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Online, Experiential Sustainability Education Can Improve Students' Self-Reported Environmental Attitudes, Behaviours and Wellbeing

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Abstract: Educating for sustainability is a critical step in moving towards a more sustainable future for humanity. As higher education moves into the online space, education for sustainability can reach larger and more diverse audiences; the University of Tasmania's Diploma of Sustainable Living is one such example. However, while sustainability education has the potential to impact student attitudes and behaviours about sustainability, these impacts are rarely evaluated. Here, we present the outcome of a study evaluating the impacts of taking a fully online unit, Backyard Biodiversity (KPZ006), part of the Diploma of Sustainable Living. In this study, we analyse 265 paired, before-after surveys to examine changes in student biodiversity knowledge, attitudes (including connectedness to nature), pro-environmental behaviours, and wellbeing. We found statistically significant increases in students' subjective knowledge and agency around biodiversity management and sustainability attitudes, including the perceived importance of biodiversity and nature connectedness. Students also reported more pro-environmental behaviours after taking the unit and many believed that taking the unit improved their wellbeing. We attribute these impacts to the unit design, which emphasised nature-based experiential learning designed to facilitate wellbeing benefits. While this study is specific to our online unit and the students who completed the survey, the results suggest that sustainability education—even fully online units—if carefully designed can create real-world impacts for sustainability and student wellbeing.

Keywords: sustainability; online learning; experiential learning; behaviour change; pro-environmental behaviour; wellbeing

Citation: Douglas, F.; Beasy, K.; Sollis, K.; Flies, E.J. Online, Experiential Sustainability Education Can Improve Students' Self-Reported Environmental Attitudes, Behaviours and Wellbeing. *Sustainability* **2024**, *16*, 2258. https://doi.org/10.3390/su16062258

Academic Editor: Víctor Jesús García-Morales

Received: 21 December 2023
Revised: 26 February 2024
Accepted: 2 March 2024
Published: 8 March 2024

1. Introduction

The world is on a dangerous sustainability trajectory of rapid climate change and increasing biodiversity loss with perilous implications for human health and wellbeing [1]. Sustainability education has been identified as a way of providing people with the knowledge, skills, motivation and attitudes to reverse this trajectory for a more sustainable future where a balance between the wellbeing and improved lives of people and the preservation, conservation and enhancement of ecosystems can be achieved [2,3].

Designated as a pillar of sustainability [4], education can be a lever for improved environmental outcomes [5]; 'quality education' is represented prominently as #4 of the 17 United Nations (UN) Sustainable Development Goals (SDGs; [6]). Under the umbrella of the UN, numerous initiatives exist to advance progress towards this important SDG. For example, the International Regional Centre of Expertise (RCE) in Education for Sustainable Development program seeks to recognise collaborations working towards the SDGs [7]. Within the higher education sector, over 500 university presidents and chancellors across

50 countries have signed up to the Talloires Declaration, agreeing to implement the "ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities" [8].

Sustainability education has been integrated into Australia's education landscape for over 20 years, with the National Action Plan (2009) for Education for Sustainability aiming "to tackle the underlying causes of unsustainable trends. . .[and] focus on systemic change" [9]. While a policy landscape exists that supports embedding sustainability in the curriculum, in practice, it remains on the periphery of classrooms, as it is typically unassessed and poorly implemented [10–12]. Research consistently finds that many educators do not feel knowledgeable or confident about sustainability education and do not know how to include it as part of their teaching practice [13,14]. While contextual factors, including resourcing and access to professional development, are barriers to implementation, a broader lack of evidence on whether and how pedagogies of sustainability education influence behaviours and attitudes of students further exacerbate the task [15,16].

Behavioural sciences and psychology are central to understanding how we might transform human behaviour toward biodiversity, sustainability and conservation, including via sustainability education [17,18]. Kollmuss and Agyeman [19] (p. 250) report that "only a small fraction of pro-environmental behavior can be directly linked to environmental knowledge and environmental awareness" and that people need to be emotionally involved and connected with nature to change their behaviour. The concept of 'nature connection', also known as nature relatedness and human-nature connection, can be thought of as having three main components: emotional/place attachment, cognitive/philosophical and experiential connection with nature [20,21]. Several studies have found that people's connection to nature is a predictor of pro-environmental behaviour [22–25] and is also linked with improved wellbeing and quality of life [26–29]. The challenge, then, is to find educational approaches that are effective in increasing people's connection to nature to achieve positive sustainability outcomes for the environment and wellbeing.

Traditional didactic teaching methods, while valuable in their own right, often fall short in cultivating the deep-rooted commitment and transformative mindset needed to embrace sustainability [30]. On the other hand, transformational learning experiences, such as those garnered through experiential learning, present unique opportunities for students to engage with sustainability in a profoundly personal and impactful manner [31]. By stepping outside the classroom and immersing themselves in real-world contexts, students confront the complexities and interdependencies of socio-environmental issues. Literature suggests that such experiences may challenge preconceived notions, stimulate critical thinking, and evoke emotional responses that are integral to personal growth and the development of a sustainability-oriented worldview [32].

The Burns Model of Sustainability Pedagogy [33] is one example of an approach to course design that acknowledges ecological systems as learning contexts and uses ecological design to cultivate personal growth and transformation [34]. In this approach, transformative learning is understood to be relational, affective, extrarational, and/or experiential [35], involving "our understanding of ourselves and our self-location; our relationships with other humans and the natural world. . ." [36]. Transformative learning is enacted through opportunities to engage in community-based learning experiences, a practice grounded in place-based learning theory [37,38]. Such experiential and place-based pedagogies are recognised as effective for transformational sustainability learning, though their use is still scant compared to traditional learning models [39].

Increasingly, literature is demonstrating how experiential and real-world learning can support learning competencies that contribute toward sustainability. Looking at a case study across two countries and four higher education institutions [40] reveal a range of basic, personal and educational elements necessary for sustainability learning. Items included authentic learning, student involvement in designing tasks and inter/transdisciplinary approaches. In their systematic review of 148 articles, Lim et al. [41] further reiterated the importance of experiential/problem/real-world-based pedagogies for 'learning to do'

sustainability. However, while they identified a range of pedagogical approaches employed in sustainability education globally, they advocate for more research on holistic models for implementing/integrating sustainability education [41].

Learning approaches that involve immersion in real world experiences have long been recognised in education theory and can be used to support sustainability education. For instance, Kolb's cycle of experiential learning theory proposes that effective learning includes observing and understanding concepts and applying them to different contexts; learning through active experience and experimentation can transform how we view the world and our role in it [42].

However, as online and hybrid learning proliferates in education delivery, understanding how such transformational, experiential learning can occur via an online learning setting is needed. Research is also needed to understand how teaching approaches in these environments can and do support the development of sustainability mindsets and behaviours [43,44]. Research with tourism and hospitality students demonstrated how digital learning was a critical moderating factor in the development of attitudes and values in support of sustainability [45]. In their studies based in Portugal, Azeteiro et al. [43] contended that e-learning can contribute to, and will play a role in, the transition to sustainable societal patterns due to the flexible style of delivery, among other affordances to student cohorts. Liu et al. [46] found that internet use can have a direct, positive effect on environmental knowledge and pro-environmental behaviours. Mahmud et al. [47] discovered that gamification using a mobile application improved knowledge and pro-environmental behaviours for students in an online sustainability learning environment. However, some students experienced barriers to online learning gamification, including time constraints, boredom with repetitive aspects of the gamification, and lack of social interaction [47].

Therefore, while education is a leverage point for achieving global sustainability targets [3,48], research on the pedagogical practices that best achieve outcomes from sustainability education initiatives is sparse [15,16]. These knowledge gaps hinder the broader application and legitimacy of (online) sustainability education as a tool to create sustainable lives and communities.

The study reported here offers important and transferrable insights into how sustainability education can be delivered in a meaningful and accessible format. Specifically, we examine a quantitative, before-after survey of adult students participating in an online unit, Backyard Biodiversity (KPZ006), part of the Diploma of Sustainable Living at the University of Tasmania. We ask the following questions:

- How does engagement with the unit influence student knowledge, attitudes and behaviours around biodiversity conservation and sustainability?
- How does participation in the unit impact student connection to nature and wellbeing?

2. Materials and Methods

2.1. The Backyard Biodiversity Unit: Content and Design

Backyard Biodiversity (KPZ006) is part of the Diploma of Sustainable Living at the University of Tasmania. As a fully subsidised and online course, students have been able to study the course flexibly without paying a fee. From the course launch in 2018 up until mid-2022, the period for this study, the diploma program reached over 6000 students, mostly from parts of the community that are poorly served by standard university offerings.

Despite being designed as an asynchronous, fully online unit, Backyard Biodiversity emphasises experiential and applied learning through place-based, outdoor activities and assessment tasks that require students to observe and engage with the plants and animals in their own backyard or local environment [49]. Activities in Backyard Biodiversity are designed according to Kolb's experiential learning cycle as personally meaningful and applied to each student's own backyard and local environment [42,49]. Key learning outcomes are that students can 'explain biodiversity and its relationship to sustainability using the United Nations Sustainable Development Goals; quantify the biodiversity and habitat present in their local environment; propose habitat modification/s that can increase

biodiversity in their local environment; and apply biodiversity skills and concepts to inform the local management of biodiversity' [49].

Learning activities include surveying animals within students' backyards, recording these observations and calculating species richness and diversity (assessment task 2: Backyard Biodiversity Assessment), and then observing the habitat available and reflecting on how it supports the observed species (assessment task 3: Backyard Habitat Assessment). The 12-week unit culminates with students developing a 'backyard biodiversity management plan' (assessment task 4) for their yard (or nearby local area), building on their observations of wildlife and habitat throughout the semester and proposing modifications that could support greater wildlife biodiversity. The students do not have to implement the plan, but early anecdotes from students have indicated that many do.

The unit, therefore, activates Kolb's two modes of grasping through abstract conceptualisation (e.g., the Sustainable Development Goals and ecosystem services) and concrete experiences of observing biodiversity and habitat. These grasping experiences are reinforced with transformative experiences; students reflect on their observations to understand why they observed the biodiversity they did, consider the habitat, and actively experiment by designing a biodiversity management plan for their property, which many plan to implement at the conclusion of the unit.

Decades of research into the benefits of connecting with nature have revealed it to have positive outcomes for both individual wellbeing and pro-environmental behaviours [20–28,50–54]. The unit therefore aims to stimulate the three aspects of nature connection through learning about biodiversity and wildlife (cognitive) and providing students with experiences (experiential) and a deeper understanding of their local environment (emotional connection to place). By simultaneously activating environmental knowledge and intrinsic drivers of pro-environmental behaviour (nature connection) with the intent to create environmentally responsible citizens, this unit aligns with the holistic approach of environmental education [55]. Therefore, we hypothesised that student connection with nature (and the benefits of such connection for wellbeing and pro-environmental behaviours) could be improved through engaging with this unit.

The unit pedagogy and survey also draw on the Theory of Planned Behaviour [56], recognising the antecedents of behaviours, attitudes, intentions and perceived behavioural control (agency), which can be affected through the learnings and activities in the unit. According to Self-determination Theory, developing competency and feelings of agency for desired behaviours can further contribute to wellbeing [57]. Figure 1 aligns unit design elements with Kolb's learning stages and with student outcomes via three main theories: nature connection's benefits (see [20,27,58] syntheses), self-determination theory [57] and theory of planned behaviour [56].

2.2. Methodology

In the study design and interpretation, we adopt a post-positivist stance, recognising our existing biases and influences on the research design and interpretation. Furthermore, through a critical realist philosophy, we acknowledge that we cannot directly observe the impacts of this unit on students but, through our survey, can observe changes in student perceptions and subjective realities [59].

2.2.1. Survey and Recruitment

Before the unit launched in June 2020, a before-after survey was designed to assess the student experience with the unit and the impact of the unit on student attitudes, behaviours and wellbeing (Supplementary Materials Appendix SA; Ethics approval no. 26397). We used a survey-based, purposive sample aiming for coverage of the total target population by offering the survey to all students enrolled in the unit. Though the voluntary nature of the survey introduces nonresponse biases, it was important from an ethical standpoint that participation in the survey was voluntary, anonymous and in no way linked to student success in the unit.

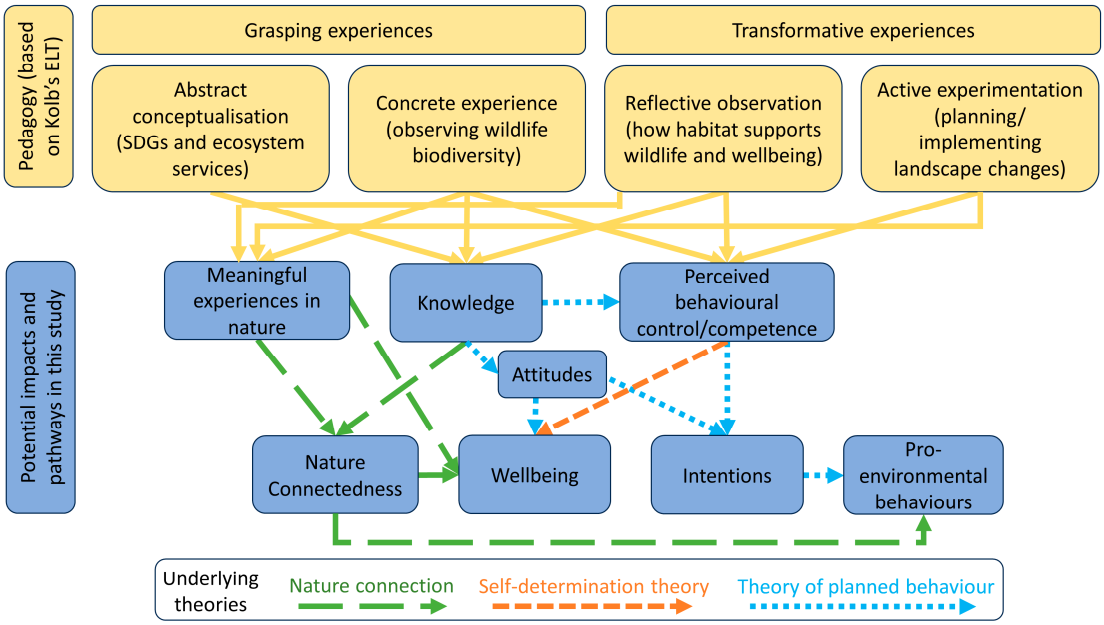

Figure 1. A conceptual model of alignment among unit features, stages in Kolb's experiential learning framework and unit impacts. Theories supporting the identified pathways are colour-coded with green reflecting research on nature connection's benefits, orange showing self-determination theory and light blue showing pathways supported by the theory of planned behaviour.

The survey is comprised of unit-specific questions and a construct-validated survey tool to examine student demographics and changes to student-perceived biodiversity-related knowledge, attitudes, pro-environmental behaviours, connection to nature, and wellbeing (Supplementary Materials Appendix SA). Questions with a Likert scale rated either the student-perceived importance of a topic or how strongly a student agreed with a statement. Though validated tools exist to explore attitudes, knowledge and behaviours, it was felt that including these tools would result in a survey that was too long and would place an undue burden on participants. The unit-specific questions were developed in tandem with the unit to specifically assess the intended outcomes of the unit design. These questions underwent a two-part validation process where they were evaluated by a colleague familiar with the unit design and intentions and colleagues expert in survey design and analysis. After the initial iterations, small amendments were made to the questions to ensure greater clarity and alignment with the research questions. These changes occasionally led to a mismatch between exact survey question wording from the before to the after survey or among survey cohorts. We detail these differences in Supplementary Materials Appendix SB: Question Variance, and have tested for any significant effects of the wording tweaks on student responses. We found that there was no difference in the results between the consistent- and inconsistent-question cohorts except for the 'nature is very important to me' question, which we have noted in the Section 3. The psychometrically validated Mayer and Frantz [23] Connectedness to Nature Scale (CNS) was used to understand students' connection to nature.

All students enrolled in the unit were invited to complete the voluntary survey before the unit began (the 'before' survey closed at the end of the first week) and after the unit ended (the 'after' survey opened at the start of the final week and stayed open for two weeks after the final assignment was due). The survey had an anonymous linking code to connect pre- and post-unit responses from the same student. The present analysis includes nine survey cohorts from 2020 to 2022.

2.2.2. Analysis

Only paired student surveys (n = 265), those that had a matched before and after survey completed, were analysed. Incomplete surveys were included; however, if a question was blank in either the before or after survey, it was not included in the analysis of that question, resulting in a slight variation in the sample size for each question, with a maximum of 261. Stata was used for data transformation and statistical testing. Parametric *t*-tests (one-sided) were used to assess differences between the two groups where the variable of interest was continuous, while Mann–Whitney–Wilcoxon tests were used where the variable of interest was measured on a Likert scale. Means were reported for continuous data, medians for ordinal data and interquartile ranges were reported for all variables for which before-after comparisons were made. For questions included only in the 'after unit' survey, percentages were used as a descriptive statistic.

One-tailed tests were used to determine whether changes from before to after the unit were significant. In each instance, the null hypothesis was that there was no significant change; the alpha (α) for significance was considered to be 0.05.

2.2.3. Likert Scale Coding

Questions with a Likert scale rated either importance or how much a respondent agreed with the statement and were coded as:

- 5: Strongly agree; Extremely important; Extremely;
- 4: Agree; Important; Relatively important; Very much;
- 3: Neither agree nor disagree; Neutral; Neither important nor unimportant; Moderately;
- 2: Disagree; Relatively unimportant; Slightly;
- 1: Strongly disagree; Extremely unimportant; Not at all.

Two questions requested respondents to report on the frequency of various activities. These responses were coded as:

8 Every day;
7 Every couple of days;
6 At least once per week;
5 At least once per fortnight;
4 At least once per month;
3 At least once per 6 months;
2 At least once per year;
1 Less than once per year.

The Mayer and Frantz [23] Connectedness to Nature Scale (CNS) was added to the survey in the last two cohorts. In this validated tool, participants respond to 14 statements using a Likert scale. Three negatively phrased questions required a reversal of coding (where 'strongly disagree' was coded as 5 instead of 1). The mean was then calculated across each of the 14 questions for each individual student, both the before and after participation survey. *t*-tests were then conducted on the before and after means.

3. Results

Across the nine cohorts included in this study (from June 2020 to September 2022), there was an average response rate of 70% (n = 1387) in the before surveys and 22% (n = 438) in the after surveys. A total of 265 students returned before and after surveys that we were able to match and include in this analysis.

Participant demographics (Table 1) broadly aligned with the overall unit composition where 77.2% of students were female-identifying (81.4% in participants), 22.6% identified as male (16.7% in participants) and 0.19% defined as other (1.9% in participants). The participant ages were slightly higher than the overall student composition: in the unit, 51.1% of students were 40+, while for survey participants, 72.6% were 40+; 29.6% of students were in the 30–39 age group (18.3% for survey participants), and 18.8% of students were in the 20–29 category (9.1% for survey participants).

Table 1. Demographics of Backyard Biodiversity survey participants—age and gender.

Age	Female		Male		Other		Total by Age Range	
	n	%	n	%	n	%	n	%
20–29	21	8.0	2	0.8	1	0.4	24	9.1
30–39	39	14.8	9	3.4	0	0	48	18.3
40–49	57	21.7	10	3.8	3	1.1	70	26.6
50–59	49	18.6	9	3.4	0	0	58	22.1
60–69	38	14.5	11	4.2	1	0.4	50	19.0
70–79	10	3.8	3	1.1	0	0	13	4.9
Total by gender	214	81.4	44	16.7	5	1.9	263	100

We found a statistically significant increase in student-reported biodiversity-related knowledge, agency, attitudes, behaviours, wellbeing-related behaviours and connection to nature from before to after taking the unit (Table 2). Students also reported feeling that taking the unit improved their wellbeing and that they were very likely to implement changes to their yard to improve biodiversity there. Results are categorised according to impacts on student-perceived biodiversity knowledge, pro-environmental agency, pro-environmental attitudes and behaviours, connection to nature and wellbeing.

Table 2 summarises the survey question results. See Supplementary Materials Appendix SB for details on the questions that changed between cohorts.

Table 2. Survey question result summary.

Survey Question/Statement	Sample Size (n)	Mean/IQR (B = before A = after)	*t*-Test Information
Biodiversity knowledge			
How many species of plants, outside of your veggie or flower garden, do you think you could currently identify in your backyard or your nearest outdoor green space?	258	B: 31.55 A: 45.93	t-stat = 4.306 ***p*-value < 0.001**
How many species of animals (including birds, mammals, reptiles, insects, etc.) do you think you could identify currently in your backyard or your nearest outdoor green space?	258	B: 20.61 A: 35.52	t-stat = 7.388 ***p*-value < 0.001**
Pro-environmental agency			
I am able to quantify biodiversity in a given location.	252	B: Mdn = 2, Q1 = 2, Q3 = 3 A: Mdn = 4, Q1 = 4, Q3 = 5	Z-stat = 13.368 ***p*-value < 0.001**
I am able to modify a location to enhance its biodiversity.	214	B: Mdn = 4, Q1 = 3, Q3 = 4 A: Mdn = 5, Q1 = 4, Q3 = 5	Z-stat = 11.379 ***p*-value < 0.001**
I am able to assess the potential risks and benefits of a modification intended to enhance biodiversity.	224	B: Mdn = 3, Q1 = 2, Q3 = 3 A: Mdn = 4, Q1 = 4, Q3 = 5	Z-stat = 12.664 ***p*-value < 0.001**
'Taking Backyard Biodiversity has increased my ability to quantify biodiversity.' [a]	256	A: Extremely (60.94%); Very much (34.38%)	NA
'Taking Backyard Biodiversity has improved my ability to quantify wildlife habitat.' [a]	251	A: Extremely (36.25%); Very much (36.25%)	NA

Table 2. *Cont.*

Survey Question/Statement	Sample Size (n)	Mean/IQR (B = before A = after)	*t*-Test Information
Pro-environmental attitudes and behaviours			
Biodiversity is important for sustainable living	226	B: Mdn = 5, Q1 = 5, Q3 = 5 A: Mdn = 5, Q1 = 5, Q3 = 5	Z-stat = 3.938 ***p*-value = < 0.001**
Biodiversity is important for human health	224	B: Mdn = 5, Q1 = 5, Q3 = 5 A: Mdn = 5, Q1 = 5, Q3 = 5	Z-stat = 4.323 ***p*-value < 0.001**
Biodiversity is important for advancing the UN SDGs	207	B: Mdn = 5, Q1 = 5, Q3 = 5 A: Mdn = 5, Q1 = 5, Q3 = 5	Z-stat = 2.418 ***p*-value = 0.007**
About how often are you actively engaging with conservation or sustainability groups?	223	B: Mdn = 3, Q1 = 1, Q3 = 5 A: Mdn = 3, Q1 = 2, Q3 = 5	Z-stat = 4.848 ***p*-value < 0.001**
Indigenous practices and knowledge are important for the conservation of Australia's biodiversity.	221	B: Mdn = 5, Q1 = 4, Q3 = 5 A: Mdn = 5, Q1 = 5, Q3 = 5	Z-stat = 3.286 ***p*-value = 0.001**
About how often are you deliberately working to enhance the biodiversity of your yard/garden/property?	212	B: Mdn = 5, Q1 = 3, Q3 = 6 A: Mdn = 6, Q1 = 5, Q3 = 7	Z-stat =7.984 ***p*-value < 0.001**
How likely are you to modify your yard/surroundings to enhance the biodiversity there? [a]	259	A: Extremely likely (71.81%) Very likely (14.29%)	NA
Connection to nature			
Nature is very important to me.	261	B: Mdn = 5, Q1 = 5, Q3 = 5 A: Mdn = 5, Q1 = 5, Q3 = 5	Z-stat = 4.116 ***p*-value < 0.001**
Connectedness to Nature Scale (CNS)	40	B: 3.913 A: 4.159	t-stat = −5.204 ***p*-value < 0.001**
Wellbeing			
About how often are you active outside. . . in good weather?	240	B: Mdn = 8, Q1 = 7, Q3 = 8 A: Mdn = 8, Q1 = 8, Q3–8	Z-stat = 3.117 ***p*-value < 0.001**
About how often are you active outside. . . in poor weather?	206	B: Mdn = 7, Q1 = 6, Q3 = 8 A: Mdn = 7, Q1 = 6, Q3 = 8	Z-stat = 1.530 *p*-value = 0.063
Taking the Backyard Biodiversity unit has improved my health or wellbeing [a]	247	Extremely (26.72%), Very much (38.06%)	NA

Note: To present changes from the before-unit survey to the after-unit survey, this table includes means and *t*-test outcomes for discrete and continuous data, medians, and Mann–Whitney–Wilcoxon test outcomes for Likert scale data. Percentages are presented as a descriptive statistics for questions only included in the after-unit survey. Significant changes are indicated with bolded significance test. [a] Question asked in the after-survey only.

3.1. Nature Knowledge

Two questions asked students to report how many plants (outside of their gardens) and animals they could identify in their yard or nearest outdoor green space. Both forms

of biodiversity knowledge increased statistically; students reported that they were able to identify approximately 14 additional plant and 15 additional animal species from before to after the unit. This change represents greater knowledge of the biodiversity in students' local environments.

3.2. Pro-Environmental Agency

There were significant changes in students' perceived ability to quantify biodiversity and habitat, modify locations to enhance biodiversity and assess potential risks and benefits from any modification.

In the after-survey questions, when asked if taking Backyard Biodiversity improved their ability to quantify habitat or quantify biodiversity, the percent that responded either very much or extremely was 93.2% and 95.3%, respectively.

3.3. Pro-Environmental Attitudes and Behaviours

There was also a significant change in student-perceived importance of biodiversity for sustainable living, despite a high initial appreciation for the importance of biodiversity. Before taking the unit, 80.5% of students strongly agreed that biodiversity is important for sustainable living and 19.5% agreed with the statement. After participation, this increased to 92.5% strongly agreeing and 7.5% agreeing.

Behaviour changes were also reported. The greatest behaviour change in this category was the reported frequency of working to enhance biodiversity in a student's own yard (from a median of 'at least once per fortnight' before the unit to a median of 'at least once per week' after the unit).

Survey results indicate significant changes in self-reported pro-environmental attitudes and behaviours relating to:

- The importance of biodiversity for human health;
- The importance of Indigenous practices and knowledge for the conservation of Australia's biodiversity;
- Frequency of engaging with conservation or sustainability groups;
- Frequency of working to enhance the biodiversity of yards.

After the unit, about 72% of students reported that they were 'extremely likely' to modify their yard to enhance the biodiversity, presumably aided by their biodiversity management plan.

3.4. Connection to Nature

The percentage of students strongly agreeing that nature 'is very important to me' rose significantly from before (86.9%) to after (95.8%) the unit. However, this may be influenced by the inconsistent question framing used in the before and after surveys for some cohorts (see Supplementary Materials Appendix SB). The high importance of nature to students before the unit further indicates the self-selecting nature of students who take this unit.

The last two iterations of the survey included the Mayer and Frantz [23] Connectedness to Nature Scale (CNS), a validated five-point scale for measuring the emotional connection with nature. Despite the small sample size, nature connectedness showed a statistically significant increase from before (mean = 3.91) to after (mean = 4.16) the unit.

3.5. Wellbeing

Two of the survey questions focused on student outdoor activity levels in good and poor weather, which is an indicator of the physical health aspect of wellbeing. The results indicate significant increases in how frequently people were active outside in good weather. Outdoor activity levels in poor weather increased slightly as well, but these changes did not quite reach significance. However, the questions specified being active 'for at least 30 minutes' and did not account for activity taking less than 30 min. After participation in Backyard Biodiversity, 97.6% of students felt that taking the unit improved their health and

wellbeing, with 26.7% reporting 'extremely', 38.1% 'very much' and 25.5% 'moderately'. Only 2.4% of students reported feeling no improvement in their wellbeing.

4. Discussion

Findings from the survey indicate that participating in the Backyard Biodiversity unit positively impacted students' nature knowledge, pro-environmental attitudes, behaviours, connection to nature, and wellbeing. Learning activities in Backyard Biodiversity supported nature-based, experiential learning in authentic environments, pedagogical approaches shown to be impactful for increasing student knowledge and positive attitude toward biodiversity [60] and sustainability [39,41]; we propose that these pedagogies contributed to the outcomes identified.

4.1. Nature Knowledge and Agency

The number of species that students believed they could identify increased from before to after the unit. A meta-analysis of five decades' worth of research found that participation in environmental education significantly improved self-reported environmental knowledge, attitudes, intentions, and behaviour [54]. Knowledge gains alone often do not contribute to changes in sustainability attitudes, behaviours, nature connection and wellbeing [61]. However, some types of knowledge, especially action-oriented or agency-based knowledges, can better support behaviour changes [62,63].

In line with the theory of planned behaviour [56], Hines et al. [64] found that predicting environmental behaviour involved a number of variables, each interacting with others and that environmental knowledge is "a prerequisite to action" [64] (p. 6). However, knowledge alone does not necessarily result in behavioural change [19]. When education for sustainability increases student knowledge and skills, students can develop the agency and 'action competence' that support real behaviour change [2,32]. Relevant knowledge includes "those courses of action which are available and most effective in a given situation" [64] (p. 6).

As others have stated (e.g., [32]), the development of sustainability agency and behaviours is not an assured outcome of sustainability education. Pedagogical approaches that integrate core content learning with opportunities to apply and 'do' experiences support transformational learning and can generate attitudinal shifts toward sustainability [33,41]. The experiential learning design of Backyard Biodiversity supports agency-based knowledge, gains which are reflected in the significant increases in student-reported agency to quantify wildlife biodiversity and habitat and to successfully modify a location to support biodiversity. These changes are exemplified in student comments in the after-unit survey: "thank you for giving me the confidence to get started in our garden" and "[this unit] has given me a better understanding of my role as 'steward' of my property and how I can improve things".

Unit activities of identifying wildlife and habitat are practical and place-based, involve observation and data collection, and are akin to nature-based citizen science [65]. Participation in nature-based citizen science projects, such as monitoring and identifying biological diversity and nature-based outdoor projects, is correlated with greater interest in the observed species, and more pro-environmental attitudes and behaviours [66]. It seems that in situ, experiential learning or 'getting to know' individual species can increase motivation to protect them [66]. Further to this, nature-based citizen science projects have the potential to improve participants' wellbeing, and mental health through increased interaction with other people and can improve "cognitive outcomes particularly among older participants" [29]. Phillips et al. [65] (p.11) highlight that nature-based learning in the form of citizen science can be "natural conduits for affecting behaviour change". Therefore, knowledge gains, while not sufficient on their own to impact changes to attitudes, behaviours and wellbeing, can lead to these outcomes if the learnings are achieved in experiential and nature-based designs.

4.2. Pro-Environmental Behaviours

Results showed that students' pro-environmental attitudes and behaviours positively increased through participation in Backyard Biodiversity. The frequency with which they were working to enhance biodiversity in their own yards increased from 'at least once per fortnight' (50.0%) to 'at least once per week' (62.7%) after the unit. These reports align with the increases in feelings of agency to modify a location to increase its biodiversity (up from 57.0% before to 98.6% after) and a high intention to take action; 86.1% of students stated they were extremely likely or very likely to modify their backyards to enhance biodiversity.

The reported behavioural changes extended beyond students' property. The frequency of actively engaging with conservation or sustainability groups at least once per fortnight rose from 19.3% before to 31.8% after the unit. These changes may reflect a growing commitment to environmentally responsible actions and a deeper understanding of the interconnectedness of individual actions and ecosystem function. Students also talk about how their actions may be infectious, stimulating others to think about biodiversity-friendly practices: "My local neighbours are already commenting on my thriving garden space, so I think the impact this course has had on me personally will be rolling out to the local neighbourhood in no time."

4.3. Connection to Nature

Undertaking Backyard Biodiversity was found to have a positive impact on students' emotional connection to nature. Despite a high initial level of connection, with a mean connectedness to nature (CNS) score of 3.86, students' emotional connection with nature rose to a mean of 4.1 in the after-unit survey. This suggests that the holistic sustainability/environmental education approaches employed in Backyard Biodiversity, such as observing nature and reflecting on how we feel about wildlife in our yards, can deepen individuals' appreciation and emotional connection to nature.

This connection to nature may be critical to behavioural outcomes. A growing body of research reveals a strong connection to nature fosters pro-environmental behaviour, promoting actions that protect and conserve environments. As Kleespies et al. [67] (p. 1) stated, "connection to nature is a predictor for environmentally friendly behaviour and can increase the positive environmental action of a person". While some studies have yielded conflicting results, a meta-analysis by Mackay and Schmitt [68] revealed a correlation between pro-environmental behaviour and a connection to nature. One study found that the increases in pro-environmental behaviour from participation in nature-based environmental education were mediated by environmental knowledge and connection to nature, with connection to nature having a much greater explanatory power [61]. These studies highlight the importance of fostering connections with nature as a means of encouraging environmentally responsible actions and that such gains can be stimulated through environmental education.

Students expressed their enjoyment of taking the time to sit in nature and observe birds and how it made them more aware of the biodiversity around them. Post-course feedback included, "I enjoyed the scientific approach to observing and quantifying the wildlife in my backyard. I would never otherwise take the time to do it. It helped me notice the biodiversity in my neighbourhood more often," and "I am now paying more attention to the biodiversity around me... today my kids and I walked around the botanical gardens, and I found myself pointing out all the birdlife and their habitat". Observing and 'actively noticing' the nature around us can support both nature connectedness and pro-environmental behaviours [53,58], which can go on to benefit wellbeing [26–29].

4.4. Wellbeing

The vast majority of students (97.6%) felt that participating in the unit contributed to their overall wellbeing. The benefits of nature-based physical activity on mental health and wellbeing are well documented [29,52,69,70]. There were significant increases in how frequently students reported being outside in good weather and almost significant increases

in outdoor activity levels in poor weather. Paired with the increases in how often students were working to enhance biodiversity in their yards, these physical activity levels may have contributed to the perceived increases in wellbeing.

However, there are also strong relationships between nature connection and mental health and wellbeing [28,29,50,52,58]. For example, greater time in nature is associated with improved mental and physical health and social connection [28]. This is supported by post-survey student comments frequently reflecting on the link between health and enjoying nature, for example, "Realising the link between health and enjoying nature during the 'bird surveillance' exercise. Seems too [sic] obvious, but you don't always stop to consider this".

Nature-based citizen science can provide opportunities for physical activity, social engagement, diverse microbiome exposure, and connection to nature [29]. It has been shown to encourage emotional involvement with the environment and to lead to positive changes in health and wellbeing for participants [66]. These findings have led to calls for nature-based citizen science activities as a way to support health for urban populations [29]. This study suggests that even online initiatives, when they support nature-based, experiential learning, can contribute to pro-environmental attitudes, behaviours, and connections and bring wellbeing benefits for participants.

5. Limitations of This Study

This study has significant limitations. First, it is a case study of one online, sustainability-focused unit. This particular unit was carefully designed around nature-based experiential learning with intended co-benefits for nature connection, wellbeing and pro-environmental behaviours. There is no reason to believe that other online units, even sustainability or biodiversity-focused ones, would necessarily lead to these same outcomes if not similarly intentionally designed.

Second, while the unit reaches up to 1000 students annually, it caters to a restricted and self-selecting segment of the population: adult students enrolling in sustainability- and biodiversity-based tertiary education. The student cohort is older and more female-dominated than traditional undergraduate units. As such, the findings may not be applicable to broader cohorts, including tertiary/community adult students in fields unrelated to sustainability or environmental studies or the general population. Further evidence of the self-selecting nature of this cohort comes from the pre-unit survey responses, which indicate that students enrolled in the Backyard Biodiversity unit already consider biodiversity to be important for sustainability and human health. While the sampling method aimed for total population sampling by offering the survey to all students enrolled in the unit, the voluntary nature of survey participation both reduced the final sample size of paired surveys and introduced nonresponse bias; survey participants were a slightly older demographic than the student population. Therefore, the students who responded to both the before and after surveys may not perfectly reflect the student population of this unit.

Third, the study relies on surveys administered to adults before and immediately after participation in the Backyard Biodiversity unit. Adults need time to practise and consolidate pro-environmental behaviours into habits [19]. Therefore, it is unclear whether the identified changes persist beyond the unit's conclusion. Inconsistencies in survey question wording across some cohorts could have influenced how students responded to these questions. While the analysis indicates such differences are insignificant, this may not hold true across a larger sample group.

This study, and most others in this field, is reliant on self-reported pro-environmental behaviour. The self-reporting approach tends to result in overestimates of pro-environmental behaviour compared to actual observed behaviour [68,71], which could have impacted the findings here.

Furthermore, the nature connection scale used here is based on Western understandings of nature connectedness and does not appropriately reflect Indigenous perspectives on interconnection and embeddedness in nature. Indigenous peoples often perceive them-

selves as closely connected and integrated with nature [72–75], but the tool used here may not have revealed those interconnections for Indigenous students.

6. Future Research Opportunities

The role of education is regarded as critical by the United Nations and led to the Decade of Education for Sustainable Development (2005–2014), yet the effect of education on long-term pro-environmental attitudes and behaviour change is still unclear. The results from this study suggest that behaviour change can occur through sustainability education—even online units. However, there are important questions about *why* the observed changes occurred and for whom; additional studies comparing units with different pedagogies, especially with and without experiential learning, online and in-person, could help explore the mechanisms and pedagogical elements responsible for impacts on students. Including demographic details in an evaluation, such as academic background and performance and socioeconomic variables, would clarify the variation in impacts across subgroups. Longitudinal studies are also needed to determine whether and for how long reported behaviour changes persist for students.

Given the contested and contextual nuances of sustainability, there are also important questions about which behaviours are the focus of transformative change and who makes such decisions. Nagrenda [76] asserts that global inclusivity and respect for local differences are imperative in sustainability education. For example, countries in the global south, in contrast to their counterparts in the global north, prioritise distinct aspects of sustainability, placing a stronger emphasis on harmony with nature and less focus on business and resource utilization [76]. Conducting more inclusive research with countries and populations under-represented in sustainability discourse, including Indigenous populations, could contextualise sustainability and pro-environmental behaviours and contribute to a more comprehensive understanding of just transformations for sustainability.

7. Conclusions

The UNESCO 2021 World Conference on Education for Sustainable Development states that "transformative learning for people and the planet is a necessity for our survival and that of future generations. The time to learn and act for our planet is now" [48]. This study highlights the potential of sustainability education to contribute to pro-environmental knowledge, attitudes, and behaviours, increase nature connectedness, and bring wellbeing benefits to participants. These impacts were seen even though the unit was delivered fully online, and the environments students engaged with were backyards and nearby parks, which could be considered degraded environments by some standards. The unit is designed according to Kolb's experiential learning cycles and incorporates place-based, nature-focussed, relevant learning activities within a sustainability framework, which we suggest contributed to the positive impacts. While the findings here are exciting, the longitudinal and transformative nature of the observed changes to knowledge, behaviours, attitudes, nature connectedness, and wellbeing remains uncertain.

Sustainability education can be a leverage point for positive outcomes for sustainability, including, as shown here, environments and student wellbeing. This study contributes important insights into pedagogical practices in sustainability education that can support international and national efforts for sustainable development agendas, including the achievement of the SDGs. Additionally, this research supports university signatories of the Talloires Declaration in the effective delivery of sustainability through teaching and learning initiatives. However, further research is needed to ensure transformative education is equitable, contextualised, just, and effective [77]. Biodiversity is a crucial pathway to sustainability, underpinning effective environmental function and, therefore, all aspects of sustainability [60,78]. Online units like Backyard Biodiversity can play an important role in shaping environmental awareness, knowledge, connections and behaviours. As we navigate the sustainability challenges of our time, investing in effective—and online—education is a key strategy. Incorporating experiential learning,

nature connection, and outdoor activities into sustainability education can lead to positive outcomes for students, environments and communities and pave the way for informed and transformational changes for sustainability.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16062258/s1, Supplementary Materials Appendix SA: Unit Survey; Supplementary Materials Appendix SB: Question Variance.

Author Contributions: Conceptualization, E.J.F.; Methodology, E.J.F., F.D. and K.S.; Investigation, E.J.F.; Resources, E.J.F.; Data analysis, F.D. and K.S.; Writing—original draft, F.D. and E.J.F.; Writing—review & editing, F.D., E.J.F., K.S. and K.B.; Supervision, E.J.F.; Project administration, E.J.F. All authors have read and agreed to the published version of the manuscript.

Funding: This project is supported with funding from the Australian Government under the National Environmental Science Program through the Sustainable Communities and Waste Hub.

Institutional Review Board Statement: This research was conducted with approval from the University of Tasmania Human Research Ethics Committee (HREC). Project approval Code: 26397; approval Date: 24 April 2022.

Informed Consent Statement: Informed or implied consent was obtained from all subjects involved in the study in accordance with the above ethics approval.

Data Availability Statement: These data are kept securely by the project investigators in accordance with the ethics application.

Acknowledgments: We acknowledge the Traditional Owners of Country throughout Australia and their continuing connection to land, sea, and community. In particular, we recognise the Palawa/Pakana people of Lutruwita (Tasmania) as the traditional owners of land and sea country on which we live and work. We pay our respects to all Traditional Owners in Australia, their cultures, and their Elders, past, present and emerging. We thank Dave Kendal for his expert advice and guidance in the development of the survey and Penny Jones for helpful feedback on a draft of the manuscript.

Conflicts of Interest: E.J.F. developed the Backyard Biodiversity unit (KPZ006) on which this research is designed and coordinated the unit until June 2023. The authors have no other conflicts of interest to declare.

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