Sustainability **2015**, *7*, 15510-15526; doi:10.3390/su71115510

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Human-Environment System Knowledge: A Correlate of Pro-Environmental Behavior

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Academic Editors: Ralf Hansmann and Ian Thomas

Received: 18 August 2015 / Accepted: 6 November 2015 / Published: 20 November 2015

Abstract: An effective program of environmental education requires the identification of the knowledge that must be imparted. This paper compares the effects of human-environment system knowledge (*i.e.*, knowledge related to environmental problems caused by humans) and environmental action knowledge (*i.e.*, knowledge of possible courses of action to reduce human impact on the environment) on pro-environmental behavior. Environmental knowledge and pro-environmental behavior of 950 Chilean adults were assessed with a survey. Both types of knowledge were related to pro-environmental behavior (r = 0.25 and r = 0.22, respectively, $p < 0.001$). These results seem to contradict previous studies that found that system knowledge is not directly related to pro-environmental behavior. However, existing scales of environmental system knowledge are behavioral-distant due to their greater number of general geography knowledge items. In contrast, our human-environmental system knowledge scale focuses on understanding global environmental problems and, therefore, can be expected to relate more closely to pro-environmental behavior. To promote pro-environmental behavior, we suggest teaching more human-environment system knowledge and environmental action knowledge. Since different forms of environmental knowledge must work together in a convergent manner in order to foster pro-environmental behavior, the present study represents an important contribution by showing that greater human-environment system knowledge is correlated with pro-environmental behavior.

Keywords: ecological behavior; pro-environmental behavior; environmental education; action knowledge; geography knowledge; effectiveness knowledge

1. Introduction

The concept of sustainable development includes three interdependent and mutually reinforcing pillars: economic development, social development and environmental protection [1]. With regards to environmental aspects of sustainability, some authors suggest that so-called "environmental problems" are actually problems of human behavior [2,3]. For this reason, researchers in the social sciences and in education have sought for decades to understand the factors that lead people to move from environmental knowledge to pro-environmental attitudes and then to pro-environmental behavior [4–6], which is a crucial part of sustainable behavior [7].

Many of the researchers believe that environmental education programs are necessary to increase environmental knowledge and, in turn, pro-environmental attitudes and behavior [8–10]. This relationship is based on the assumption that people who are more knowledgeable about the environment should in turn be more aware of the environment and its problems and, thus, be more motivated to act positively toward the environment [11,12]. Indeed, knowledge of environmental problems, their causes, and consequences has been shown to be an important determinant of peoples' environmental behavior [13,14].

The opinion that increased environmental knowledge leads to pro-environmental behavior has been disputed for quite some time. For example, Hungerford and Volk [15] demonstrated that knowledge does not lead to behavior change in the environmental dimension. On the other hand, several other studies have found positive relationships between environmental knowledge and behavior. The amount of behavioral variance that can be explained by environmental knowledge varies between 6% [16] and 18% [17].

Kaiser and Fuhrer [18] argued that the influence of environmental knowledge on pro-environmental behavior has been systematically underestimated because the underlying structure of environmental knowledge has not been addressed adequately. They suggested that it is necessary to consider different forms of environmental knowledge to understand their effects on pro-environmental behavior. Kaiser and Frick [17], Kaiser and Fuhrer [18] and Frick *et al.* [16] defined the following three forms of environmental knowledge:

(1) System knowledge (or know-what) concerns the knowledge of how ecosystems function. For example [16]: In a humid climate (such as the central Swiss plateau), how long does it take for 10 cm (4 inches) of soil to form? Why are some alpine rivers milky and grayish? What causes wind? Where does groundwater come from?
However, system knowledge also concerns knowledge of environmental problems caused by humans. For example [16]: Why is carbon dioxide (CO_2) a problem? If the concentration of atmospheric carbon dioxide (CO_2) doubled, the global mean average temperature would rise by about … (X °C). Why is ozone a problem? If all ozone-destroying emissions were eliminated right now, how long would it take for almost complete regeneration of the ozone layer?

(2) Action knowledge (or know-how) refers to knowledge of behavioral options and possible courses of action to reduce human impact on the environment. For example [16]: How can soil erosion be prevented? How can ozone build-up be reduced in summertime?
(3) Effectiveness knowledge addresses the relative conservational effectiveness that is associated with a particular behavior. With effectiveness knowledge, the focus of action knowledge gets extended from a mere knowing how to conserve to knowing how to get the greatest environmental benefit. For example [16]: Recycling which of the following materials saves the most energy as compared to producing new material? What type of milk packaging is the most damaging to the environment? What type of lamp consumes the least energy for the same amount of light? To travel 1 km (1 mile), how much more energy is consumed per person by car as compared to by train?

With regard to system knowledge, we emphasize that the definition of Frick *et al.* [16] contains two subclasses of system knowledge: (1) knowledge of how ecosystems function; and (2) knowledge of how environmental problems can be caused by humans. To distinguish between these two subclasses of system knowledge, we will refer to knowledge of how ecosystems function as "geography-environment system knowledge", while knowledge related to environmental problems caused by humans will be referred to as "human-environment system knowledge".

Frick *et al.* [16] demonstrated that the effect of system knowledge on pro-environmental behavior was not significant. Kaiser and Fuhrer [18] and Frick *et al.* [16] postulated that system knowledge forms the basis for behavior related to proximal knowledge types (action and effectiveness knowledge), which, in turn, has direct effects on pro-environmental behavior. However, only seven out of 21 items of the system knowledge scale of Frick *et al.* [16] were human-environment items. In line with Frick *et al.* [16], we argue that geography-environment system knowledge does not directly relate to pro-environmental behavior. However, in addition, we argue that a focus on human-environment system knowledge could reveal a direct link to pro-environmental behavior. Indeed, it is likely that human-environment system knowledge can induce an internal locus of control in relation to the environment and/or guilt for the environment, which is known to improve pro-environmental behavior [19–21].

2. Research Goals

We hypothesized that awareness and understanding of global environmental problems would have a positive effect on pro-environmental behavior. To this end, the first aim of this study was to develop a reliable and valid scale of human-environment system knowledge. The second aim was to determine the effect of human-environment system knowledge on pro-environmental behavior.

We also note that the scales of system, action and effectiveness knowledge were developed and validated using a sample of Swiss professors and students with high levels of education [17]. Frick *et al.* [16] demonstrated that these knowledge scales had a high degree of difficulty when applied to a general sample of the Swiss population. Although our previous studies [22–24] attempted to environmental knowledge scales applicable to the general public, the resulting scales had low reliabilities. Thus, the third aim of this study was to develop and validate scales of action and effectiveness knowledge with a focus on easier items, and to test their applicability to the general public.

3. Methods

3.1. Participants of the Pilot Questionnaire

The pilot questionnaire was applied with a sample of 92 people. Only 9% of the participants in the pilot study had not completed highschool, 15% had a highschool degree, 15% were students or graduates of technical programs, 16% were students or graduates with ≤4 years of university studies, 30% were students or graduates with ≥4 years of postsecondary education, and 14% had a postgraduate degree (Master or Doctorate).

3.2. Participants of the Final Sample

The final sample consisted of 950 people. Participants of the pilot survey were not included in the final sample. The mean age of the participants (ranging from age 18 to 86), was 36 ± 14 years old (average ± standard deviation), and 65% were female. The majority of participants (41%) were university students or graduates, 22% were technical students or graduates, 20% had a highschool degree, and 9% had not completed highschool. Only 8% had a postgraduate degree (Master or Doctorate). These percentages indicate that the participants of this study had a higher education than the average Chilean population [25]. Even though the monthly family income distribution of our sample was not representative of the national distribution in Chile (see [25]), it nevertheless varied widely, with 8% earning ≤ USD 400, 16% earning USD 400–800, 18% earning USD 800–1200, 21% earning USD 1200–2000, 26% earning USD 2000–6000, 7% earning USD 6000–10,000 and 2% earning ≥ USD 10,000).

3.3. Procedure

To obtain information for this study, a quantitative method was used: data were gathered using surveys completed by adults who were aged 18 or older and selected at random in February 2014. The questionnaire (Supplementary Material) consisted of (1) a set of sociodemographic questions (age, gender, income, and education level); (2) three sets of environmental knowledge questions, corresponding to the three forms of environmental knowledge (Tables 1–3); and (3) a set of pro-environmental behavior statements.

The surveys were performed on beaches and surrounding areas (market places, squares, *etc.*) in the Valparaíso Region (central Chile), as this area offers heterogeneity in terms of age, gender, income and education level [26]. Additionally, people on the beach may be more relaxed and, as such, more open to participating in a survey.

Table 1. Human-environment system knowledge questionnaire developed in this study.

Human-Environment System Knowledge	Reference	Domain	Delta *	MS Infit **	Correct Answer %
s15. Which of the following gases has greater contribution to the greenhouse effect?	New item	Climate change	**2.03**	1.16	9
s14. Which is the major cause of pollution of groundwater with nitrates?	Frick *et al.* [16]	Pollution	**1.48**	1.12	15
s02. Which of these gases does not belong to the greenhouse gases?	New item	Climate change	**1.27**	1.19	15
s05. Which of these substances is the most harmful to humans?	New item	Pollution	**1.09**	1.08	20
s03. What is the carbon footprint of a product?	Geiger *et al.* [23]	Climate change	**1.04**	1.28	20
s18. What is the effect of the use of fossil fuels on the environment?	Richards [24]	Climate change	0.60	0.94	27
s13. Which of the following diseases would not be caused by heavy metals (such as mercury, lead and arsenic) in drinking water?	Geiger *et al.* [23]	Pollution	0.56	1.05	28
s07. What is the sector that uses the most water in Chile?	New item	Resource availability	0.42	1.12	31
s06. Which of these forms of energy is conventional?	New item	Resource availability	−0.32	0.94	45
s12. Which of the following practices is accepted in organic farming?	Geiger *et al.* [23]	Pollution	−0.44	0.93	48
s01. What is the greenhouse effect?	New item	Climate change	−0.56	0.85	50
s09. Which of the following phenomena is the main cause of the increase in global temperature over the last 20 years?	Geiger *et al.* [23]	Climate change	−0.59	0.83	51
s17. Which is the batteries' impact on the environment?	Richards [24]	Pollution	−0.79	0.96	55
s16. What is the impact that detergents have on the environment?	Barazarte *et al.* [22]	Pollution	***−0.80***	0.93	55
s08. What is drought?	New item	Climate change	***−0.81***	0.93	56
s11. What is wrong with carbon dioxide (CO_2)?	Frick *et al.* [16]	Climate change	***−0.87***	0.98	57
s10. Which of these forms of energy is not renewable?	Geiger *et al.* [23]	Resource availability	***−1.30***	0.88	65
s04. What are the effects of global warming?	New item	Climate change	***−2.00***	0.87	78

* Average ± standard deviation: −0.55 ± 1.1 (*n* = 947). Here and below, item difficulties (delta) are expressed in logits, the basic units of Rasch scales. Larger logit values indicate that a person knows more about the environment. Conversely, a smaller logit value indicates that one knows less. Logits in bold indicate the 5 most difficult (high positive numbers), logits in bold-italic the 5 easiest items (low negative numbers). ** Here and below, the MS (mean square) fit statistic reflects the relative discrepancy in the variation between model prediction and observed data independent of the sample size. Perfect model prediction is expressed by a MS value of 1.0. MS values above 1.0 indicate excessive variation (e.g., a value of 1.2 indicates 20% excessive variation). A commonly acceptable upper value is 1.2.

3.4. Development of a Scale for Environmental Education

In accordance with the first and second aims of the study, we focused our new system knowledge scale on knowledge of environmental problems caused by humans (human-environment system knowledge) rather than on knowledge of how ecosystems function (geography-environment system knowledge). In particular, we focused our scale of human-environment system knowledge on the following broad environmental topics: climate change, pollution, and resource availability. In our opinion as environmental scientists, these topics are the most important environmental issues that human beings are currently facing on a global scale, as a consequence of the increase in population and the expansion of technology (e.g., [27]). With regards to climate change, we followed the mainstream opinion that it is caused by an increase in atmospheric CO_2 concentrations due to burning of fossil fuels [28,29], even though we are aware of an alternative opinion of a minority of scientists that climate change is a natural phenomenon not related to humans [30–32].

With regards to the domain of resource availability, we emphasize its importance in the environmental action knowledge sub-scale since this domain is directly related to the pro-environmental behavior. For this reason, we included the domain of resource availability in the human-environment system knowledge sub-scale (questions 6, 7, and 10 in the Table 1), despite the fact that this domain does not relate to environmental problems caused by humans *per se*.

In accordance with the third aim of the study, we also made an attempt to develop of action and effectiveness knowledge scales applicable to the general public. In the following discussion, we will refer to these two types of environmental knowledge as "environmental action knowledge" and "environmental effectiveness knowledge", respectively. In our scales (Tables 1–3), we took six items from the scale of Frick *et al.* [16]. We used items that better suit Chilean cultural or geographical contexts, based on the opinion of a group of environmental scientists. The wording of some questions and answers was modified to make them easier. Likewise, we took some items from our previous studies. Specifically, 20 items were taken from the scale of Geiger *et al.* [23], four items from the scale of Barazarte *et al.* [22], and three items from the scale of Richards [24]. We focused our scales of environmental action knowledge and environmental effectiveness knowledge on the same environmental topics as in the case of human-environment system knowledge: climate change, pollution, and resource availability. Finally, 20 new items were developed by a group of environmental scientists based on the same criteria. A five-option multiple-choice format was used with a scoring system of one point for the correct answer (of which there was only one) and zero points for the other four answers.

The pilot questionnaire included questions on effectiveness knowledge (Table 3), but it was decided not to include them in the final questionnaire due to the low reliability shown by this sub-scale (Table 4). Therefore, the final environmental knowledge questionnaire included a total of 35 items, with 18 questions regarding human-environment system knowledge (Table 1) and 17 regarding environmental action knowledge (Table 2).

Table 2. Environmental action knowledge questionnaire developed in this study.

Environmental Action Knowledge	Reference	Domain	Delta *	MS Infit	Correct Answer %
a26. Why is it important to recycle aluminum rather than throw it away?	Frick *et al.* [16]	Resource availability	**1.63**	1.13	18
a28. Which of the following actions does not save water?	Geiger *et al.* [23]	Resource availability	**1.09**	1.12	26
a25. Why one should use the least amount of detergent possible?	Barazarte *et al.* [22]	Pollution	**1.01**	1.60	28
a20. Which action does not reduce greenhouse gases?	Geiger *et al.* [23]	Climate change	**0.90**	1.10	30
a33. Are there advantages in buying locally made products over imports?	Richards [24]	Climate change	**0.88**	0.96	30
a19. Which action does not help to reduce garbage?	Geiger *et al.* [23]	Pollution	0.80	0.98	31
a32. How can more efficiently use paper?	Barazarte *et al.* [22]	Resource availability	0.73	1.01	33
a22. Which of these options indicates the amount of water used in the production of a product?	New item	Resource availability	0.72	0.99	33
a30. How much water is used in a shower about 5 min?	New item	Resource availability	0.28	1.30	42
a27. Which form of consumption is not considered ecological *per se*?	Geiger *et al.* [23]	Resource availability	0.05	0.90	46
a24. How one can get companies to reduce their emissions of greenhouse gases?	New item	Climate change	−0.46	0.98	58
a34. What action does not help the sustainable development?	New item	Resource availability	−0.53	0.96	58
a23. Which action does not help to save energy costs in everyday life?	Geiger *et al.* [23]	Resource availability	***−1.18***	0.86	71
a35. What action does not help to reduce gas consumption?	New item	Resource availability	***−1.19***	0.85	71
a31. How the use of detergents can be reduced?	Barazarte *et al.* [22]	Pollution	***−1.21***	0.83	71
a21. Which of these products should not be thrown away for being highly polluting?	Geiger *et al.* [23]	Pollution	***−1.51***	0.89	76
a29. Which of the following waste is not biodegradable?	Geiger *et al.* [23]	Pollution	***−2.02***	0.87	83

* Average ± standard deviation: −0.16 ± 1.1 (n = 944); Item difficulties (delta) are expressed in logits, the basic units of Rasch scales (please see above). Logits in bold indicate the 5 most difficult (high positive numbers), logits in bold-italic the 5 easiest items (low negative numbers).

Table 3. Effectiveness knowledge questionnaire developed in this study (used in pilot questionnaire only).

Effectiveness Knowledge	Reference	Domain	Delta *	MS Infit	Correct Answer %
e46. Which of these appliances use more energy put into the "stand by" mode?	Geiger *et al.* [23]	Resource availability	**1.58**	0.97	6.5
e44. Which of these products has a higher water footprint?	New item	Resource availability	**1.27**	0.87	8.7
e41. How much less spend the LED bulbs compared to conventional?	Frick *et al.* [16]	Resource availability	**0.91**	1.02	12
e47. Which means of transport spends less energy (per person per kilometer)?	Geiger *et al.* [23]	Resource availability	**0.72**	1.05	14
e51. Which recycled material saves more energy in comparison to produce it?	Frick *et al.* [16]	Resource availability	**0.39**	0.87	18
e50. After how many years is completely degraded plastic bag in a landfill?	Geiger *et al.* [23]	Pollution	0.32	0.99	20
e42. Which of these wastes have high degradation time?	New item	Pollution	0.25	1.01	21
e49. The production and transport of batteries need ... more energy than containing	Frick *et al.* [16]	Resource availability	0.25	0.98	21
e55. How much electricity consumes approximately a Chilean household of 4 people per month?	New item	Resource availability	0.05	1.12	24
e48. How many times more water is needed to produce one kilogram of beef, compared to a kilogram of staple foods such as potatoes, corn or wheat?	Geiger *et al.* [23]	Resource availability	−0.3	0.99	30
e52. Returnable beer containers can be reused on average ...	Geiger *et al.* [23]	Resource availability	−0.35	0.97	32
e56. How much time is necessary to recover the cost of an efficient light bulb?	Geiger *et al.* [23]	Climate change	−0.41	1.06	33
e54. How much water a person spends per day on average in Chile?	New item	Resource availability	−0.41	1.01	33
e53. How much water is needed for a bath in the tub?	Geiger *et al.* [23]	Resource availability	−0.46	0.9	34
e45. On average, more energy is spent at home to...:	Geiger *et al.* [23]	Resource availability	***−0.51***	1.06	35
e43. Which of the following pack emits less CO_2 in their life cycle?	New item	Climate change	***−0.51***	1.02	35
e57. When driving a car, which of these activities causes more fuel to be spent than necessary?	New item	Resource availability	***−0.51***	0.97	35

Table 3. *Cont.*

Effectiveness Knowledge	Reference	Domain	Delta	MS Infit	Correct Answer %
e39. What is the appliance that consumes more energy?	New item	Resource availability	***−0.76***	1.13	40
e40. Which food causes more CO_2 emissions per kilogram produced?	Geiger *et al.* [23]	Climate change	***−1.49***	0.94	57

* Average ± standard deviation: −1.2 ± 0.81 (*n* = 90); Item difficulties (delta) are expressed in logits, the basic units of Rasch scales (please see above). Logits in bold indicate the 5 most difficult (high positive numbers), logits in bold-italic the 5 easiest items (low negative numbers).

Table 4. Scale reliability [1] in the present study and in other studies.

	Frick *et al.* [16]	Geiger *et al.* [23]	Our Study	Pre-Test
Pro-environmental behavior	0.76	0.76	0.65	0.76
Overall knowledge [2]	0.71	0.57	0.83	0.85
Geography-environment system knowledge	0.67			
Human-environment system knowledge			0.70	0.72
Environmental action knowledge	0.66		0.72	0.74
Environmental effectiveness knowledge	0.50			0.45

[1] The reliability of a test describes how exact the test can measure what it is supposed to measure within a range from 0 to 1. A reliability of 0 would mean that the test is unreliable and not able to measure anything. A reliability of 1 is perfect. Thus, the closer the reliability is to 1 the better is the test. [2] Overall knowledge includes geography-environment system knowledge, environmental action and environmental effectiveness knowledge (in the studies of Frick *et al.* [16] and Geiger *et al.* [23]) and human-environment system knowledge and environmental action knowledge (in this study).

3.5. Pro-Environmental Behavior Scale

The pro-environmental behavior scale had 35 items. We used 30 items from the scale of Kaiser and Wilson [33] that better suits Chilean cultural or geographical contexts. Likewise, five new items were developed by a group of environmental scientists based on the same criterion. The scale was validated by Kaiser [34]; the accuracy of self-reports obtained using this scale was demonstrated by Kaiser *et al.* [35].

A yes/no format was used for 12 pro-environmental behavior items (e.g., I reuse my shopping bags), whereas 23 items were performed on a Likert-type five-point scale ranging from never to always; among these items, 12 were negatively formulated. Responses to these latter items were reversed in coding. For 35 items, “Not applicable” is a response alternative when an answer was, for whatever reason, not possible; such responses were coded as missing values.

3.6. Data Analysis

The maximum likelihood estimated model (MLE model) was used to calculate each person’s score for environmental knowledge and pro-environmental behavior [36,37]. The scores for each scale are expressed in logits, which stands for the natural logarithm of the behavioral engagement/non-engagement (or correct/incorrect response for knowledge scales) of a person across all questions on each of the scales (*i.e.*, behavior or knowledge). Technically, the logit scores are the result of modeling the data (*i.e.*, individuals' answers) according to a certain method, which, in our case, is based on the MLE modeling approach. The logit scores are the equivalent of sum scores used in classical test theory and can be used similarly in further analysis (*i.e.*, inferential statistics). Thus, larger logit values indicate that a person knows more about the environment (knowledge) or does more for the environment (behavior). Conversely, a smaller logit value indicates that one knows or does less. Individual scores, fit measures and the reliability of the two scales were calculated using Quest [37]. All reported reliabilities of this study are Item Response Theory-based person-reliabilities [36,37].

For several individuals from the main sample some variables could not be calculated, thus, the numbers for most analyses are slightly lower than 950, the total number of participants. For the scale of action knowledge, the scores of six participants could not be calculated because two had all wrong answers, and four had all correct answers. For the scale of human-environment system knowledge, the scores of three participants could not be calculated because they had only wrong answers. Nevertheless, these participants' zero or perfect scores were still used to calculate the Rasch-models. Furthermore, for one participant, all answers on the GEB were missing.

To validate the scale, simple regressions were performed between environmental knowledge and (1) age; (2) educational level; (3) income; and (4) pro-environmental behavior.

4. Results and Discussion

4.1. Scale Reliability

In the pilot questionnaire, effectiveness knowledge showed low reliability (0.45, Table 4) in comparison to the sub-scales for human-environment system knowledge (reliability of 0.72) and environmental action knowledge (reliability of 0.74). However, this low reliability is similar to that found by Frick *et al.* [16] (Table 4).

One of the reasons for this low reliability is the high degree of difficulty of these questions, as reflected by the low percentage of correct answers (26%). This percentage of correct answers is particularly surprising, when taking into account that 60% of the participants were either currently university students or had university degrees. The lack of effectiveness knowledge among individuals may be due to a lack of teaching in this area or because several of these items had numerical answers, making reflection more difficult. Therefore, for the final questionnaire, it was decided to exclude effectiveness knowledge and to focus on the human-environment system knowledge and environmental action knowledge sub-scales, which have proven reliability.

The overall environmental knowledge scale and the sub-scales of human-environment system knowledge and environmental action knowledge showed a reliability of 0.83, 0.70, and 0.72, respectively (n = 950 for all three scales), which is better than that reported in the studies by Frick *et al.* [16] and Geiger *et al.* [23] (Table 4). All overall environmental knowledge, human-environment system knowledge and environmental action knowledge items fit well (MS $\leq$ 1.24, MS $\leq$ 1.28, and MS $\leq$ 1.19, respectively).

For the pilot study we used the full pro-environmental behavior scale of Kaiser and Wilson [33] with 50 items. For the main study we decided to reduce the number of items to reduce the inconveniently long time (approximately 60 min) needed to complete the whole questionnaire. As expected due to this reduction of items (*i.e.*, only 35 as compared to 50 items), the reliability of the pro-environmental behavior scale (0.65; Table 4) was somewhat lower in comparison to previous studies (e.g., [16,23]) and our pilot study. All the items of pro-environmental behavior fit well (MS ≤ 1.16).

4.2. Scale Validity

We validated our scale by correlations between environmental knowledge and (1) educational level; (2) income; and (3) pro-environmental behavior.

(1) It is logical to assume that more educated people possess more environmental knowledge. Thus, we validated our scales by demonstrating a positive correlation between overall environmental knowledge and educational level ($r = 0.46$; $p \leq 0.001$; $n = 949$), in line with the results of many researchers [4,38–40].

(2) A positive correlation has been found between income (*i.e.*, socio-economic status) and educational level [41]. It is logical to assume a positive correlation between income and environmental knowledge because, in our study, income was strongly correlated with educational level ($r = 0.62$; $R^2 = 0.39$; $p \leq 0.001$; $n = 949$).

Thus, we validated our scales by demonstrating a positive correlation between overall environmental knowledge and income ($r = 0.46$; $p \leq 0.001$; $n = 949$), which agrees with the results of multiple studies [4,38,42].

(3) Finally, we validated our scales by demonstrating a positive correlation between environmental knowledge and pro-environmental behavior ($r = 0.27$; $R^2 = 0.07$; $p \leq 0.001$; $n = 949$). The current data are in line with the corroborated finding that the amount of behavioral variance that can be explained by environmental knowledge varies between 6% [16] and 18% [17]. As expected, environmental action knowledge and human-environment system knowledge were correlated to each other ($r = 0.62$; $p \leq 0.001$; $n = 941$), which is similar to the correlation between these two types of knowledge ($r = 0.54$; $p \leq 0.001$) reported by Frick *et al.* [16].

4.3. Effects of Different Knowledge Types on Pro-Environmental Behavior

Similar to the findings of Frick *et al.* [16], the effect of environmental action knowledge on pro-environmental behavior was significant ($r = 0.22$; $p \leq 0.001$; $n = 943$; Table 5). In addition, our new human-environment system knowledge scale was directly related to pro-environmental behavior ($r = 0.25$; $p \leq 0.001$; $n = 946$; Table 5).

While Frick *et al.* [16] found no direct effect of system knowledge on pro-environmental behavior, with our focus on human-environment system knowledge, we were able to find a correlation to pro-environmental behavior. These findings do not contradict each other, as the system knowledge of Frick *et al.* [16] consisted of a large share of behavioral-distant items, in the form of geography-environment items, whereas our human-environment system knowledge items related much more closely to pro-environmental behavior.

Table 5. The effect of environmental knowledge on pro-environmental behavior. Pearson correlation coefficients are shown ($p \leq 0.001$).

	Frick *et al.*, [16]	Our Study	Our Study, Controlled for Income [1]
Overall knowledge [2]	0.24	0.27	0.34
Geography-environment system knowledge	n.s.		
Human-environment system knowledge		0.25	0.30
Environmental action knowledge	0.12	0.22	0.27
Environmental effectiveness knowledge	0.18		

n.s. = not significant; [1] A correlation between two variables describes their covariation. However, this covariation or parts of it can be due to a third variable that is related to both of them. By using a regression model we can control the influence of this third variable. Thus, controlling for income means to uncover the relation between the two other variables above and beyond their correlation with income; [2] Overall knowledge includes geography-environment system knowledge, environmental action and environmental effectiveness knowledge (in the studies of Frick *et al.* [16] and Geiger *et al.* [23]) and human-environment system knowledge and environmental action knowledge (in this study).

The findings confirm our hypothesis that a greater awareness and a better understanding of global environmental problems have a positive effect on pro-environmental behavior. It is likely that human-environment system knowledge induces the feeling of guilt for the environment, and thereby improves pro-environmental behavior. Indeed, Kaiser and Shimoda [20] reported that feeling guilt determines about 44% of a person’s morality-related feelings of responsibility, which, in turn, predict 45% of self-ascribed moral responsibility for the environment. This responsibility judgment then predicts 55% of a person’s pro-environmental behavior.

The findings of this study can be also explained in terms of the concept of locus of control. The situation in which an individual feels that his own actions bring about an outcome is defined as an internal locus of control, while a sense of powerlessness and lack of control over an outcome is defined as an external locus of control [43]. It is likely that greater human-environment system knowledge induces an internal locus of control in relation to the environment, and thereby improves pro-environmental behavior. Indeed, Smith-Sebasto and Fortner [21] reported that the Environmental Action Internal Control Index—a measure of environmentally specific locus of control—can accurately predict environmentally responsible behavior. Likewise, Fielding and Head [19] demonstrated that individuals with higher environmentally specific internal locus of control exhibited stronger pro-environmental behavior, and less environmentally harmful behavior.

In future research, we plan on including in the survey some items on environmentally specific locus of control and guilt for the environment. This set up will allow determining the effects of these variables on pro-environmental behavior in the Chilean adult population.

4.4. Effect of Income on the Relationship between Environmental Knowledge and Pro-Environmental Behavior

Based on single-item measures, Otto *et al.* [26] found that environmental knowledge is significantly related to pro-environmental behavior. When controlled for income, this relation became insignificant. It was found that income accounts for the relation between environmental knowledge and pro-environmental behavior. While income determines general education, which includes objective environmental knowledge, income also directly influences the availability of more or less environmentally friendly behavioral options. However, Otto *et al.* [26] focused on two specific behavior-knowledge pairs, showing that income can provide a powerful explanation for specific knowledge and behavior relations. In the present study, we used broad index measures of environmental knowledge and behavior.

When we controlled the relations between environmental knowledge and pro-environmental behavior for income, we found that the relations were still considerable and significant (Table 5). Therefore, the scale developed in this study shows high utility, as the relation between pro-environmental behavior and environmental knowledge is only partially confounded by income.

5. Practical Implications of the Present Study

The scales have been designed with items of a wide difficulty range for possible application with graduates, students and the general public as an environmental knowledge evaluation tool. Thus, they can be used in the creation of plans, programs and campaigns to promote the environmental knowledge necessary to achieve pro-environmental behavior. Likewise, to promote pro-environmental behavior, we suggest teaching more human-environment system knowledge and environmental action knowledge because we found these two forms of environmental knowledge to be related to pro-environmental behavior (Table 5).

This study demonstrated a remarkable deficit in environmental effectiveness knowledge in a Chilean sample. A similar deficit in environmental effectiveness knowledge was reported by Frick *et al.* [16] for Swiss samples. Environmental effectiveness knowledge helps a person to effectively choose from different behavioral alternatives, and thus might improve the outcome of pro-environmental behavior [44]. To this end, to promote pro-environmental behavior, we also suggest teaching more environmental effectiveness knowledge, taking into account the detected ignorance of this type of knowledge.

6. Conclusions

This paper presents a scale of human-environment system knowledge (*i.e.*, system knowledge related to environmental problems caused by humans) and a scale for environmental action knowledge (*i.e.*, knowledge of possible courses of action to reduce human impact on the environment). The scales were developed based on scales of Frick *et al.* [16] and our previous studies [22–24]. We tested our scales on a Chilean sample. The scales of human-environment system knowledge and environmental action knowledge were successfully validated by demonstrating a correlation between environmental knowledge and (1) educational level; (2) income; and (3) pro-environmental behavior. Additional studies need to be undertaken to demonstrate the applicability of our scales in other samples.

Both human-environment system knowledge and environmental action knowledge were related to pro-environmental behavior ($r = 0.25$ and $r = 0.22$, respectively, $p < 0.001$, Table 5). This result seems to contradict previous studies that demonstrated that system knowledge is not significantly related to pro-environmental behavior. However, existing scales of environmental system knowledge are behavioral-distant due to an abundance of questions regarding general geography knowledge. In contrast, our environmental system knowledge scale focused more on understanding global environmental problems and, therefore, could be expected to relate more closely to pro-environmental behavior.

Good reliability was obtained for the overall environmental knowledge scale and the sub-scales of human-environment system knowledge and environmental action knowledge. However, the sub-scale of effectiveness knowledge exhibited poor reliability in a pilot study due to its high difficulty. Thus, further efforts should be made in creating a suitable sub-scale for effectiveness knowledge by further reducing the difficulty of the items of this scale. For instance, one could reduce the difficulty of the items by replacing those in search of specific numbers with items in search of easier comparisons, e.g., what type of transport produces more CO_2 per passenger per kilometer (plane, train, bus or car)?

Since an effective program of environmental education requires the identification of the knowledge that must be imparted [45] and that different forms of environmental knowledge must work together in a convergent manner in order to foster pro-environmental behavior [18], the present study represents an important contribution by showing that greater human-environment system knowledge is correlated with pro-environmental behavior (Table 5).

Finally, now that we have learned that a focus on human-environment system knowledge results in a significant correlation with pro-environmental behavior, it could be tested in a future study if a further increase in scale specificity would lead to an increase in the relation between the specific environmental knowledge (*i.e.*, on climate change, pollution and recourse availability) and the respective specific behavior.

Author Contributions

Pablo Díaz, Siegmar Otto and Alexander Neaman designed the research; Pablo Díaz performed the research; Siegmar Otto, Pablo Díaz-Siefer, Juan L. Celis-Diez, Eduardo Salgado and Alexander Neaman analyzed the data; Pablo Díaz, Siegmar Otto and Alexander Neaman wrote the paper. Siegmar Otto is the senior author of the paper. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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