Validity Evidence of the Ecological Citizenship Scale for Adolescents

Samanta SIMONAVICE
Klaipeda University, Lithuania
0009-0008-9317-1322
samanta.simonavice@ku.lt

Abstract
The growing world population is gradually disrupting the balance of the natural world and the environment. Unawareness and improper use of resources contribute to environmental imbalances, leading to ecological problems. To prevent or address these issues, it is crucial for individuals to possess a certain level of ecological citizenship. It is found that there is no scale aiming to assess the level of adolescents' ecological citizenship. The purpose of the research conducted is to develop a valid and reliable tool to assess the ecological citizenship levels of adolescents. As part of this goal, a literature review on ecology and ecological citizenship was carried out. The Ecological Citizenship scale was originally developed for adolescents ages 14–17 years old and was presented as valuable for comparing that age group with older participants. This study aims to assess the validity evidence of the Ecological Citizenship Scale (ECS) designed for adolescents. The scale comprises three key constructs: Knowledge, Responsibility and Duty, and Behaviour. This paper presents the results of factor analysis, internal consistency reliability, and normality tests, demonstrating the validity and reliability of the scale. Findings indicate that the ECS exhibits strong internal consistency, with high Cronbach's alpha values across the components, and provides an empirically grounded measure of ecological citizenship for adolescents.

Keywords: Ecological citizenship; sustainability; adolescents.

JEL Classification: Q01, Q56.

DOI: https://doi.org/10.24818/ejis.2025.15

1. Introduction

Environmental challenges present a substantial existential threat to both the contemporary and future viability of life on Earth (Steffen et al., 2015). Given that both individual and collective human actions are major drivers of these environmental crises, the promotion of sustainable lifestyles has emerged as a paramount global objective (Wynes & Nicholas, 2017). Children are integral to addressing these issues, serving as current agents of change and as future leaders and decision-makers (Bandura & Cherry, 2020). Indeed, youth activists, such as Greta Thunberg, are already advocating for coordinated efforts to advance global sustainability (Marris, 2019; Wallis & Loy, 2021).

The measurement of ecological attitudes and beliefs has been an ongoing focus of social science research for decades (Hawcroft & Milfont, 2010; Stern et al., 2014). Ecological citizenship is anthropocentric (Dobson, 2004; 2007), distinguishing between the human species and other species (animals and other organisms). It asserts that it is within humanity's power to address ecological problems while protecting other species, and these responsibilities are a collective duty of all people, based on existing ecological knowledge. It is argued that the human-nature relationship should not be assessed from an ecocentric perspective, as implementing ecological citizenship does not necessarily require extensive changes in individual behaviour (Dobson,

Received: 16 June 2025; Revised: 6 September 2025; Accepted: 28 November 2025

2004). However, according to Smith (1998), ecological citizenship and its commitments demand ecocentrism. He argues that "the shift from an anthropocentric to an ecocentric relationship between society and nature would imply significant changes in human assumptions, behaviour, and institutional structures" (Smith, 1998, p. 99-100).

Berkowitz et al. (2005), extending Dobson's theoretical framework, conceptualized ecological citizenship through five pivotal components. The first component, ecological literacy, denotes a comprehensive understanding of foundational ecological systems through an ecological paradigm, as well as an awareness of the epistemological nature of ecology as a scientific discipline and its interrelationship with societal structures. The second component, civic literacy, refers to the capacity to critically engage with and understand the fundamental social, economic, cultural, and political systems, employing requisite analytical and evaluative skills for informed decision-making. The third component, perception of values, involves the recognition of one's personal environmental values and the capacity to synthesize these values with empirical knowledge and practical wisdom when formulating decisions and implementing actions. The fourth component, autonomy, signifies the ability to autonomously acquire knowledge and engage in actions that are congruent with individual values and interests concerning environmental sustainability. The fifth component, practical wisdom, is defined as the application of experiential knowledge and pragmatic judgment in the formulation of decisions and the execution of actions related to ecological matters.

Jagers et al. (2014), utilizing Dobson's theory of ecological citizenship, delineated several fundamental components: Social justice, The dissolution of the public-private dichotomy, Unbounded responsibilities, and Non-reciprocal responsibility. The social justice component encompasses a fundamental sense of equity towards the environment, an understanding of one's ecological footprint, and the underlying motivations driving pro-environmental behaviour. The dissolution of the public-private dichotomy involves the recognition of the pervasive influence exerted by political and governmental institutions on individual and collective behaviour, thus eroding the distinction between private actions and public policy. Unbounded responsibilities refer to duties and obligations that transcend territorial demarcations, guided by a universal, global ethical imperative. Finally, non-reciprocal responsibility entails the acceptance of an ethical obligation to mitigate detrimental environmental impacts, without the expectation of personal gain or reciprocal benefit.

Expanding on Dobson's idea, Wolf (2011, p. 120) states that "ecological citizens not only have knowledge of environmental issues and are concerned about them but also recognize the need for their participation and express a willingness to take action to help alleviate the problems," and identified four components of ecological citizenship. The first component is justice, which refers to the care and compassion for the environment. The second component is knowledge about ecological problems. The third component is attitude, which is associated with responsibility for environmental issues and human impact on nature. The fourth component is engagement, which is linked to personal connection with the environment and participation in social activities. Agreeing with Dobson's view that ecological citizenship goes beyond traditional citizenship and is anthropocentric, Wolf (2011) highlights the justice component, which represents care and compassion for all living species as a moral principle. Achieving environmental justice requires knowledge and understanding of environmental issues – the knowledge component (Wolf, 2011), which consists of knowledge about animals, pollution, ecology, water, energy, and waste recycling (Ogunjinmi et al., 2015). In identifying the responsibility component, Wolf notes that ecological citizenship requires an attitude towards environmental problems and human civic responsibility for one's actions.

The importance of attitudes is supported by Ogunjinmi et al. (2015), who identify components such as attitudes towards animals, pollution, ecology, water, energy, and waste recycling. The engagement component indicates that a person's connection with the environment and responsibility is reflected in their behaviour, both individually and collectively (Wolf, 2011). Kaiser (1998) supports this view, highlighting the importance of ecological behaviour, which triggers engagement in activities, and identifying components such as eco-friendly waste sorting, water and energy conservation, waste reduction, and voluntary environmental protection activities.

Building on Dobson's conceptual framework, Hayward (2013), with a focus on democratic participation, delineated five core principles of ecological citizenship. The first component, social agency, pertains to the education of citizens regarding the adoption of environmentally responsible actions and the facilitation of engagement with others in ecological endeavours. The second component, environmental education, involves cultivating citizens' understanding of environmental issues, fostering a sense of place, integrating cultural values, and enhancing scientific literacy. The third component, justice, emphasizes the development of citizens' competencies in addressing daily challenges, thereby contributing to environmental conservation through the promotion of justice. The fourth component, discussion and listening, focuses on educating citizens in effective listening skills, including the engagement with individuals holding divergent perspectives. The fifth and final component, ecological awareness, encourages citizens to adopt a long-term perspective that extends beyond immediate personal concerns, enabling the consideration of the needs of other species and the broader ecosystem.

Building upon the theoretical frameworks of Dobson (2004) and Wolf (2011), Karatekin and Uysal (2018) conceptualized ecological citizenship as comprising four distinct dimensions: the Participation dimension, the Sustainability dimension, the Responsibility dimension, and the Rights and Justice dimension. Within the Participation dimension, Karatekin and Uysal (2018) emphasize the active engagement of individuals in decision-making processes and community-oriented activities. The Sustainability dimension pertains to an individual's ecological knowledge, which informs their understanding of environmental sustainability. The Responsibility dimension is characterized by a commitment to maintaining ecological balance, grounded in tacit, ethical obligations. Lastly, the Rights and Justice dimension concerns the recognition of both individual and environmental rights, as well as an understanding of the corresponding duties and entitlements.

Expanding upon Dobson's conceptual framework, Hadjichambis and Paraskeva-Hadjichambi (2020) further developed a model of environmental citizenship education for students, breaking it down into distinct components. These components include: (1) Past actions as an environmental citizen, which pertains to an individual's historical engagement in environmentally responsible activities; (2) Environmental citizenship knowledge, which refers to an individual's understanding of environmental issues, natural systems, and organizations dedicated to sustainability; (3) The concept of environmental citizenship, which is linked to knowledge of citizenship and civic engagement; (4) Environmental citizenship skills, involving the acquisition of civic competencies and their practical application in sustainable behaviour; (5) Environmental citizenship attitudes, which are shaped by an individual's perception of what it means to fulfil the role of a responsible citizen; (6) Environmental citizenship values, reflected through behaviours and attitudes that promote sustainability; (7) Future actions within the school, concerning an individual's commitment to implementing sustainable practices within the school environment; (8) Future actions outside the school, reflecting an individual's intention to engage in sustainable behaviours beyond the school context; and (9) Change agents, associated with the capacity to drive sustainable change and foster community involvement.

Environmental citizenship is revealed as a multidimensional term, which is defined differently by authors, including its components. Based on Dobson's (2004, 2007) theory, one component of ecological citizenship is the knowledge of ecological issues, which encompasses both living and non-living nature, on land and underwater (Hoshaw, 2009; Dobson, 2004), affected by harmful and selfish human activities (Payet & Obura, 2004; Huimin, 2013). According to Fisher-Vanden and Olmstead (2013), ecological problems include water, air, land, and atmospheric issues. The knowledge of ecological problems is linked to the impact of human activities on nature, including the degradation of living and non-living nature on land and underwater (Aceves-Bueno et al., 2021; Poissant et al., 2024), noise pollution (Singh & Davar, 2004; Hristopulos et al., 2021), air pollution (Vallero, 2014; Dominski et al., 2021), water body pollution (Zahoor & Mushtaq, 2023; Shahady, 2024), deforestation (Hoang & Kanemoto, 2021; Kumar et al., 2022), growing population (Crist et al., 2017), climate change (Romshoo et al., 2022; Du et al., 2022), fossil fuel use (Akalin et al., 2021; Fang et al., 2024), excessive consumption (Cohen et al., 2011). This knowledge of ecological issues is also referred to as ecological literacy by Berkowitz et al. (2005), which includes the knowledge about population growth, species and soil degradation, deforestation, accelerating climate change, resource depletion, air and water pollution, and other trends (Lewinsohn et al., 2015). However, Wolf (2011) and Hayward (2013) both agree that it is most appropriate to define this component of ecological citizenship as knowledge of ecological problems. According to Dobson (2004; 2007), having knowledge of ecological issues allows a person to understand the consequences for future generations. Knowledge is necessary to comprehend the impact of ecological systems through ecological thinking (Berkowitz et al., 2005). The knowledge of ecological consequences for future generations includes the impact of human activities on biodiversity (Mona et al., 2019; Prakash & Verma, 2022), water quality (Peters & Meybeck, 2000; Mishra et al., 2021), food (Manning, 2008), and air quality (Marinello et al., 2021), climate change (Trenberth, 2018; Abbass et al., 2022), environmental pollution by waste (Unuofin, 2020). The knowledge about ecological problems and their impacts, according to Usmi and Murdiono (2021), is necessary to understand how human activities affect nature, critically assess, and actively participate in addressing ecological issues. Knowing these factors allows individuals to understand the significance of ecological changes and their agents (Charli-Joseph et al., 2018). The role of ecological change agents is to encourage changing established views or behaviours, contributing to nature conservation (Pastakia, 1998; Lunenburg, 2010; Malone, 2013). Change agents who influence and promote sustainable change include individuals (Wade, 1999; Redman et al., 2021), businesses and industries (Buhr et al., 2023; Schaltegger et al., 2024), media (Ostman, 2014; Maihanyar & Sakhawati, 2024), communities (Kennedy, 2011; Budowle et al., 2021), and environmental organizations (Solly et al., 2022; Mittal & Bansal, 2024).

The subsequent component of ecological citizenship is responsibility and duty. This concept encompasses an individual's intrinsic connection to the natural environment, fostering a sense of accountability for ecological well-being and an obligation to contribute to environmental change (Skelly & Bradley, 2007). According to Dobson (2004, 2007), ecological citizenship is characterized by a profound human-nature relationship, accompanied by a sense of responsibility and a duty to steward the environment. Wolf (2011) asserts that a sense of care and compassion for nature facilitates the formation of a bond with the natural world. The sense of responsibility and duty is not confined to territorial boundaries but is driven by a global ethical framework (Jagers et al., 2014). This responsibility towards environmental conservation is predicated on tacit commitments to preserve ecological balance (Karatekin & Uysal, 2018). The duty to protect nature, rooted in this sense of responsibility, cultivates practical wisdom and competencies in decision-making and action concerning environmental issues (Berkowitz et al., 2005).

Another component of ecological citizenship is behaviour. Behavioural components include nature conservation (Karatekin & Uysal, 2018), the participation in ecological activities (Schulz et al., 2018), and the engagement in solving ecological problems (Geijsel et al., 2012). According to Dobson's (2004, 2007) theory, the environmentally friendly behaviour in both public and private spaces transcends the boundaries of state and generations. To adapt to global changes and reduce human impacts on nature, it is important to broaden one's worldview and develop eco-friendly behaviour, as environmentally responsible actions foster a natural connection with nature and its preservation (Leiserowitz et al., 2006). An ecological citizen can contribute to solving ecological problems through active participation in both public and private spheres (Jagers & Matti, 2010). Hayward (2013) emphasizes that ecological citizenship means not only taking nature-friendly actions but also engaging others in such activities. Engagement is one of the key concepts of community citizenship, encouraging citizens' involvement in various aspects of life (Geijsel et al., 2012). The engagement of an ecological citizen is reflected in initiatives (Bamberg et al., 2015), voluntary activities (White, 2021), environmental activities in schools (Veselinovska & Osogovska, 2012), and environmental activities outside schools (Bhide & Chunawala, 2017).

2. Methods

Ecological citizenship, a concept central to sustainable development, refers to the responsibility individuals feel toward environmental protection and their role in addressing ecological issues. Adolescents, as the future stewards of the planet, are crucial to the success of global environmental initiatives. As such, a reliable and valid scale to measure their ecological citizenship is essential.

The research method employs a quantitative approach to test the hypothetical factors of the theoretical framework. The Ecological Citizenship Scale (ECS) for adolescents is designed to measure three key components: knowledge, responsibility and duty, and behaviour. This study evaluates the construct validity and reliability of the ECS to ensure it provides meaningful and consistent results across adolescent populations. The study sample consisted of 468 adolescents, all of whom provided valid responses in Table 1. No missing data were recorded, ensuring that the dataset was complete. Data analysis was performed with IBM SPSS Statistics for Windows, Version 29.0.

Table 1. Sample description

Gender	**N**	**%**
Female	288	61.5
Male	164	35.0
Other	16	3.4
Place of residence	*N*	*%*
Village	80	17.1
Town	88	18.8
City	300	64.1
Age	*N*	*%*
14	5	.8
15	209	44.7
16	188	40.2
17	67	14.3

Source: Author's research

In the initial stage of scale development, the relevant literature was reviewed to identify the characteristics of individuals who could be considered ecological citizens. The following procedures were followed in preparing this measurement tool:

- Pre-evaluation of the scale items.
- Evaluation of the appropriateness of the scale items.
- Ensuring the content and face validity of the scale items through assessment, consultation with Lithuanian language experts, and feedback from field experts.
- Before applying the measurement tool, it was reviewed by teachers working in public schools to assess the clarity and appropriateness of the scale items. Additionally, the opinions of field experts were sought to ensure the content and face validity of the items (including feedback from assessment and evaluation experts and Lithuanian language specialists).
- Based on the feedback received, necessary corrections and additions were made to the items. Incomprehensible and redundant items were removed. The final version of the "Ecological Citizenship Scale," containing 63 items, was prepared for pre-application.

The measuring tool, which was given its final shape for the pre-application, consists of four parts. In the first part of the measurement tool, there are items measuring the Knowledge of ecological problems, Knowledge of ecological impacts, and Knowledge of change agents, in the second part, the items measuring the Responsibility for environmental well-being and Duty to contribute to ecological change, in the third part, the items measuring the Behaviour related to the protection of Nature, Participation in ecological activities, Involvement in solving ecological problems, and in the fourth part, the personal information part. For the first three sections, a 5-point Likert rating was made. According to this; It was defined as (1) Totally Disagree, (2) Disagree, (3) Neither Agree nor Disagree, (4) Agree, and (5) Totally Agree.

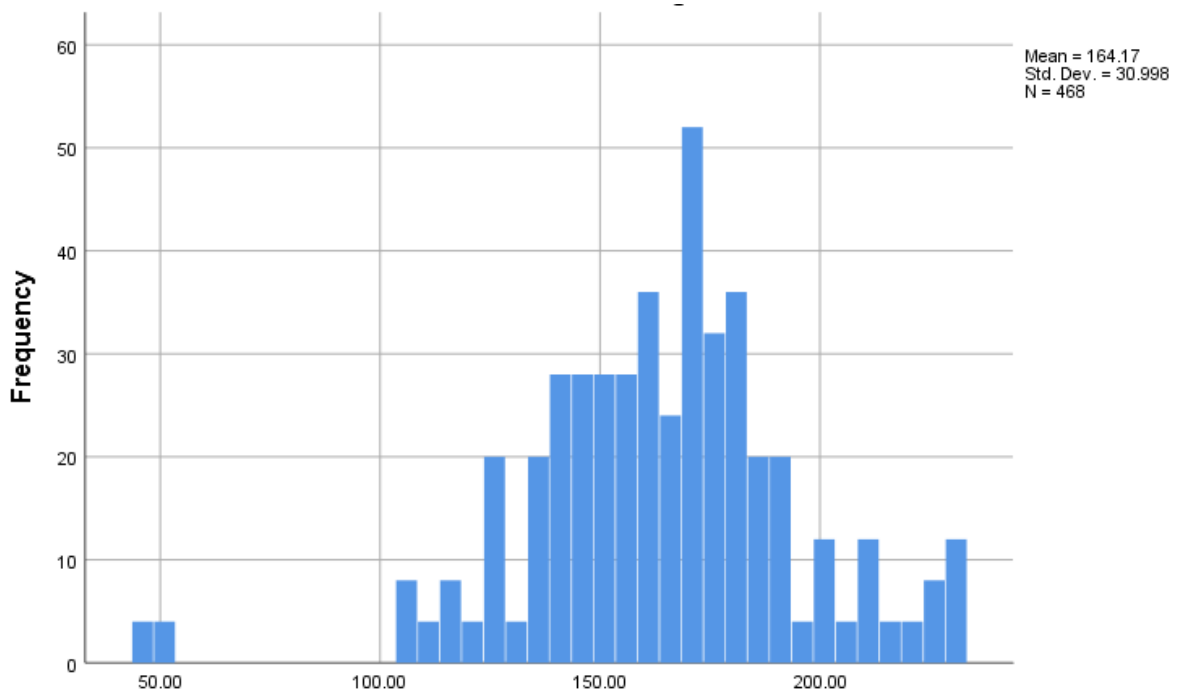
In evaluating the arithmetic averages of the responses provided by the participants to the research questions, the following criteria were used: “1.00 – 1.79 = Strongly Disagree,” “1.80 – 2.59 = Disagree,” “2.60 – 3.39 = Neither Agree nor Disagree,” “3.40 – 4.19 = Agree,” and “4.20 – 5.00 = Totally Agree.” Based on this, the ecological citizenship levels of adolescents who score 4.20 and above are considered “very good”; those scoring between 3.40 and 4.19 are categorized as “good”; those with scores between 2.60 and 3.39 as “medium”; and those with scores between 1.80 and 2.59 as “low.”

The preliminary application of the research involved the participation of older adolescents. The required number of participants for meaningful statistical analysis and clear factor loadings following the pre-application is a subject of debate. Existing opinions can be categorized into three groups: the number of items/number of observations, the absolute number of observations, and the expected number of factors/number of observations (Yilmaz & Yurdugül, 2013). Comrey and Lee (2013) consider 300 participants to be "good" for factor formations based on absolute observation width. Osborne and Costello (2004) suggest that the number of observations should be 11 times the number of factors. In this study, the first application was conducted with 468 older adolescents, which is more than seven times the number of items in the 63-item measurement tool.

The principle of voluntary participation was upheld when applying the scale to the study group, whose characteristics had been previously defined. For applications conducted over multiple sessions, the researchers carried out the process, ensuring that all necessary permissions were obtained beforehand. The participants were informed about the scale, and the intended use of their responses was explained to enhance motivation and ensure the reliability of the measures.

No personal identifying information was requested from the participants, allowing them to respond to the scale honestly and accurately.

Graph 1. Histogram graph for scale scores



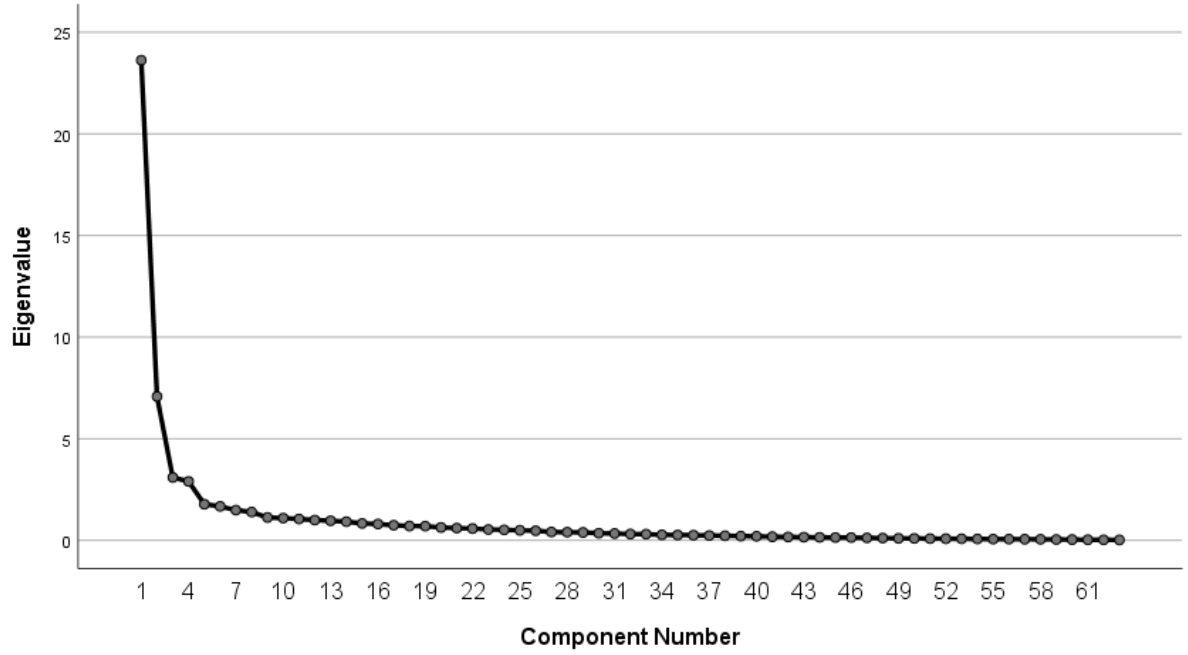
Source: Author's research

An examination of the histogram of the scale scores in Graph 1 reveals that the distribution of the scores closely mirrors a normal distribution, indicating a balanced and representative set of data. This observation suggests that the sample may accurately reflect the broader population. Following this, a thorough analysis of descriptive statistics was conducted to provide a deeper understanding of the data's central tendencies and variations. In addition, validity and reliability tests were performed to assess the key characteristics of ecological citizenship. These tests aimed to ensure that the measurement tools used were both accurate and consistent in capturing the intended psychological constructs. This step was essential for confirming that the scale was not only statistically sound but also meaningful in the context of ecological citizenship, establishing a foundation for further research and interpretation.

3. Results

This section presents the results related to the validity and reliability analyses. The table includes item-total correlations, factor loadings, explained variance, KMO value, Bartlett's sphericity value, and Cronbach's Alpha coefficient. For the validity and reliability analysis, 63 items were initially included in the "Ecological Citizenship Scale" before the pre-application. The reliability of the scale was tested by calculating Cronbach's Alpha internal consistency coefficient and item-total correlations. Items with item-total correlations below .30 were excluded from further evaluation, and the validity and reliability analyses were repeated.

Graph 2. Scree plot graph



Source: Author's research

The analysis was conducted on a scale comprising 63 items. Upon examining Graph 2, it was observed that the eigenvalue of the first factor was significantly high, and the slope of the curve flattened out after the third factor. Additionally, using the variable number criterion where factors that explain 2/3 of the total variance are considered important it was determined that a four-factor structure aligned well with the measured psychological construct. As a result, the analysis was repeated using this four-factor structure. In the revised analysis, factor loadings below the threshold of 0.32 (Tabachnick & Fidell, 2007) and items with factor loads above the acceptance value across multiple factors were excluded. Based on these criteria, 17 items were removed from the scale due to low factor loadings. These items were extracted in the following order: (responsibility5; responsibility6; behaviour_engagement6; behaviour_protection2; behaviour_protection3; behaviour_protection4; behaviour_protection7; behaviour_protection8; duty4; duty5; duty6; knowledge_agents2; knowledge_agents4; knowledge_agents5; knowledge_agents7; knowledge_consequences8; knowledge_problem7). The final structure, consisting of 46 items, formed three factors with eigenvalues greater than 1. The EFA results for this three-factor structure are presented in Table 2.

Table 2. Factors obtained as EFA result and factor loads related to the items

Knowledge		Responsibility and duty		Behaviour	
Item	Factor Load	Item	Factor Load	Item	Factor Load
knowledge_problem6	0.761	duty1	0.698	behaviour_involvement2	0.828
knowledge_consequences5	0.733	responsibility3	0.685	behaviour_involvement7	0.811
knowledge_consequences6	0.717	responsibility1	0.670	behaviour_participation5	0.807
knowledge_consequences3	0.692	responsibility8	0.657	behaviour_participation1	0.781
knowledge_consequences1	0.648	duty2	0.613	behaviour_participation7	0.778
knowledge_problem5	0.639	duty3	0.626	behaviour_participation2	0.777
knowledge_consequences8	0.632	duty8	0.600	behaviour_involvement4	0.772
knowledge_consequences2	0.554	responsibility4	0.589	behaviour_involvement5	0.732
knowledge_consequences4	0.550	duty7	0.586	behaviour_involvement3	0.712
knowledge_consequences7	0.545	responsibility2	0.582	behaviour_participation8	0.710
knowledge_problem4	0.526	responsibility7	0.527	behaviour_participation4	0.706
knowledge_agents6	0.520			behaviour_involvement1	0.686
knowledge_problem2	0.505			behaviour_participation3	0.680
knowledge_problem3	0.495			behaviour_participation6	0.659
knowledge_agents3	0.479			behaviour_involvement8	0.652
knowledge_problem1	0.401			behaviour_retention6	0.530
knowledge_agents1	0.325			behaviour_retention5	0.438
				behaviour_retention1	0.413

Source: Author's research

The Ecological Citizenship Scale, which was determined to consist of four distinct dimensions as part of this study, underwent an internal consistency analysis to assess its reliability. For this purpose, the Cronbach alpha coefficient was calculated. This coefficient is a widely used statistical measure that provides insight into the degree of internal consistency within the scale, both at the individual factor level and across the entire scale. A higher Cronbach alpha indicates stronger internal consistency, meaning the items within the scale are more closely related to one another and are measuring the same underlying construct. The results of these calculations, including the specific alpha values for each dimension as well as the overall scale, are detailed in Table 3, which serves as a comprehensive reference for understanding the reliability of the Ecological Citizenship Scale in the context of this study.

Table 3. Reliability indices by dimension

Dimensions	Items Number	Cronbach Alpha Coefficient
Knowledge	17	.929
Responsibility and Duty	11	.953
Behaviour	18	.949
Overall of the Scale	46	.972

Source: Author's research

Table 3 presents the Cronbach alpha coefficients for the overall scale and its sub-dimensions. The coefficient for the entire 46-item scale exceeded 0.90, indicating a high level of internal consistency, suggesting that the scale is a reliable measure of ecological citizenship. When examining the coefficients by dimension, it was noted that the Cronbach alpha decreased as the number of items in each sub-dimension decreased. The lowest coefficient was observed for the Knowledge dimension. Despite this, the overall scale maintained high internal consistency. The Ecological Citizenship Scale, consisting of three dimensions, demonstrated strong reliability, making it a dependable tool for measuring ecological citizenship in adolescent populations.

To assess the suitability of the scale for exploratory factor analysis, the Kaiser-Meyer-Olkin (KMO) value and Bartlett's sphericity test were analysed. The data set, with a KMO value of

.972 and a significant Bartlett test (p<.01), was deemed suitable for factor analysis. According to George and Mallery (2024) data are suitable for factor analysis if the KMO coefficient is greater than .60 and the Bartlett test is significant. At this point, exploratory factor analysis was conducted to examine the construct validity of the scale, followed by confirmatory factor analysis to verify the suitability of the model identified during exploratory factor analysis.

In the exploratory factor analysis, three distinct components – knowledge, responsibilities and duties, and behaviour - were considered separately, with each component being treated as a single factor construct. This approach allows each component to function as an independent measurement tool. The validity values for each of the three components are provided below.

Table 4. Knowledge validity values

Knowledge Item	**Factor**
Biodiversity in the oceans will decrease if fishing is not regulated.	.577
An environmental activist consistently defends nature and promotes a sustainable lifestyle.	.565
Extreme weather events (e.g., hurricanes, floods, droughts) will become more frequent if deforested areas are not replanted.	.548
Tuna fishing in the ocean also results in many dolphins being killed.	.319
Chemicals from farms contribute to water pollution.	.592
Sea levels will rise and flood land areas if climate change is not stopped.	.589
The availability of quality food will decrease if its excessive consumption is not limited.	.549
Mass deforestation poses a threat to wildlife.	.669
Air quality will worsen if fossil fuel burning is not limited.	.650
Air pollution increases with fossil fuel burning.	.549
Excessive consumption contributes to environmental pollution with waste.	.649
The rapidly growing population contributes to increasing consumption and depletion of land resources.	.504
Clean water sources will decrease if chemical runoff from farms is not restricted.	.599
Noise pollution poses a threat to land and marine animals.	.659
Governments make political decisions on ecological issues to protect nature and ensure public health.	.660
Marine mammal populations in the oceans and seas will decrease if noise pollution is not limited.	.742
Local communities organize environmental projects to promote a sustainable lifestyle and strengthen community ties.	.662
Eigenvalue %	***7.080***
Variation	***11.238%***
Cumulative %	***48.738%***
Bartlett's Test of Sphericity	***p<.05***

Source: Author's research

The values of the knowledge component and the reliability of the statements, ranging from 0.319 to 0.742, indicate a statistically significant relationship between the statements and the examined factor. These values fall within acceptable reliability limits, allowing the statements to be considered suitable and usable in further analysis. This confirms that the statements are sufficiently reliable and can be integrated into relevant models or assessments to ensure accuracy and objectivity. Therefore, based on the obtained statistical values, it can be concluded that these statements meet the established criteria and are appropriate for further use in both theoretical and practical contexts.

Table 5. Responsibility and duty validity values

Responsibility and Duty	Factor
I feel a responsibility to protect animals and thus contribute to the preservation of biodiversity.	.753
As hunger increases worldwide, I feel responsible for reducing food waste.	.680
As rare animal species are disappearing around the world, I feel responsible for the preservation of biodiversity.	.683
As landfill waste increases, I feel responsible for reducing excessive consumption.	.588
I feel a duty to save water and energy, thus contributing to the reduction of water pollution.	.574
I feel a responsibility to consume food responsibly and thus reduce food waste.	.769
I feel a responsibility to sort and reduce waste, contributing to the reduction of environmental pollution.	.705
As deforestation occurs on a massive scale worldwide, I feel responsible for protecting green spaces.	.696
I feel a duty to buy and consume responsibly, thus contributing to the reduction of human impact on climate change.	.746
As freshwater resources decrease worldwide, I feel responsible for reducing water pollution.	.728
As human impact on climate change increases, I feel responsible for living a sustainable lifestyle and encouraging others to do the same.	.627
Eigenvalue %	***23.625***
Variation	***37.500%***
Cumulative %	***37.500%***
Bartlett's Test of Sphericity	***p<.05***

Source: Author's research

The Responsibility and Duty component, with values ranging from 0.574 to 0.769, demonstrates a statistically significant relationship with the examined factor. These values indicate an acceptable level of reliability, suggesting that the component accurately reflects the concepts of responsibility and duty within the context of the study. The range of values confirms that the component is sufficiently robust and can be effectively utilized in further analyses or assessments. Consequently, these values suggest that the Responsibility and Duty component meets the necessary criteria for inclusion in both theoretical models and practical applications.

Table 6. Behaviour Validity Values

Behaviour Item	Factor
I initiate environmental events (at school or in the community).	.347
I collaborate with classmates, teachers, and others to solve ecological problems.	.614
I participate in ecological discussions at school and in the city.	.669
I take part in environmental clean-up events.	.701
I volunteer for an organization that aims to achieve ecological goals.	.692
I participate in environmental greening actions (e.g., tree planting, landscaping).	.553
I create content (e.g., texts, videos) on social media about ecological issues.	.684
I am interested in the political decisions being made on ecological matters.	.688
I deepen my knowledge about the ecological situation in my environment, Lithuania, and the world.	.690
I share (repost) content on social media about ecological issues.	.762
I participate in school or community initiatives aimed at protecting nature.	.703
I discuss ecological topics with others.	.704
I participate in excursions, exhibitions, and lectures on ecological topics.	.853
I share knowledge about ecological issues with friends and family.	.707
I set an example for others on how to live sustainably.	.671
I avoid buying items from fast fashion stores.	.703
For travel, I choose low-emission transportation options.	.722
I "revive" items for a new life (e.g., creating new items from old, unused ones).	.669
Eigenvalue %	***3.094***
Variation	***4.910%***
Cumulative %	***53.648%***
Bartlett's Test of Sphericity	***p<.05***

Source: Author's research

The Behaviour component, with values ranging from 0.347 to 0.853, shows a statistically significant correlation with the examined factor. These values indicate a broad spectrum of reliability, with the lower bound still providing sufficient consistency and the upper bound demonstrating a stronger, more robust relationship. This variability suggests that the Behaviour component can effectively capture and represent the relevant behavioural aspects within the context of the study. Given the range of values, it can be concluded that the Behaviour component is both reliable and applicable for further use in analysis and practical settings, meeting the required criteria for inclusion.

Table 7. Correlation situations between Ecological Citizenship Components

	Correlation between components		
Ecological citizenship	Knowledge	Responsibility and Duty	Behaviour
Knowledge	1.000	0.529	0.739
Responsibility and Duty	0.529	1.000	0.608
Behaviour	0.739	0.608	1.000

Source: Author's research

The statistical data provided represents the correlation coefficients between the components of ecological citizenship: Knowledge, Responsibility and Duty, and Behaviour. The correlation between Knowledge and Responsibility and Duty is 0.529, suggesting a moderate positive relationship. As individuals acquire more knowledge about environmental issues, their sense of responsibility and duty toward ecological sustainability tends to increase. The correlation between Knowledge and Behaviour is 0.739, indicating a strong positive relationship. This suggests that greater knowledge about ecological matters leads to more sustainable behaviours in individuals. The correlation between Responsibility and Duty and Behaviour is 0.608, showing a moderate to strong positive relationship. This implies that individuals who feel a strong sense of responsibility and duty are more likely to adopt sustainable behaviours. Overall, the data reflects that as knowledge increases, so does the sense of responsibility and the likelihood of engaging in sustainable behaviour, with behaviour being most strongly correlated with knowledge.

4. Conclusion

The results of the analysis indicate that the Ecological Citizenship Scale for Adolescents with 47 items is a reliable and valid instrument for measuring ecological citizenship in adolescent populations. The scale's three components: Knowledge, Responsibility and Duty, and Behaviour, are empirically supported by the factor analysis and demonstrate high internal consistency. This suggests that the scale effectively captures the multidimensional nature of ecological citizenship, providing a solid foundation for future research in this area.

The findings further suggest that adolescents possess a well-developed understanding of ecological issues, which is reflected in the Knowledge component. This component appears to be strongly correlated with a sense of environmental responsibility, as shown in the Responsibility and Duty component, indicating that adolescents feel a significant level of obligation towards environmental stewardship. Additionally, the results highlight a moderate level of engagement in pro-environmental behaviours, as reflected in the Behaviour component.

The results of the exploratory factor analysis indicate that the scale is highly suitable for further analysis, with a Kaiser-Meyer-Olkin (KMO) value of .972 and a significant Bartlett's sphericity

test ($p<.01$), confirming that the data meets the necessary criteria for factor analysis, as outlined by George and Mallery (2024). The Cronbach's Alpha value of 0.961 further supports the internal consistency of the scale, demonstrating high reliability. These findings collectively support the construct validity of the scale, which was further verified through confirmatory factor analysis. The analysis reveals that adolescents exhibit a well-developed understanding of ecological issues, as evidenced by the strong correlation between the Knowledge and Responsibility and Duty components. This suggests that adolescents not only have substantial environmental knowledge but also recognize their responsibility towards environmental sustainability. Furthermore, although the correlation between Responsibility and Duty and Behaviour is moderate, the results indicate a moderate level of pro-environmental behaviour, suggesting that while adolescents acknowledge their environmental obligations, this awareness does not always fully translate into consistent, sustainable actions. These findings highlight the importance of reinforcing both knowledge and responsibility to foster stronger, more widespread engagement in pro-environmental behaviours.

Notably, the slightly skewed distributions observed in the Responsibility and Duty and Knowledge components, with a tendency toward higher responses, suggest that adolescents generally view ecological responsibility in a positive light. They likely perceive themselves as being informed and responsible when it comes to environmental issues. In contrast, the Behaviour component shows a more neutral distribution, indicating that while many adolescents recognize the importance of ecological citizenship, their actual engagement in pro-environmental actions may not be as strong or consistent. This could reflect challenges in translating ecological knowledge and responsibility into concrete behaviours, potentially due to barriers such as lack of resources, awareness, or opportunity.

Despite these minor deviations from normality, the large sample size helps mitigate the impact of non-normality, ensuring that the statistical analyses remain robust and reliable. This strengthens the validity of the scale as a tool for assessing ecological citizenship among adolescents. However, it is important to acknowledge that the scale might benefit from further refinement to address these nuances in response patterns, particularly in the Behaviour component.

Future studies could explore the impact of sociodemographic variables such as age, gender, and location on ecological citizenship scores. Such investigations could further validate the scale across different demographic groups and contexts, helping to identify potential factors that influence adolescents' ecological attitudes and behaviours. Additionally, longitudinal studies might shed light on how ecological citizenship evolves over time and what interventions or educational strategies might foster greater engagement in pro-environmental behaviours among young people.

References:

Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. Environmental Science and Pollution Research, 29(28), 42539-42559. https://doi.org/10.1007/s11356-022-19718-6

Aceves-Bueno, E., Read, A. J., & Cisneros-Mata, M. A. (2021). Illegal fisheries, environmental crime, and the conservation of marine resources. Conservation Biology, 35(4), 1120-1129. https://doi.org/10.1111/cobi.13674

Akalin, G., Erdogan, S., & Sarkodie, S. A. (2021). Do dependence on fossil fuels and corruption spur ecological footprint?. Environmental Impact Assessment Review, 90, 106641. https://doi.org/10.1016/j.eiar.2021.106641

Bamberg, S., Rees, J., & Seebauer, S. (2015). Collective climate action: Determinants of participation intention in community-based pro-environmental initiatives. Journal of Environmental Psychology, 43, 155-165. https://doi.org/10.1016/j.jenvp.2015.06.006

Bandura, A., & Cherry, L. (2020). Enlisting the power of youth for climate change. The American Psychologist, 75(7), 945-951. https://doi.org/10.1037/amp0000512

Berkowitz, A. R., Ford, M. E., & Brewer, C. A. (2005). A Framework for Integrating Ecological Literacy, Civics Literacy and Environmental Citizenship in Environmental Education. In Johnson, E. A., Mappin, M. J. (eds.) Environmental Education and Advocacy: Perspectives of Ecology and Education, pp. 227-266. Cambridge: Cambridge University Press.

Bhide, S., & Chunawala, S. (2017). Making a case for outdoor engagement in environmental studies at Indian schools. Conexão Ciência, 12(2), 223-230.

Budowle, R., Krszjzaniek, E., & Taylor, C. (2021). Students as change agents for community–university sustainability transition partnerships. Sustainability, 13(11), 6036.

Buhr, M., Harms, D., & Schaltegger, S. (2023). Individual change agents for corporate sustainability transformation: a systematic literature review. Benchmarking: An International Journal, 30(10), 4221-4247.

Charli-Joseph, L., Siqueiros-Garcia, J. M., Eakin, H., Manuel-Navarrete, D., & Shelton, R. (2018). Promoting agency for social-ecological transformation: A transformation-lab in the Xochimilco social-ecological system. Ecology and Society, 23(2), 46. https://doi.org/10.5751/ES-10214-230246

Cohen, S. A., Higham, J. E., & Cavaliere, C. T. (2011). Binge flying: Behavioural addiction and climate change. Annals of Tourism Research, 38(3), 1070-1089.

Comrey, A. L., & Lee, H. B. (2013). A first course in factor analysis. Psychology Press.

Crist, E., Mora, C., & Engelman, R. (2017). The interaction of human population, food production, and biodiversity protection. Science, 356(6335), 260-264. https://doi.org/10.1126/science.aal201

Dobson, A. (2004). Citizenship and the Environment. United States: Oxford University Press.

Dobson, A. (2007). Ecological Citizenship: Towards Sustainable Development. Sustainable Development, 15, 276–285.

Dominski, F. H., Branco, J. H. L., Buonanno, G., Stabile, L., da Silva, M. G., & Andrade, A. (2021). Effects of air pollution on health: A mapping review of systematic reviews and meta-analyses. Environmental research, 201, 111487.

Du, Z. H., Wang, L., Wei, Z. Q., Liu, J. F., Lin, P. L., Lin, J. H., & Xiao, C. D. (2022). CH4 and CO2 observations from a melting high mountain glacier, Laohugou Glacier No. 12. Advances in Climate Change Research, 13(1), 146-155. https://doi.org/10.1016/j.accre.2021.11.007

Fang, H., Akhayere, E., Adebayo, T. S., Kavaz, D., & Ojekemi, O. R. (2024). The synergy of renewable energy consumption, technological innovation, and ecological quality: SDG policy proposals for developing countries. Natural Resources Forum, 49(1), 561-577. https://doi.org/10.1111/1477-8947.12404

Fisher-Vanden, K., & Olmstead, S. (2013). Moving pollution trading from air to water: potential, problems, and prognosis. Journal of Economic Perspectives, 27(1), 147-172. https://doi.org/10.1257/jep.27.1.147

Geijsel, F., Ledoux, G., Reumerman, R., & Ten Dam, G. (2012). Citizenship in young people's daily lives: differences in citizenship competences of adolescents in the Netherlands. Journal of Youth Studies, 15(6), 711-729. https://doi.org/10.1080/13676261.2012.671932

George, D., & Mallery, P. (2024). IBM SPSS statistics 29 step by step: A simple guide and reference. Routledge.

Hadjichambis, A. C., & Paraskeva-Hadjichambi, D. (2020). Environmental Citizenship Questionnaire (ECQ): The Development and Validation of an Evaluation Instrument for Secondary School Students. Sustainability, 12(3), 821-831.

Hawcroft, L. J., & Milfont, T. L. (2010). The use (and abuse) of the new Environmental Paradigm Scale over the last 30 years: A meta-analysis. Journal of Environmental Psychology, 30(2), 143-158. doi:10.1016/j.jenvp.2009.10.003

Hayward, B. (2013). Children, citizenship and environment: Nurturing a democratic imagination in a changing world. Children, Youth and Environments, 23 (3), 194-196.

Hoang, N. T., & Kanemoto, K. (2021). Mapping the deforestation footprint of nations reveals growing threat to tropical forests. *Nature Ecology & Evolution*, *5*(6), 845-853.

Hoshaw, M. R. (2009). The contribution of reflective writing to ecological awareness at the H.J. Andrews experimental forest. A thesis for the degree of master of science. Environmental studies program, University of Oregon.

Hristopulos, D. T., Spagnolo, B., & Valenti, D. (2021). Open challenges in environmental data analysis and ecological complex systems. *Europhysics Letters*, *132*(6), 68001.

Huimin, L. (2013). The impact of human behavior on ecological threshold: Positive or negative? Grey relational analysis of ecological footprint, energy consumption and environmental protection. *Energy Policy*, *56*, 711-719.

Jagers, S. C., Martinsson, J., & Matti, S. (2014). Ecological citizenship: a driver of pro-environmental behaviour?. Environmental Politics, 23(3), 434-453.

Jagers, S. C., & Matti, S. (2010). Ecological citizens: Identifying values and beliefs that support individual environmental responsibility among Swedes. *Sustainability*, 2(4), 1055-1079. https://doi.org/10.3390/su2041055

Kaiser, F. G. (1998). Ecological behavior and environmental protection: The role of self-determination. Journal of Environmental Psychology, 18(2), 132-145.

Karatekin, K., & Uysal, O. (2018). Dimensions of ecological citizenship: Participation, sustainability, responsibility, and rights/justice. Sustainability, 10(11), 3874.

Kennedy, E. H. (2011). Rethinking ecological citizenship: the role of neighbourhood networks in cultural change. Environmental Politics, 20(6), 843-860.

Kumar, R., Kumar, A., & Saikia, P. (2022). Deforestation and forests degradation impacts on the environment. In *Environmental degradation: Challenges and strategies for mitigation* (pp. 19-46). Cham: Springer International Publishing.

Leiserowitz, A. A., Kates, R. W., & Parris, T. M. (2006). Sustainability values, attitudes, and behaviors: A review of multinational and global trends. Annual Review of Environment and Resources, 31, 413-444. https://doi.org/10.1146/annurev.energy.31.102505.133552

Lewinsohn, T. M., Attayde, J. L., Fonseca, C. R., Ganade, G., Jorge, L. R., Kollmann, J., & Weisser, W. W. (2015). Ecological literacy and beyond: Problem-based learning for future professionals. Ambio, 44, 154-162.

Lunenburg, F. C. (2010). Managing change: The role of the change agent. International Journal of Management, Business, and Administration, 13(1), 1-6.

Maihanyar, S., & Sakhawati, M. E. (2024). Television's Role in Environmental Awareness: A Study of Public Perception in Northern Afghanistan. Journal of Social Sciences & Humanities, 1(1), 68-86.

Malone, K. (2013). "The future lies in our hands": Children as researchers and environmental change agents in designing a child-friendly neighbourhood. Local environment, 18(3), 372-395.

Manning, L. (2008). The impact of water quality and availability on food production. *British Food Journal*, *110*(8), 762-780.

Marinello, S., Butturi, M. A., & Gamberini, R. (2021). How changes in human activities during the lockdown impacted air quality parameters: A review. *Environmental progress & sustainable energy*, *40*(4), e13672.

Marris, E. (2019). Why young climate activists have captured the world's attention. Nature, 573(7775), 471-472. https://doi.org/10.1038/d41586-019-02696-0

Mishra, B. K., Kumar, P., Saraswat, C., Chakraborty, S., & Gautam, A. (2021). Water security in a changing environment: Concept, challenges, and solutions. Water, 13(4), 490. https://doi.org/10.3390/w13040490

Mittal, P., Bansal, R. (2024). Empowering Students as Agents of Change: Building a Culture of Sustainability in Higher Education Institutions. In Community Engagement for Sustainable Practices in Higher Education: From Awareness to Action, 261-276.

Mona, M. H., El-Naggar, H. A., El-Gayar, E. E., Masood, M. F., & Mohamed, E. S. N. (2019). Effect of human activities on biodiversity in Nabq Protected Area, South Sinai, Egypt. The Egyptian Journal of Aquatic Research, 45(1), 33-43. https://doi.org/10.1016/j.ejar.2018.12.001

Ogunjinmi, A. A., Oluwatuyi, B. G., & Oniya, B. J. (2015). Determining ecological knowledge and attitudes of students: the role of personal factors and school exposure. International Journal of Conservation Science, 6(3).

Osborne, J. W., & Costello, A. B. (2004). Sample size and subject to item ratio in principal components analysis. Practical Assessment, Research, and Evaluation, 9(1), 11. https://doi.org/10.7275/ktzq-jq66

Ostman, J. (2014). The influence of media use on environmental engagement: A political socialization approach. Environmental Communication, 8(1), 92-109.

Pastakia, A. (1998). Grassroots ecopreneurs: change agents for a sustainable society. Journal of Organizational Change Management, 11(2), 157-173. https://doi.org/10.1108/09534819810212142

Payet, R., & Obura, D. (2004). The negative impacts of human activities in the Eastern African region: An international waters perspective. AMBIO: A Journal of the Human Environment, 33(1), 24-33.

Peters, N. E., & Meybeck, M. (2000). Water quality degradation effects on freshwater availability: impacts of human activities. *Water International*, *25*(2), 185-193.

Poissant, D., Coomes, O. T., Robinson, B. E., & Vargas Dávila, G. (2024). Fishers' ecological knowledge points to fishing-induced changes in the Peruvian Amazon. Ecological Applications, 34(5), e2964. https://doi.org/10.1002/eap.2964

Prakash, S., & Verma, A. K. (2022). Anthropogenic activities and biodiversity threats. International Journal of Biological Innovations, 4(1), 94-103.

Redman, A., Rowe, D., Brundiers, K., & Brock, A. (2021). What motivates students to be sustainability change agents in the face of adversity?. Sustainability and Climate Change, 14(5), 313-322. https://doi.org/10.1089/scc.2021.0024

Romshoo, S. A., Murtaza, K. O., Shah, W., Ramzan, T., Ameen, U., & Bhat, M. H. (2022). Anthropogenic climate change drives melting of glaciers in the Himalaya. Environmental Science and Pollution Research, 29(35), 52732-52751.

Schaltegger, S., Girschik, V., Trittin-Ulbrich, H., Weissbrod, I., & Daudigeos, T. (2024). Corporate change agents for sustainability: Transforming organizations from the inside out. *Business Ethics, the Environment & Responsibility*, *33*(2), 145-156.

Schulz, W., Ainley, J., Fraillon, J., Losito, B., Agrusti, G., Friedman, T. (2018). Becoming citizens in a changing world: IEA international civic and citizenship education study 2016 international report (p. 243). Springer Nature.

Shahady, T. (2024). Mitigating strategies for agricultural water pollution exacerbated by climate change. In *Living with Climate Change* (pp. 173-195). Elsevier.

Singh, N., Davar, S. C. (2004). Noise pollution-sources, effects and control. Journal of Human Ecology, 16(3), 181-187.

Skelly, S. M., & Bradley, J. C. (2007). The growing phenomenon of school gardens: Measuring their variation and their affect on students' sense of responsibility and attitudes toward science and the environment. *Applied Environmental Education and Communication*, *6*(1), 97-104.

Smith, M. J. (1998). Ecologism: Towards Ecological Citizenship. United Kingdom: Open University Press.

Solly, K., Smyer, M. A., Nichols, K., Steffens, N. K., Kastelle, T. H., & Pachana, N. A. (2022). Volunteering for a better future: A pilot Sustainability Ambassadors Training Program. *Australasian Journal on Ageing*, *41*(2), e206-e209.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223), 1259855. https://doi.org/10.1126/science.1259855

Stern, M. J., Powell, R. B., & Hill, D. (2014). Environmental education program evaluation in the new millennium: What do we measure and what have we learned? Environmental Education Research, 20(5), 581-611. https://doi.org/10.1080/13504622.2013.838749

Tabachnick, B. G., & Fidell, L. S. (2007). Experimental designs using ANOVA (Vol. 724). Belmont, CA: Thomson/Brooks/Cole.

Trenberth, K. E. (2018). Climate change caused by human activities is happening and it already has major consequences. *Journal of energy & natural resources law*, *36*(4), 463-481.

Unuofin, J. O. (2020). Garbage in garbage out: the contribution of our industrial advancement to wastewater degeneration. Environmental Science and Pollution Research, 27(18), 22319-22335. https://doi.org/10.1007/s11356-020-08944-5

Usmi, R., & Murdiono, M. (2021). Ecological citizenship in textbooks on Pancasila and Citizenship Education subjects at the secondary education level. Journal Civics: Media Kajian Kewarganegaraan, 18(2), 242-256.

Vallero, D. (2014). The science of air pollution. *Fundamentals of air pollution*, 43-81.

Veselinovska, S. S., & Osogovska, T. L. (2012). Engagement of students in environmental activities in school. *Procedia-Social and Behavioral Sciences*, *46*, 5015-5020.

Wade, J. A. (1999). Students as environmental change agents. *International journal of contemporary hospitality management*, *11*(5), 251-255.

Wallis, H., & Loy, L. S. (2021). What drives pro-environmental activism of young people? A survey study on the Fridays For Future movement. Journal of Environmental Psychology, 74, 101581. https://doi.org/10.1016/j.jenvp.2021.101581

White, E. S. (2021). Parent values, civic participation, and children's volunteering. *Children and Youth Services Review*, *127*, 106115.

Wolf, J. (2011). Ecological citizenship as public engagement with climate change. In Whitmarsh, L., Lorenzoni, I., O'Neill, S. (eds.) Engaging the public with climate change: Behaviour change and communication, pp. 120-137. London: Routledge.

Wynes, S., & Nicholas, K. A. (2017). The climate mitigation gap: Education and government recommendations miss the most effective individual actions. Environmental Research Letters, 12(7), 074024. https://doi.org/10.1088/1748-9326/aa7541

Yılmaz, E. O., & Yurdugül, H. (2013). The perception of learning in asynchronous online discussions: A scale development study. Procedia-Social and Behavioral Sciences, 83, 776-780. https://doi.org/ 10.1016/j.sbspro.2013.06.146

Zahoor, I., & Mushtaq, A. (2023). Water pollution from agricultural activities: A critical global review. International Journal of Chemical and Biochemical Sciences, 23(1), 164-176.