of sewage produced from human activities is discharged into surface water bodies and oceans without undergoing any form of treatment. This reckless disposal leads to environmental contamination and contributes to the proliferation of over 50 waterborne diseases in humans [2]. Furthermore, the degradation of freshwater ecosystems, primarily attributed to water resource pollution and aquatic ecosystem contamination, is estimated to have resulted in a significant reduction in approximately one-third of global biodiversity [3].

Technologies rooted in the principles of the NBS definition can help to improve this situation by the treatment of punctual or diffuse discharges, thereby mitigating their adverse effects on natural ecosystems [4]. Moreover, NBS interventions can play an important role in the restoration of freshwater bodies themselves [5]. NBS have numerous advantages over conventional technologies, including the creation of new habitats, enhancement of biodiversity, promotion of pollination, valuation of amenities, sequestration of carbon sequestration, regulation of temperature, production of biomass, and reuse of water [6,7]. These benefits render NBS technologies highly appealing for implementation when compared to conventional solutions.

Despite the evident advantages of NBS, the adoption of specific NBS technologies, such as constructed wetlands (CWs) for wastewater treatment—a technology that has undergone significant advancements in both design and application over more than five decades [8]—remains limited, particularly in Latin America. Only 0.22% of the wastewater in the region is treated using CWs [9]. Latin America faces challenges, with only 40% of wastewater receiving treatment, encompassing both urban and rural areas [10]. For instance, while treatment coverage is close to 100% in urban areas in Chile, rural settlements experience treatment rates below 10%, with CWs accounting for less than 0.2% of this coverage [11]. Leveraging CWs alongside other NBS technologies could significantly enhance wastewater treatment coverage for populations in Chile and Latin America, but particularly in rural places and peri-urban areas [12].

The execution of projects utilizing CWs or NBS technologies necessitates a comprehensive framework involving various stakeholders and governmental policies. Successful NBS applications aimed at improving water quality demand specialized expertise, highlighting the significance of addressing the shortage of specialists as a factor contributing to the limited adoption of these technologies in Latin America [13]. McQuaid et al. [14] emphasize that access to education, training, and skill development, often facilitated through university collaborations, is pivotal in fostering infrastructure development with NBS implementations. Hence, transferring NBS knowledge from these specialists to a new generation of professionals is imperative for confronting the challenges of water pollution control amidst a changing global landscape.

Currently, there is a growing need for both education and training programs directed towards developing infrastructure utilizing NBS technologies. However, the integration of NBS concepts into curricula or specialized courses remains unclear, particularly at a university level [15], and even more so in a Latin American context [16]. Versini et al. [17] recently evaluated the incorporation of NBS for climate change adaptation within French master's programs, highlighting numerous gaps that need addressing for more effective integration of NBS concepts into higher education. Addressing this gap, a specialized course, like NBS' implementation for water pollution control, would serve as a valuable contribution for filling the identified void in postgraduate education [15]. Thus, the introduction of a new university-level course would significantly enhance the training of professionals in

NBS technologies. Considering the aforementioned points, the objective of this paper is to propose a course aimed at fostering the development of water infrastructure utilizing NBS, with a primary focus on water pollution control, in order to educate and equip a new generation of professionals.

2. Materials and Methods

The methodology employed for developing a course proposal, which aimed to educate professionals on water pollution control through NBS technologies, was divided into three main phases: the initial planning and course design, actual course delivery, and assessment of learning outcomes. Figure 1 illustrates this methodology, including the preliminary analyses.

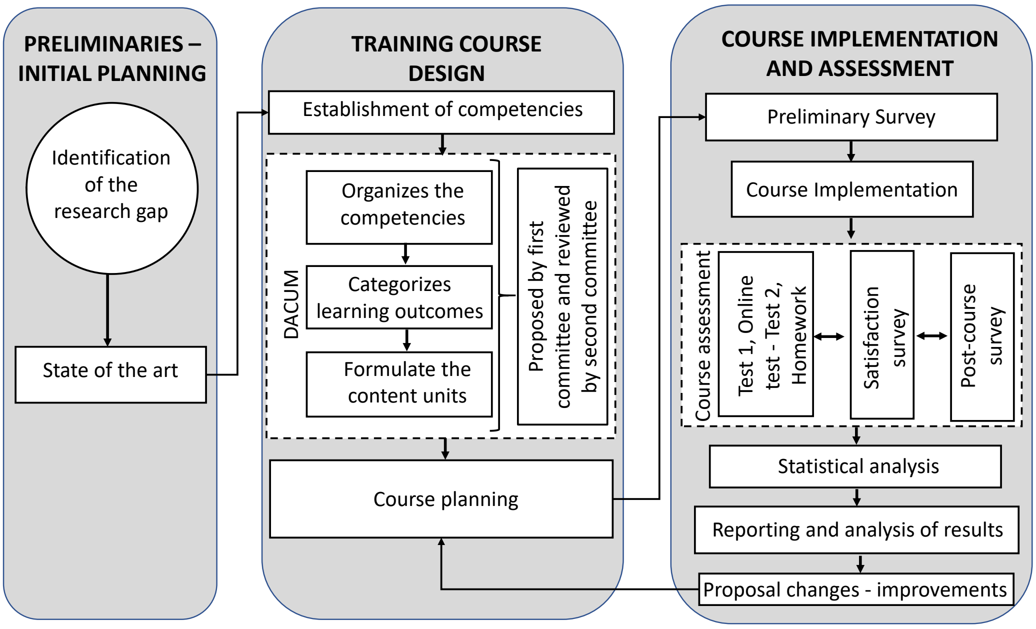

Figure 1. Flow chart for experimental development.

2.1. Initial Planning and Course Design

The initial phase commenced with the establishment of a competency framework, drawing from the competencies delineated by Vera-Puerto et al. [6] for engineering education concentrating on NBS water infrastructure development in urban settings. Subsequently, the final competencies were defined utilizing the Developing a Curriculum Method (DACUM), which is a process designed to analyze job positions and tasks for the purpose of defining training curricula [18]. The implementation of this method involved a facilitator and a panel of seven experts representing various multidisciplinary fields. The selection criteria for the expert panel encompassed their proficiency and experience across diverse domains such as biology, water quality, wastewater treatment, and NBS, with backgrounds spanning consulting, research, and real project implementations. This group of experts organized the baseline competencies for the NBS according to their professional roles and responsibilities, and subsequently categorized them into specific learning outcomes. The initial competencies proposal reflected a multidisciplinary view consistent with the demands of NBS projects and the expertise of the committee. Subsequently, the committee formulated the content for the course.

A second committee, comprised of five experts from diverse disciplines, undertook a thorough review of the initial DACUM committee's proposal, providing valuable insights and observations. The experts who participated in the first and second committee were employed at universities or research centers, or were employed as consultants. Subsequently, the initial committee assessed and incorporated the pertinent modifications in response to the feedback received. In the concluding phase, the committee devised the course curriculum, encompassing the competencies, learning outcomes, thematic content, and other aspects pertinent to the course implementation.

2.2. Course Implementation

Once the course program was finalized, an open invitation was disseminated via social media platforms, inviting individuals to enroll in the course free of charge. The course was conducted in a hybrid format, including online and in-person sessions, and was delivered in Spanish. Upon their enrollment, the participants were required to complete a preliminary questionnaire, including their motivations for taking the course (maximum 250 words) and were assessed for their background (e.g., a bachelor student, postgraduate student, professional in industry, professional in institutions, professor), in addition to their professional experience. The data analyses pertaining to the participants' motivations were conducted using NVivo software version 20 [19], with the objective of obtaining an initial understanding of each participant's motivations prior to engaging with the course content. Although 95 individuals initially enrolled in the course, ultimately, only 50 participants actively attended the sessions.

2.3. Assessment of Learning Outcomes

At the conclusion of the first week, a test was devised to assess the content covered during that period, which comprised 20 multiple-choice questions and was administered online (Supplementary Material S1). In the second week, the students underwent an evaluation through a final assignment which involved applying calculus to determine the required surface area for an NBS project using water quality data collected prior to the course in two rural wastewater treatment plants (WWTPs) in the Maule Region, Chile. Following the completion of the course, a satisfaction survey was administered utilizing a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree) and was segmented into six distinct areas: (1) Teacher, (2) Technology, (3) Course Structure, (4) Interaction, (5) Results, and (6) Overall Satisfaction (Supplementary Material S2). This survey methodology is based on the proposal of Frenze [20] for assessing student satisfaction with courses. The participants' responses from the survey were subjected to analyses using statistical techniques tailored to the questionnaire data, adhering to the sequence described by Vera-Puerto et al. [6]:

(a) Cronbach's reliability test (α) was conducted to validate the reliability of the questionnaire based on its responses. The values vary from 0 to 1. The values above 0.7 are considered acceptable for further analyses [21,22].
(b) The Shapiro–Wilk normality test was conducted to test the normality of the responses. This test helps to decide whether parametric or nonparametric tests are suitable for further analyses [22].
(c) The average (M) was determined to estimate the degree of satisfaction. In addition, the Standard Deviation (SD) was calculated.
(d) The Interrater Agreement Statistics (IRA; a_{wg}) was conducted to analyze and validate the students' agreements among the respondent groups. The IRA analysis was made with the code deduced by Lebreton and Senter [23] as follows: (a) $0.00 < a_{wg} < 0.30$ "lack of agreement"; (b) $0.31 < a_{wg} < 0.50$, "weak agreement"; (c) $0.51 < a_{wg} < 0.70$ "moderate agreement"; (d) $0.71 < a_{wg} < 0.90$ "strong agreement"; and (e) $0.91 < a_{wg} < 1.00$ "very strong agreement".

Finally, three months post-NBS course implementation, a survey regarding the application of the acquired knowledge was administered to the participants (post-course survey). All statistical analyses were performed using R software version 4.3.1 [24].

3. Results and Discussion

3.1. Course Planification

3.1.1. Competencies and Learning Outcomes

Table 1 presents the competencies identified for the participants to attain throughout the course implementation. These competencies, established by experts using the DACUM methodology, comprise the four core areas, in a conventional sequence, for designing and implementing NBS projects. Table 2 outlines the seven learning outcomes (LO1, LO2, LO3, LO4, LO5, LO6, and LO7) corresponding to the four competencies delineated in Table 1.

Table 1. Defined competencies and codification for NBS course implementation.

Competency	Code
Know the scientific, technical, social, and legal aspects of the treatment process, linking them with NBS projects to improve water quality	C1
Comprehend the scientific–technical basis of NBS projects focused on improving water quality	C2
Design an NBS project based on the technical and legal criteria to improve water quality	C3
Analyze the implementation of an NBS project using the criteria for startup and achieve the operability of the process	C4

Table 2. Learning outcomes for NBS course and relationship with competencies.

Competency	Learning Outcome	Code
C1	Know the key concepts about water quality for implementing treatment processes to improve its quality according to current regulations in Chile and abroad	LO1
	Identify aspects of the treatment process to improve water quality	LO2
C2	Associate aspects to be taken into account for the implementation of NBS projects in order to improve water quality	LO3
	Comprehend the natural resource management and circular economy principles for the development of NBS projects	LO4
C3	Apply theoretical bases and design criteria for the development of NBS projects for treatment and improvement of water quality	LO5
C4	Analyze the start-up and operation of an NBS project using criteria adapted to the technology, to achieve optimal operation of the process	LO6
	Comprehend the potential failures associated with start-up and operation, to establish solution mechanisms for an NBS project in order to improve water quality	LO7

The competency C1, with its two learning outcomes (LO1, LO2), was established to ensure that professionals possess comprehensive knowledge concerning different aspects of the treatment process, particularly focusing on wastewater treatment. These aspects encompass technical fundamentals, legal framework, and social acceptance, with emphasis on their influence on the planning of NBS projects, which must be incorporated into the course curriculum. The competency C2, with both LO3 and LO4, was specially crafted to introduce the concept of NBS, addressing three key questions to achieve the learning outcomes: (a) What are NBS?; (b) What kind of NBS can be useful for improving water quality, considering the wastewater treatment process?; and (c) How can the concepts of circular economy be implemented when NBS projects are implemented? The competencies C3 and C4, along with their learning outcomes LO5, and LO6 and LO7, respectively, were designed to focus on the technological design of NBS, employing internationally accepted methodologies, addressing construction aspects, and delving into post-implementation analyses of these technologies. This latter aspect is particularly important, especially in instances where technologies, not limited to NBS, are required for wastewater treatment in rural areas. In settings such as developing countries, where resources and capacities differ significantly from urban areas, these crucial considerations become even more critical.

3.1.2. Planification Proposal

Table 3 shows the course planning, detailing the correlation between the competencies, learning outcomes, units, and topics, along with the suggested time allocation for the teaching of each component. Additionally, as shown in Table 3, the course implementation incorporates a field trip. In the field trip, two WWTPs were visited. These WWTPs serve rural communities. The visited WWTPs employed two different technologies: activated sludge and facultative ponds. Thus, the field trip was included with the aim of reinforcing the diverse knowledge imparted within the classroom setting.

Table 3. Course planification outlining main teaching topics.

Competency	Learning Outcome	Unit	Topic	Time (Percentage)
C1	LO1	1. Water quality and the treatment	Introduction	0.8
			Characteristics of water	2.3
			Methods for water/wastewater examination: solids, organic matter, nitrogen, phosphorus, and pathogens	3.0
			Regulations: environmental protection, discharge, and reuse	2.3
			Basic concepts to water quality improvement	2.3
	LO2		Principles for wastewater treatment	1.5
			Steps in a wastewater treatment process	3.0
			Principles for Stormwater management	3.0
			Citizen participation process with emphasis on water technologies implementation	3.0
C2	LO3	2. Introduction to NBS and its application to water quality improvement	Brief introduction to the NBS concept	1.5
			Biogeochemical cycle and its relationship with NBS for water quality improvement	1.5
			Environmental problems that push the NBS towards water quality improvement	1.5
			Advantages of NBS applications (ecosystem services)	3.0
	LO4		Introduction to circular economy concepts	1.5
			Management of natural resources for implementation of NBS	3.0
			Economic analyses for NBS projects: costs and valuation of resource recovery	3.0
C3	LO5	3. Design and construction of NBS project for water quality improvement	Importance of plants and biodiversity during NBS applications	4.5
			Necessary information for NBS designs	3.0
			Theoretical fundamentals for NBS designs	6.1
			Design process: different approaches for NBS technologies	18.2
C4	LO6; LO7	4. Start-up and operation of NBS projects for water quality improvement	Activities for the start-up process in NBS	3.0
			Indicators for operation of NBS projects: guidelines for operation	2.3
			Main problems during operation: solutions	2.3
C1, C2, C3	LO1; LO2; LO3; LO5	5. Field Trip	Visit to two rural wastewater treatment plants	12.1

Unit 1 serves as an academic leveling component tailored to accommodate the diverse type of professionals engaged in NBS projects. The successful preparation and execution of NBS projects necessitates the involvement of various disciplines, such as engineering, biology, architecture, and social sciences. Thus, this unit is indispensable within the course curriculum for leveling the diversity of the disciplines involved. Unit 2 is essential for comprehending the novel concept of NBS and elucidating how technologies grounded in the NBS principles can contribute to water pollution control within the framework of the circular economy principles. Regarding units 3 and 4, which focus on design, construction, and implementation, the technology selected as an example of NBS was constructed wetlands. This selection is justified by extensive research and implementation, spanning over 50 years globally, rendering it a technology with well-established knowledge in terms of design and practical applications [8]. Finally, complementary aspects such as the training of communities for the maintenance, management and handling of the NBS, life cycle analyses, carbon footprint, water footprint, and technological risk analyses could be considered as a part of the course in future implementations. However, for this time, these points were not identified as result of the DACUM.

3.2. Course Implementation

The course was conducted over a span of 33 h across 2 weeks. In the first week, 12.5 h were dedicated to online sessions, which primarily focused on the fundamental concepts of water quality and treatment, alongside the fundamentals of NBS (Units 1 and 2, as outlined in Table 3). Subsequently, in the second week, 20.5 h were conducted in-person, taking place in the city of Talca, Chile, South America. This segment addressed basic NBS concepts pertaining to design procedures, construction, start-up, and operation processes. During this week, participants had the opportunity to participate in a technical field trip, visiting two wastewater treatment plants (WWTPs). These WWTPs serve rural communities with two contrasting technologies: (a) activated sludge treatment systems and (b) facultative ponds (as commented before). The purpose of visiting these facilities was to comprehend the advantages and limitations associated with the implementation of NBS in wastewater treatment. The participants had the chance to observe and discuss, on-site, the differences in the mechanical elements, energy usage, chemical usage, sludge management, and spatial requirements when employing these divergent technologies for wastewater treatment. This experience enabled the participants to gain insights into the advantages and limitations of NBS, particularly in comparison to the technologies taught in-depth during the course, such as constructed wetlands. Prior to the course lectures, water quality samples were collected at the inlet and outlet of both WWTPs over a period of six months. The water quality samples were collected and processed prior to the course by the team of Universidad Católica del Maule (not by the course participants). This data, encompassing various water quality parameters including pH, chemical oxygen demand (COD), 5-day biological oxygen demand (BOD_5), total suspended solids (TSS), total nitrogen, ammonium and phosphate, served as the foundation for the final assignment for the participants.

Figure 2 illustrates the participants' motivations to take part in the course, as well as their characterizations by both type of participant and professional experience. Notably, the 50 participants maintained an attendance rate of around 95% throughout the course activities, including the online sessions, in-person sessions, and field trip.

Related to the participants' motivations, the tag cloud graph displayed three words that are highlighted in Figure 2: "knowledge", "water", and "solutions". Other important words in the cloud graph included ideas such as "management", "nature", "based" "wastewater", "treatment", "workshop", and "opportunity", which also held importance as parts of the participants' motivations. All of these words reflect that the people had a strong motivation to acquire knowledge about water and NBS in a nexus, viewing the course as an opportunity to enhance their understanding of water pollution management, particularly focusing on wastewater, and to expand their skills for potential future benefits. That is interesting, because over 60% of the course participants (Figure 2b) were professionals, engaged in government institutions and industry, possessing expertise in various water-related areas (Figure 3c), but not specifically in NBS technologies. Notably, a significant proportion of the participants hailed from governmental institutions, indicating a growing interest within the public sector. However, more than 50% of the participants had five or less years of experience (including zero), which potentially explains their heightened motivations (Figure 3c). Alongside professionals, bachelor students, who were primarily from civil engineering programs, were the second-largest type of participant group attending the course, which aligns with the participants lacking experience (Figure 2b). Postgraduate students, who were mainly enrolled in PhD programs related to engineering and environmental studies, constituted only 6% of the participants (Figure 2b).

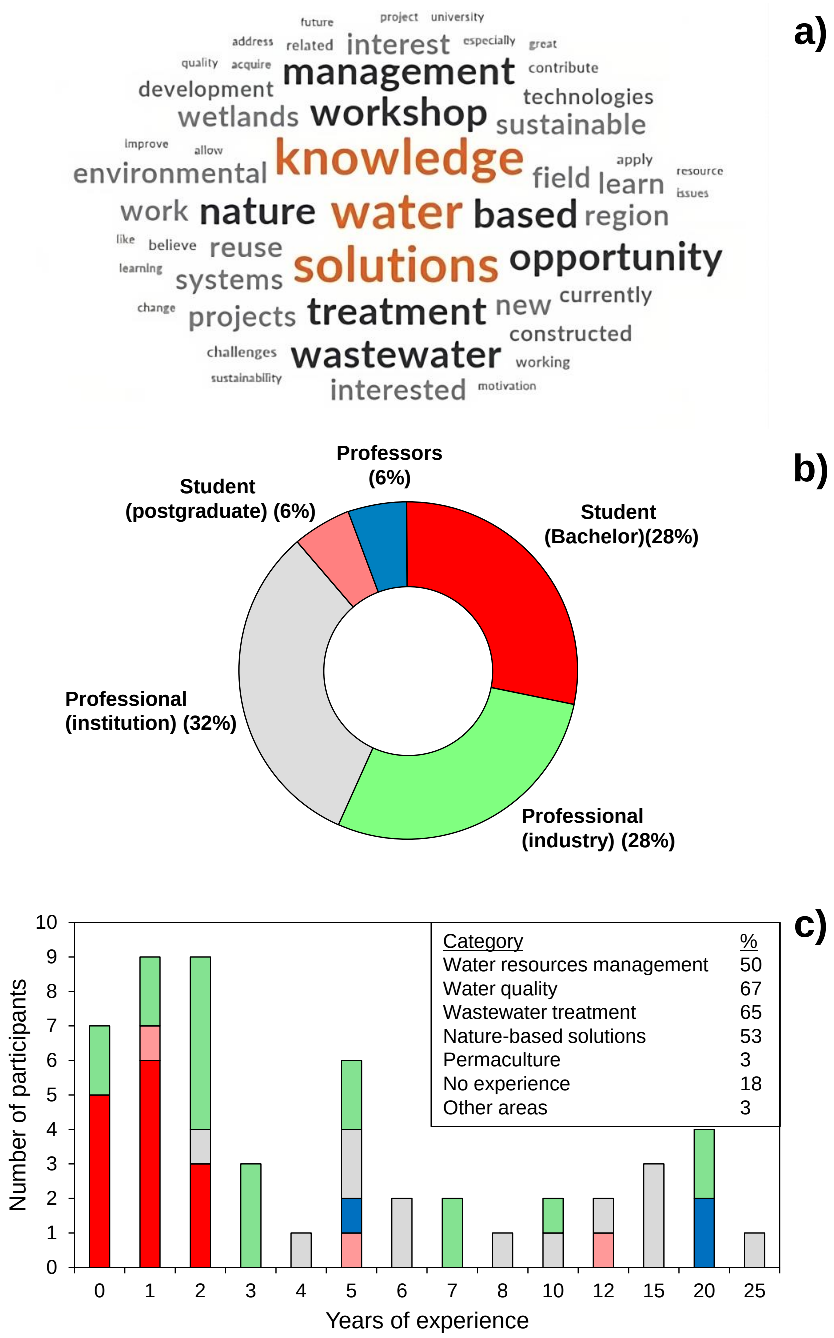

Figure 2. Results from initial survey. (**a**) words related to motivations; (**b**) type of participant; (**c**) professional experience.

3.3. Evaluation of Course Implementation

Figure 3 presents the outcomes of the first online test administered at the conclusion of week one, assessing the competencies C1 and C2, along with their respective learning outcomes (LO1 to LO4). A passing grade threshold of 50% was established. The results indicate that the majority of the participants achieved grades ranging between 60 and 80% (Figure 3a). Less than 20% of the participants attained grades below 50%. The group labeled "professionals in institution" exhibited the poorest performance, with 6% failing to meet the passing threshold (Figure 3b). However, across all types of participants (Figure 3b), over 50% of the individuals in each group successfully passed the test. Considering these results, it can be inferred that by the end of week one, the objectives of units 1 and 2, aimed at providing an academic leveling for the participants with their varying backgrounds, were largely met. The questions that received the highest performance from all the participants were those pertaining to NBS and circular economy concepts (LO3 and LO4, Q15 and Q16, Table 2) (Figure 3c). This can be attributed to the participants' motivations to delve deeper into the NBS concepts and their nexus with both water and circular economy (Figure 2a). Conversely, a question related also to NBS (Q12) registered the lowest success rate among the participants (Figure 3c), indicating that there are challenges in acquiring the knowledge despite their motivation to learn about NBS.

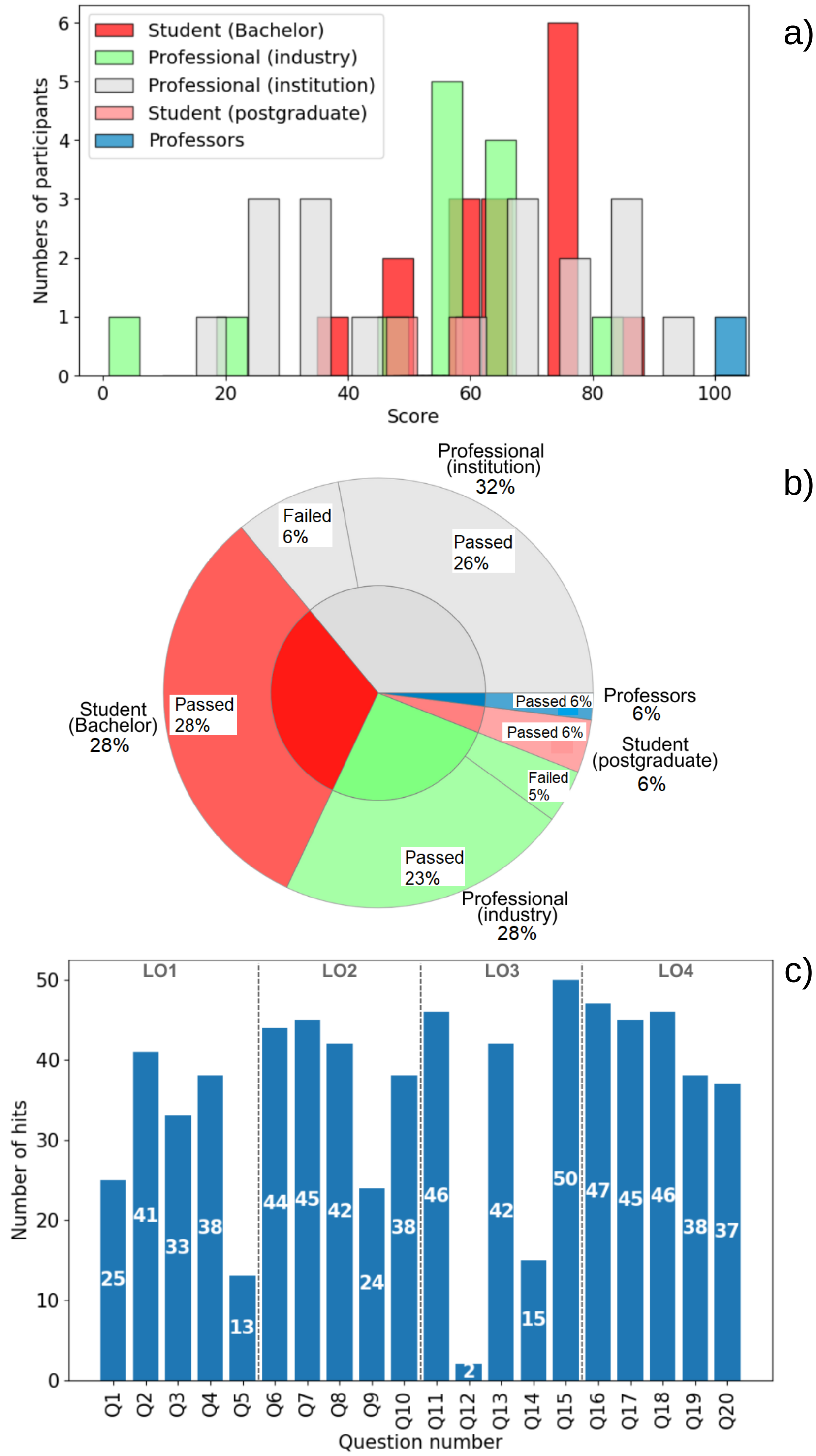

Figure 3. Results of testing after week one. (**a**) Grades classified by type of professional on a 0–100 scale. (**b**) Percentage passed and failed, divided by type of participant. (**c**) Quantity of participants with right answer for each question.

Table 4 provides a detailed analysis of the performance of each type of participant for every question and its associated learning outcome. The results indicate that LO1 (Q1 to Q5) and LO2 (Q6 to Q10) showed correct answers for all types of participants at a satisfactory percentage (above 50%), with the exception of Q5. Question 5, which pertained to pathogens, appeared to pose a relatively greater challenge for the participants. Nevertheless, the results suggest that the competency C1 (encompassing LO1 and LO2, as outlined in Table 2) was successfully achieved by all the participants (as was commented in the previous paragraph). This achievement can be attributed to two factors. Firstly, for the bachelor students, many of whom are enrolled in civil engineering programs, these topics were likely covered recently in their coursework. Secondly, for professionals, over 60% of the participants had prior experience in water quality and wastewater treatment before attending the course (Figure 2c). Thus, while the competency C1 and its associated learning outcomes may serve as a review for certain types of participants, they remain crucial for those who are new to the concepts related to water and treatment (particularly those with 0 years of experience) and for bachelor students, especially those in disciplines such as architecture or construction, where these topics may not be part of their regular curriculum.

Table 4. Results of online test after first week, categorized by the type of participant, question, and associated learning outcome. Percentages indicate correct responses.

Learning Outcome	LO1					LO2					LO3					LO4				
Question	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**	**Q11**	**Q12**	**Q13**	**Q14**	**Q15**	**Q16**	**Q17**	**Q18**	**Q19**	**Q20**
Type of Participant																				
Professional (institution)	50.0	77.8	66.7	72.2	27.8	77.8	83.3	77.8	27.8	66.7	88.9	11.1	83.3	38.9	100	94.4	83.3	94.4	83.3	88.9
Professional (industry)	30.8	61.5	61.5	84.6	23.1	84.6	84.6	76.9	53.8	76.9	92.3	0.0	76.9	30.8	100	84.6	92.3	84.6	69.2	84.6
Student (bachelor)	68.8	93.8	75.0	75.0	31.3	100	100	93.8	62.5	81.3	93.8	0.0	87.5	12.5	100	100	93.8	100	75.0	43.8
Student (postgraduate)	100	100	0	50.0	0	100	100	100	50.0	100	100	0.0	100	50.0	100	100	100	50.0	50.0	100
Professors	100	100	100	100	0	100	100	100	100	100	100	0	100	100	100	100	100	100	100	100

For the competency C2, the performance of LO3 was notably weaker, as indicated by the two questions where less than 50% of the participants from the different groups answered correctly: Q12 (related to criteria selection for NBS) and Q14 (focused on recognizing grey infrastructure for stormwater management). Conversely, the LO4 achieved the most favorable results, with all questions surpassing a 50% correct response rate across the different types of participants. These divergent results underscore the challenge of teaching new knowledge related to NBS for all types of participants. Nevertheless, based on the results in Figure 3 and Table 4, it can be inferred that the competency C2 and its associated learning outcomes, LO3 and LO4, were successfully attained by the different types of participants. Thus, regardless the type of the participant, their level of interest and prior experience with NBS (with over 50% expressing prior experience, as shown in Figure 2c), the content pertaining to the competency C2 must be meticulously prepared and delivered.

Figure 4 shows the outcomes of the final satisfaction survey regarding the course. The reliability of the questionnaire was assessed, and demonstrated both proper construction and good internal consistency based on the responses (Cronbach's α: 0.91; above 0.7). Then, the normality test showed that the responses were not normally distributed ($p < 0.05$). All of the aspects (teacher, technology, course structure, interaction, and results) were evaluated by more than 65% of the participants as "strongly agree" (the M for all questions was above 4.5 with the SD below 0.9), indicating a high level of satisfaction across all of the evaluated areas. Moreover, this result aligns with the overall course satisfaction, with over 75% of the participants also expressing that they "strongly agree" with the course quality (Q26, M = 4.89; SD = 0.3). Additionally, the Interrater Agreement Statistics (a_{wg}), with values above 0.71, show a "strong agreement" among the participants for all the questions. These findings suggest that the proposed course structure was successful and met the participants' expectations (as depicted in Figure 2a). The aspect related to the teachers was highlighted by the participants as a crucial factor in the course's success, with the responses indicating high levels of satisfaction (Q4-Q6, M above 4.85, SD below 0.42). The selection of teachers for this course was based on their extensive general experience (more than 15 years) and specific expertise in NBS (more than 5 years). The positive assessments and comments from the participants, such as "the quality of the teachers, their level of knowledge and their availability to resolve questions are appreciated" further underscore the significance of this aspect for this first course implementation and its success. Consequently, for future course implementations, teacher selection should prioritize candidates with experience in both general wastewater treatment topics and the applications of NBS for water quality improvement.

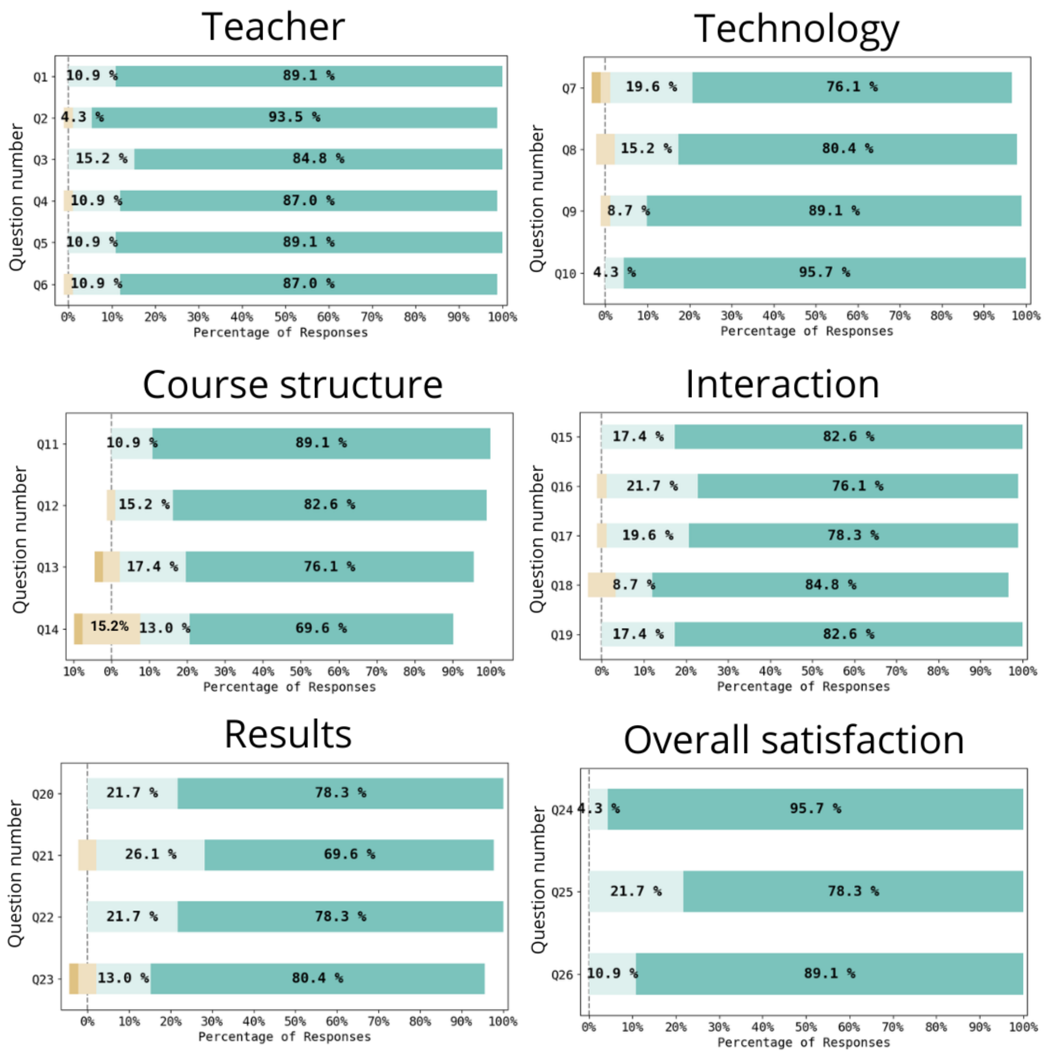

Figure 4. Results of satisfaction survey for each dimension. ( ) Disagree; ( ) Neutral; ( ) Agree; ( ) Strongly Agree. Note: strongly disagree is not plotted because was not selected by participants in any question.

The question with the worst evaluation was related to the field trip (Q14) (M = 4.5; SD = 0.84). Around 20% of the participants selected the option pertaining to "indifferent", "disagree", or "strongly disagree" (below 3.0). Based on the participant feedback, the primary issues identified during the field trip were related to the technologies showcased at the WWTPs and the conduct of the activity leader. Despite visiting one NBS technology (a facultative pond), the participants had anticipated observing a constructed wetland, aligning with their motivations for enrolling in the course (Figure 2a). Consequently, a recommendation for future course implementations is to organize field trips to sites featuring NBS technologies that align with the participants' motivations and their chosen areas of in-depth study during the course. This approach will ensure that the participants' expectations will be met. Regarding the conduct of the activity leader, the participants expressed concerns about the discourse or explanations provided during the visit. The feedback primarily stemmed from one of the two groups into which the participants were divided. To ensure the success of future field trips, particularly when the participants are divided into groups, it is crucial to ensure a consistent and unified explanation is provided. Additionally, conducting a preliminary visit to the field-trip site is highly recommended. This preparatory step allows for the identification of key learning outcomes aligned with the course objectives and ensures that the field trip meets the participants' expectations.

Figure 5 presents the results of the home assignment, where the participants were tasked with estimating the surface area required for a constructed wetland using the data provided by the teaching team. Upon completion, the participants submitted their assignments via email to the course coordinator. The average grades across all participant types were approximately 60%, with the exception of the postgraduate students, who averaged 55% (Figure 5). This suggests that the competencies C3 and C4, along with the associated learning outcomes (LO5, LO6 and LO7, as outlined in Table 2) were achieved by the different types of participants. The issues identified during the assignment review included challenges related to the selection of rates for the area calculation (such as the use of first-order areal rate constants to estimate the BOD5 removal) and the choice of the constructed wetland type for specific applications. Additionally, there were concerns about the verification procedures to ensure appropriate dimensioning. These issues may be related to time limitations for developing more in-depth exercises during the in-person part of the course. The course structure allocated 7.5 h, representing 18% of the total time, for teaching the design aspects, including the guidelines of two countries (Denmark and France) and the procedures and recommendations for Spain. This volume of information may have been overwhelming for all types of participants. As a recommendation for future implementations, it may be beneficial to focus more on one model as a guideline, with a combination of equations for defining areas, guiding the participants through the calculations step by step during the in-person sessions. That probably means more time for this part of the course. Alternatively, more time could be allocated to teaching the calculation methods for dimensioning, particularly if various approaches are desired.

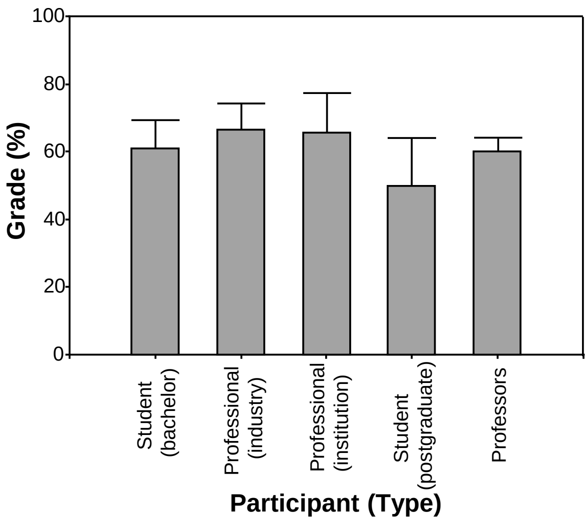

Figure 5. Results of the homework divided by types of participants.

Finally, Figure 6 shows the results of the post-course survey. In total, 70% of the participants chose the option "yes" when asked about the use of the learnings related to NBS taught during the course. That result suggests that the course contents were appropriate. Additionally, the areas related to real implementations, such as "Construction", "Start-up and Operation", and "Supervision and/or Inspection", were selected by fewer than 25% of the participants (Figure 6b), indicating that real implementations of NBS, especially in Chile, are still limited. However, Figure 6b also reveals that the area of "Design and Consulting", selected by around 50% of the participants, was the most selected, indicating that new projects are under design and there is an increasing interest in the application of NBS. Conversely, 30% of the participants chose the option "No". This result may be explained by the fact that 80% of those who selected this option were bachelor students, who are currently not involved in the labor market. For the remaining participants, the reasons for not applying NBS during the three months after the course implementation are unclear, and could be associated with issues such as adequate funding and a lack of understanding of the public perception of NBS values in all their forms (economic, functional, hedonic, and symbolic) by the private or public sector [25].

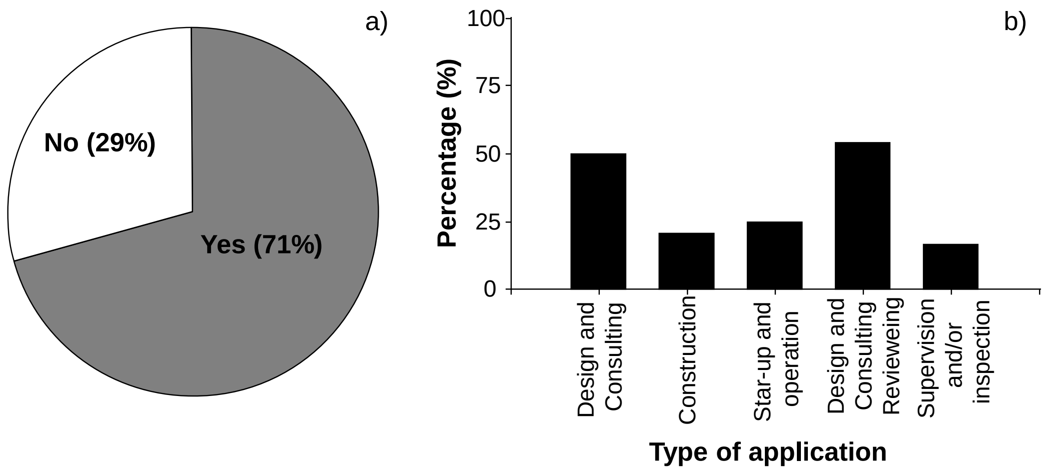

Figure 6. Results from survey about the application of knowledge acquired during course of NBS (post-course survey). (**a**) Application of acquired knowledge of NBS (yes or no); (**b**) Type of application.

4. Conclusions

A pioneering course on Nature-Based Solutions (NBS) for water pollution control was meticulously designed and executed. The course participants, classified by the different types of participants, including professionals in institutions or industry, professors, and bachelor or postgraduate students, successfully attained the four competencies and seven learning outcomes, regardless of their prior experience and time spent gaining this professional experience. This achievement underscores the well-designed and well-developed course structure. Therefore, this initial implementation of a NBS course showcases a successful teaching experience and sets a precedent as a model for future specialized courses or potential integration into postgraduate programs across higher education institutions. While the course design was commendable, minor enhancements are recommended. These improvements include heightening the leader preparation for field trip and a better selection of the place to be visited. Additionally, in the part related to design, the number of guidelines or models for design has to be reduced or more time has to be allocated for this part of the course. Addressing these aspects will further enhance even more successful future teaching experiences. Thus, this course proposal serves as a valuable contribution to the education of professionals in a specific application of the broad NBS concept: water pollution control. The post-course survey validates this impact, with the majority of participants reporting that the various course teachings were employed in their professional endeavors. Consequently, the newly educated professionals are poised to bridge the gap in specialized personnel within the private and public sectors, being capable of designing, implementing, and supervising both new and existing NBS systems.

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