Learning about Sustainability—What Influences Students' Self-Perceived Sustainability Actions after Undergraduate Education?

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Abstract: Changing societies' minds about sustainability requires knowledge about the situation, awareness of what needs to be done and actions to change today's unsustainable behaviors. Universities are challenged to develop students' ability to appreciate the complexities of sustainability and translate sustainability knowledge of education into systemic, anticipatory and critical thinking and actions. To meet this challenge, universities provide specific study programs and courses and integrate sustainability in education and activities. There is limited research on the results of such efforts from a student perspective. The study focused on an identical cohort of 108 undergraduate students who answered a survey about their self-perceived knowledge, awareness and actions before and after their studies in a Swedish university. All 108 students had sustainability integrated into their study programs; forty-eight also attended specific sustainability courses. The test model explains variations in students' self-perceived sustainability actions at the end of their studies. There were differences already in students' initial self-perceived knowledge between the groups. The students' female gender, self-perceived initial actions, studying sustainability courses as well as the increase in self-perceived sustainability knowledge contribute significantly to the later sustainability actions. The results show student development, which can encourage those working with education for sustainable development in universities.

Keywords: awareness; ESD; gender; higher education; integration; longitudinal study; knowledge

1. Introduction

Companies are increasingly integrating sustainability into their business agendas so they need professionals who have been educated in the topic [1]. This requires that university students have the opportunity during their education to develop the ability to understand the need for sustainability and act on it by integrating social, environmental and economic considerations in their decision making [2,3]. Universities are being challenged to provide students opportunities to develop an understanding of the complexities of sustainable development (SD) [4] and to translate the knowledge from education for sustainable development (ESD) into systemic and anticipatory critical thinking and actions [5].

To address this challenge, universities provide courses focusing on sustainability on educational programs and integrate sustainability issues into regular disciplinary course content [6–8] to support the need for sustainability competences [9]. This requires that faculty and staff have relevant competences to integrate sustainability in the disciplinary curriculum and operations for the benefit of the students [2,10].

Students' learning can in a simplified way be described as following a linear path, so that the knowledge of facts that a person gains through studies or experience [11] develops into a deeper understanding and ability to act based on what has previously been learned [12]. When sustainability is integrated in education, students gain basic cognitive knowledge. By developing an affective deeper understanding [11] or awareness of the need for sustainability, their ability to take conative action increases based on previous learning [13]. Hicks [14] indicated that learning about global issues such as sustainability and acting upon it can never be solely a cognitive matter, but must also involve an affective understanding. Nonetheless, increasing knowledge may not automatically result in changes in awareness and actions [15], so educational institutions aim at development of deeper circular learning patterns, where the knowledge is reflected upon and questioned in learning loops before application [12,16–18]

Several studies have focused on students' perceptions of sustainability [19–21], the impact of the amount and type of coursework on students' conceptualizations of sustainability [22], and the relationships of demographic factors on students' environmental awareness, knowledge and behavior [23,24]. However, limited studies exist on the results of sustainability implementation in education, as was highlighted by Tilbury [25], and on students' learning progress about sustainability during their university studies, according to McKeown [26]. To our knowledge, no empirical longitudinal study analyzing the changes in students' sustainability knowledge, awareness and actions has yet been carried out. This paper presents a longitudinal case study that contributes by exploring the students' self-perceived sustainability progress via the development and testing of a knowledge-awareness-action model (Figure 1) covering their learning from the beginning to the end of a three-year undergraduate university education. Research attention is especially paid to the factors that influence the development of students' self-perceived actions by the end of their studies.
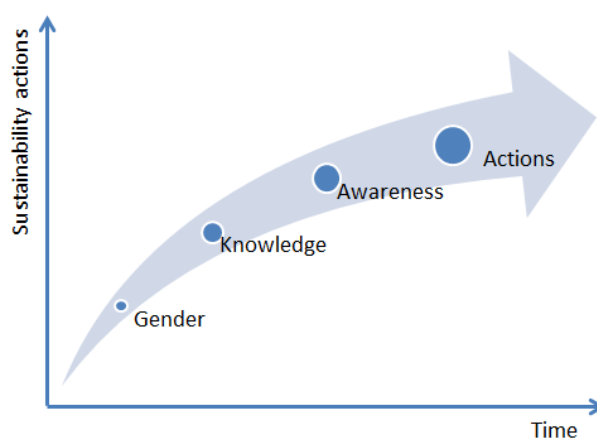

Figure 1. A conceptual model of the research.

The paper is structured as follows: Section 2 discusses previous research regarding students' sustainability knowledge, awareness and actions; Section 3 presents the method used in this study; Section 4 presents the results, which are discussed in Section 5; and Section 6 presents the research conclusions.

2. Students' Sustainability Knowledge, Awareness and Actions

The sustainability concept has been widely discussed, revealing disagreements among scholars and practitioners in how to define it [27]. However, the most common definition chosen for this paper, is largely based on the WCED's [28] document Our Common Future. The knowledge needed for sustainable development is "At a minimum . . . to not endanger the natural systems that support life on Earth: the atmosphere, the waters, the soils, and the living beings" [28] (§2.I.9). This definition is based on ethical understanding that sustainability is founded on "moral obligation to other living

beings and future generations" [28] (§2.5.55). Consequently, sustainability knowledge can be defined as knowledge required for understanding and becoming aware of the need for sustainability as a basis for actions for it.

2.1. Student Learning and Knowledge of Sustainability

As Posch and Steiner [12] claimed, students' learning follows a linear path, where cognitive sustainability knowledge based on education and experience goes through a process to develop affective awareness, which results in conative actions based on previous learning. Luthans proposed the term attitude as something that "is used in describing people and explaining their behavior" [29] (p. 224) and divides learning into three types of individual attitudes. Lozano further delineates the informational attitudes as the individual's beliefs and information about sustainability, the emotional attitudes as feelings and affects (positive, neutral and negative) about sustainability, and the behavioral attitudes as the actions taken for sustainability [30]. These attitudes are mutually dependent and correspond to what in this study is called "knowledge, awareness and actions", and follow a three-part sequence:

(1) the process from change in information through learning *i.e.*, increase in knowledge;
(2) changes in emotional attitudes *i.e.*, awareness of what sustainability is and the need for it; and
(3) changes in behavioral attitudes, *i.e.*, actions for sustainability [30].

In order for an individual to change, there needs to be congruence between the informational, the emotional and behavioral attitudes so that what is learned, what is thought and what is done agree [30].

Research shows that students are interested in learning about sustainability [20,31]. Even those lacking necessary knowledge are positive and willing to learn more [19]. Students particularly emphasize the need for radical change in the society for sustainability, although it affects their lifestyles as consumers [15,19,32]. Emanuel and Adams [33] found that the "knowledge-gap" (whether a person knows what she is expected to know, such as that paper should be sorted in bins for recycling) seems to be little or non-existent in relation to the "commitment-gap" (the discrepancy between what a person does and what the person knows should be done, for example throwing paper into a waste bin for incineration rather than a recycling bin), which implies that the knowledge of such concepts as recycling does not result in personal actions.

Awareness requires, in addition to knowledge, the facts gained through studies or experience [11] and a deeper understanding [11] of the need for sustainability.

In spite of having sustainability knowledge and even awareness, students do not necessarily act in agreement with those [34], since they think that their daily activities on campus do not affect the environment in any way [20]. Zsóka *et al.* [32], who studied the influence of environmental education, conclude that although students' attitudes are not fully reflected in actions, conscious actions correspond to the intensity of environmental education.

2.2. Student Learning of Sustainability in Education

Based on the results of student learning about environmental sustainability, it is apparent that the wider concept of sustainability in discipline-specific courses is preferable to generic "awareness" courses, since the former not only make a difference in attitudes but also actions [35]. This is in line with Fisher and McAdams's conclusions that the number of sustainability courses in study programs has less impact on students' perceptions of sustainability than integrating sustainability themes in disciplinary classes [22]. However, Warburton highlighted that the interconnectedness of environmental, social, and economic issues in sustainability and deep learning (finding the underlying meaning to form a coherent whole of information) can be lost if the students have a strong disciplinary background and focus in their studies [36]. This can limit the development of understanding the

complexities of sustainability and converting the knowledge of ESD into systemic and anticipatory critical thinking and actions [5].

Previous studies on demographic factors' influence on environmental knowledge, awareness and behavior conclude that females have stronger environmental attitudes and behavior than males [23,24], for example based on their stronger domestic social engagement [23]. This is contradicted by Shields and Zeng in their studies in China, where the males show a stronger environmental concern than females based on different educational and economic conditions for the genders [37].

This study uses a simplified linear model of learning; knowledge—awareness—actions [12] (Figure 1) to analyze the results, although it cannot be excluded that the students also are involved at least in single-loop learning. Students entering university have experienced limited influence from university education during their first months of study but have some varying knowledge, awareness and understanding of sustainability based on media and previous studies in secondary education. At the case university, students are in an environment where sustainability is integrated in study programs, research and campus activities such as recycling waste and participating in sustainability-related activities. The degree of integration in programs varies; some programs provide additional special sustainability courses as part of the curriculum. The students' sustainability knowledge and awareness could, therefore, be expected to increase partly due to general sustainability integration at the university, and partly due to specific sustainability courses that result in actions.

The study explores two groups of students with sustainability integrated into their study programs—those without specific sustainability courses in their curricula and those with specific sustainability courses in their curricula with the following research questions:

(1) How do the students' self-perceived sustainability knowledge, awareness and actions in the beginning and at the end of their studies differ?
(2) How do students' gender, having sustainability integrated in their studies and having compulsory sustainability courses in study programs affect students' self-perceived actions at the end of their studies?

3. Methods

The study uses *a priori* and *a posteriori* designs with two cross-sectional survey studies, where the study variables, students' self-perceived knowledge, awareness of and actions for sustainability were assessed at two points in time (2010 and 2013). The University of Gävle, with 55 educational programs, and Novia University of applied sciences in Finland with 34 educational programs, were chosen as cases in a comparative analysis that provided continuous access to students. Fourteen equivalent programs were included at both universities, which were at the time certified according to ISO 14001. It was, however, not possible to carry out the comparative follow-up research because Novia closed down their work for sustainable development. The fourteen undergraduate study programs included nursing, social work, economics and ten programs in technology, which are here called engineering programs although some of them provide Bachelor of Science degrees. The lack of replies from the third-year social work and economics students due to delivery problems excluded these program students from the study in 2013. Table 1 in Section 4 below shows the number of registered students in the ten programs included in the study, the number and percentage of students who replied in 2010 and 2013, respectively, based on the number of registered students in 2010, and replies 2010, and the gender.

An identical undergraduate student cohort answered the same survey during the first and third year of their studies at the university. In the ISO 14001-certified environmental management system, education and research are the main sustainability aspects of the efforts to integrate sustainability in relevant courses and research based on the University Policy for Sustainable Development initiated by the University Board in 2002. All programs are therefore assumed to include sustainability integration to some degree; in addition, some programs provide regular courses with a specific sustainability focus.

Table 1. The reply rates in the study in 2010 and 2013, European Credit Transfer and Accumulation System (ETCS) credits of sustainability (SD) in the study program plans with Swedish (Sw) and international (Intl) students in 2010, number of student with and without SD courses as well as gender of students.

Program	2010			2013					ECTS Credits SD in Program	Female	Male
	Registered	Replies	% of reg.	Replies	% of Replies 2010	% of reg. 2010	Same Students as in 2010	Complete Replies			
Computer eng. (Sw)	12	12	100	7	58	58	2	2	4	0	2
Computer eng.(Intl)	22	15	68	17	113	77	7	4	2	3	1
Electronics eng. (Sw)	9	9	100	7	78	78	4	4	4	0	4
Ind.eng and mgm. (Sw)	14	13	93	12	92	86	9	7	4	5	2
Mechanical eng. (Sw)	13	11	85	9	82	69	6	6	4	1	5
Nursing (Sw)	81	62	77	70	113	86	39	38	4	31	7
Ind. Mgm. and logistics (Sw sd)	24	22	92	12	55	50	12	10	22.5	3	7
Ind. Mgm. and logistics (Intl sd)	35	30	86	19	63	54	16	15	22.5	13	2
Building eng. (Sw sd)	35	27	77	19	70	54	14	14	19	5	9
Energy syst. eng. (Intl sd)	28	15	54	16	107	57	10	8	11	6	2
Tot	273	216	79	188	87	69	119	108		67	41
With sustainability courses								47		27	20
Without sustainability courses								61		40	21
With sustainability courses (%)								47		57	43
Without sustainability courses (%)								61		66	34

The questionnaire was initially prepared by two students as part of their Master's of Science thesis [38]. The background questions addressed the study program and asked for the gender, the name, and e-mail address of the respondents for delivery of movie tickets that were raffled among those who replied. The students were informed that, by answering the survey, they were included in a research study. The first sections of the questionnaire included statements for the students to report their self-perceived general knowledge about sustainability and knowledge of the three sustainability dimensions (environmental, social and economic) [39], stating the degree of agreement with statements on a 5-point Likert-type scale (1. Strongly disagree, 2. Disagree, 3. Undecided, 4. Agree, 5. Strongly agree).

The next questions were designed to explore students' self-perceived awareness by asking them how they agreed with five statements about current sustainability issues discussed in the media. The statements were about pressure from population growth [40], protection of fresh water resources [40], choice of personal life-style in promoting SD [3], the reliability of reports on damaging the ecosystem [40] and studying about SD [32]. The scale was the same as in question one.

The final eight questions used on a practical construct focused on the self-perceived actions with examples from students' daily life (waste sorting, buying second-hand items, discussing sustainability issues with family and friends, saving water in showering, attending activities dealing with SD, print-outs from computers and using public transportation. They were graded from 1 to 5 based on the "How often do you do the following to contribute to sustainable development?" (1. Never, 2. Seldom, 3. Sometimes, 4. Often, 5. Always).

3.1. Data Collection

A priori and *a posteriori* design with two cross-sectional observations was used for the study variables by asking the students to answer the same questionnaire in the beginning and at the end of their studies. To assure the highest possible response, lecturers were contacted to deliver the survey, which required 5–10 min to complete, to students, who were allowed to answer during class time. The same lecturers also collected the answers. The students represent Swedish and mainly Chinese international students.

3.2. Data Analysis

The quantitative results were compiled in Microsoft Excel and the data was analyzed using IBM SPSS Statistics 22 software (IBM, Armonk, NY, USA) [41]. Exploratory factor analysis (principal component) was used to assess the validity of the three constructs (knowledge, awareness and actions) and factor loadings, total variance and Cronbach's alpha were calculated [42]. For further analysis, an index, indicating the mean value of the knowledge, awareness and actions questions, was used to represent the three dimensions. The index was then tested for normality [42]; the result was affirmative. Finally, multiple regression analysis in three steps was used to test if university education has had an effect on sustainability actions [42]. A paired-samples *t*-test was used to compare differences between the results of the two years [42].

The total response rate in 2010 was 79%; in 2013, 69%. The response rates ranged from 54% to 100% (2010) and from 50% to 86% (2013) among the initial registered students in the different programs, which can be assumed to increase the reliability of the study.

The generalizability of the findings to test the model knowledge—awareness—actions and possible changes is limited by the fact that the study was based on specific groups of students in one university. This could be improved in further research by choosing a totally random population of students in a whole university or several universities.

The questionnaire was pretested in a different group of students to increase the validity of the study [38]. Different data sources and methods were used by studying program plans and courses, and replies in the two surveys from students in the different study programs at two occasions were sampled to increase the validity of the study. The study plans that were used in 2010 were checked for

sustainability content in the program descriptions, aims and specific courses and marked as SD content in the program. The validity could be limited by the fact that the study focused on a small group of students out of a whole university student population. The reliability of the study was strengthened by the fact that it was an identical cohort of students who answered the same survey both years.

To reduce bias and to test the content and validity, the questionnaire was discussed and modified in the University Council for Sustainable Development with representatives of all the faculties and students.

3.3. Limitations of the Method

Since a majority of the students had given their names in the survey; identical students could be recognized for the analysis. The response rate was, however, reduced by the fact that the students answering the survey were not identical in 2010 and 2013. A reason for this potential non-response bias could be that some students were dropping out or falling behind in their studies. This explains the response rates over 100% in 2013 in Table 1, since some students who had failed to complete their studies in time were now attending the classes together with students who started in 2010.

The survey provides data intended to gain an overall picture of the changes in students' self-perceived knowledge, awareness and actions regarding SD. In hindsight, some questions can be seen as ambiguous and inappropriate or in the wrong question group. The original Swedish questionnaires were translated into Chinese by a Chinese native to reduce misunderstandings due to the language.

Another limitation is that the questions in the study were mainly focused on environmental sustainability, especially regarding actions and not the wider sustainability content.

A study in one university cannot be generalized, and it is difficult to measure how much of the change from 2010 to 2013 is due to university education and how much is due to other influences, but the study gives an indication of changes during studies and tests a method to do a follow-up of a specific cohort of students. Another limitation to generalizability is that the sample was not random representing all students and all programs at the university.

4. Results

In 2010, there were a total of 273 registered students in the study programs and 216 (79%) of them returned the questionnaire. In 2013, 188 students returned the survey corresponding to 69% of the registered students in 2010 and 87% of the 2010 replies. In the study, 119 of these were recognized as identical students replying both in 2010 and 2013. Out of these, 11 students had not answered all questions, leaving 108 to be included in the final analysis (Table 1).

Sustainability was included in the ten study program plans; four of them also contained specific courses focusing on sustainability. Seven and one-half European Credit Transfer and Accumulation System (ETCS) credits in SD courses correspond to five weeks of full-time study, less than 7.5 ECTS (four or two ETCS credits) indicates that sustainability is integrated as part of a course.

The university course database system, as a continuous effort, requires the lecturer who is responsible for the course plan to classify the sustainability content of the course when registering it in the database. Courses are classified according to whether the majority of the course content deals with sustainability, the course has sustainability integrated in it, the course has potential for sustainability integration in the future, or sustainability is irrelevant for the course. The aim of this classification is to give the lecturer an opportunity to reflect on the sustainability connection of the course [43]. The results for 1047 courses in 2010 show that 12% of the courses focused on sustainable development, and 57% had integrated sustainability, 8% had potential to do it in the future, and in 22%, sustainability was irrelevant based on the lecturer's judgement.

The descriptive statistics of the variables, sustainability knowledge, awareness and actions for 2010 and 2013 respectively, as well as changes in them, are presented in Table 2.

Table 2. The descriptive statistics of the variables, sustainability knowledge, awareness and actions for 2010 and 2013, along with changes in them.

	N	Min	Max	Mean	Std. Deviation
SD Knowledge 2010 index	108	1.00	4.33	2.9568	0.71346
SD Awareness 2010 index	108	3.25	5.00	4.5556	0.42461
SD Actions 2010 index	108	1.50	4.50	2.8302	0.66899
SD Knowledge 2013 index	108	1.00	5.00	3.3919	0.76370
SD Awareness 2013 index	108	3.75	5.00	4.6910	0.36029
SD Actions 2013 index	108	1.17	4.50	2.8611	0.69991
SD Knowledge change index	108	−2.67	3.33	0.4198	0.91641
SD Awareness change index	108	−1.25	1.00	0.1354	0.44667
SD Actions change index	108	−3.59	3.31	0.0000	1.08158
Valid N (listwise)	108				

SD—sustainable development; N—number in the sample; Min—minimum value; Max—maximum value; Std. Deviation—Standard Deviation.

4.1. Factor Analysis

The factor analysis was, used in order to test construct validity. Knowledge was measured using three items, awareness using five items, and actions using eight items (Appendix).

All three knowledge items for 2013 loaded onto a single factor between 0.754 and 0.818. For the knowledge items for the year 2010, factor loadings were between 0.718 and 0.848, total variance explained was 63%, and Cronbach's alpha was 0.70.

All five awareness items did not load onto a single factor with eigenvalues above 1.0. After item number 4 (damage to ecosystems) was removed, the items loaded onto a single item with factor loading between 0.758 and 0.889, total variance explained was 65% and Cronbach's alpha was 0.812 for the year 2013. In subsequent analysis, items 1–3 and 5 will represent sustainability awareness. Corresponding numbers for 2010 were factor loadings between 0.53 and 0.79, total variance explained was 43 % and Cronbach's alpha was 0.51.

The factor analysis for the actions shows that all eight action items also failed to load onto one single item with the eigenvalue threshold being 1.0. After removing items 6 (print-outs from computers) and 7 (use of disposable items), the remaining six items did load onto a single factor with factor loadings between 0.491 and 0.799. Total variance explained was 43%, while Cronbach's alpha was 0.72 for the year 2013. The numbers for 2010 are factor loadings between 0.554 and 0.719, total variance explained was 40% and Cronbach's alpha was 0.70. Sustainability action will thus be measured using items 1–5 and 8 in subsequent analysis.

4.2. Normality Check

Sustainability knowledge and sustainability awareness were both normally distributed for 2010 and 2013, whereas sustainability awareness was skewed for both years. However, the change in sustainability awareness was normally distributed, after three outliers were removed. These three respondents had consistently marked an extremely low level of awareness in 2013 (mostly 1's on a scale from 1 to 5), yet they had answered in line with the mean values in 2010. Consequently, the value for awareness in 2010 was replaced with the mean value for the index variable for these three respondents. Correlations for the six variables, knowledge, awareness and actions in 2010 and 2013, are shown in Table 3.

The difference between those who had studied specific sustainability courses (Yes) and those who had not (No), and all students are presented in Tables 4–6.

Table 3. Correlations (Pearson) between the variables knowledge, awareness and actions in 2010 and 2013.

| | **2010** | | | **2013** | | |
	SD Knowledge	SD Awareness	SD Actions	SD Knowledge	SD Awareness	SD Actions
SD Knowledge 2010	1					
SD Awareness 2010	0.239 *	1				
SD Actions 2010	0.536 **	0.375 **	1			
SD Knowledge 2013	0.287 **	0.199 *	0.278 **	1		
SD Awareness 2013	0.244 *	0.361 **	0.170	0.301 **	1	
SD Actions 2013	0.339 **	0.115	0.438 **	0.541 **	0.208 *	1

$* \ p < 0.05$; $** \ p < 0.01$, $n = 108$.

Table 4. Differences in knowledge, awareness and actions between students without (No) and with (Yes) sustainability (SD) course and all students in 2010.

	SD Course	SD Knowledge in 2010 **	SD Awareness in 2010 *	SD Action in 2010 *
No	Mean	2.7869	4.4713	2.6995
	N	61	61	61
	Std. Deviation	0.66953	0.45894	0.51892
Yes	Mean	3.1773	4.6649	3.0000
	N	47	47	47
	Std. Deviation	0.71509	0.35076	0.79855
All	Mean	2.9568	4.5556	2.8302
	N	108	108	108
	Std. Deviation	0.71346	0.42461	0.66899

$* \ p < 0.05$; $** \ p < 0.01$.

Table 5. Differences in knowledge, awareness and actions between students without (No) and with (Yes) sustainability (SD) courses and all students in 2013.

	SD Course	SD Knowledge in 2013 **	SD Awareness in 2013	SD Action in 2013 **
No	Mean	3.0655	4.6537	2.6448
	N	61	61	61
	Std. Deviation	0.67990	0.38890	0.57931
Yes	Mean	3.8156	4.7394	3.1418
	N	47	47	47
	Std. Deviation	0.65500	0.31690	0.74777
All	Mean	3.3919	4.6910	2.8611
	N	108	108	108
	Std. Deviation	0.76370	0.36029	0.69991

$** \ p < 0.01$.

There is a significant difference between students who have taken sustainability courses and those who have not. This showed already at the beginning of their studies in 2010 (Tables 4 and 5), and the change in knowledge is significantly higher for those that have taken SD courses. However, there is no corresponding change in awareness and actions.

Table 6. Differences in change in knowledge, awareness and actions between students without (No) and with sustainability (SD) courses (Yes) and all students in 2010 and 2013.

	SD Course	SD Knowledge in 2013 *	SD Awareness in 2013	SD Action in 2013
	Mean	0.2514	0.1824	−0.0547
No	N	61	61	61
	Std. Deviation	0.86422	0.41179	0.64817
	Mean	0.6383	0.0745	0.1418
Yes	N	47	47	47
	Std. Deviation	0.94493	0.48599	0.81054
	Mean	0.4198	0.1354	0.0308
All	N	108	108	108
	Std. Deviation	0.91641	0.44667	0.72637

Independent samples *t*-test * $p < 0.05$, ** $p < 0.01$.

4.3. Regression Analysis

In order to test whether the university education has had an effect on sustainability actions, a regression analysis in three steps was conducted (Table 6); the first with only the control variables, the second step with the impact of the sustainability course and the third step with the effect of the increase in sustainability knowledge. The method allows dissemination of both the effect of each variable and the additional impact of each added variable on the explanatory power of the model.

The largest predictor of the behavior of a student in 2013 is likely to be the previous (2010) behavior of the same student. Sustainability actions in 2010 were, therefore, included as the first control variable. The second control variable was the gender of the student (a dummy variable), where 0 represents male and 1 represents female, as we would expect females to have higher levels of sustainability actions based on previous research [23,24]. The results show that, as predicted, both the gender and previous sustainability of actions are strongly associated with sustainability actions in 2013.

After this, a test was performed to explore whether participating in the sustainability courses had an impact on sustainability actions, in addition to the actions taken previously by the same student in 2010. This variable is also a dummy variable, with 1 representing taking the course and 0 not taking it. Finally, a test was done to find out whether the increased sustainability knowledge the student obtained over the three years of studies would have an additional impact on sustainability actions. The results in Table 7 show that the fact that the students had taken the sustainability course is strongly associated with sustainability actions in 2013. Moreover, the increase in sustainability knowledge the students had acquired over the course of three years, whether due to the sustainability course or not, is also strongly associated with sustainability actions in 2013. This effect is in addition to the direct effects of taking the sustainability course.

In summary, the regression analysis shows that all four independent variable actions in 2010—gender, sustainability courses and change in knowledge—contribute significantly to sustainability actions, with significance levels consistently below 0.01 and standardized beta coefficients ranging from 0.217 to 0.362.

The model shows high explanatory power, with adjusted R square ranging from 0.27 when only the control variables were included, to 0.39 when all variables were included. Moreover, each added variable increases the explanatory power of the model to a significant extent. The F value is also at a satisfactory level. The residuals were checked and were behaving normally, and the collinearity was not a problem since the VIF (variance inflation factor) statistics were consistently low, at between 1.03 and 1.18. In all, the previously mentioned statistics shows that the four variables explain the variation in sustainability actions to a high degree and that the data fits the model well.

Table 7. Test of how independent variables gender and SD actions in 2010 (Step 1), taken sustainability course (Step 2) and change in knowledge (Step 3) contribute to sustainability actions at the end of studies in 2013.

	Step 1		Step 2		Step 3	
Variables	**Std. Beta**	**Sig.**	**Std. Beta**	**Sig.**	**Std. Beta**	**Sig.**
(Constant)		0.000		0.000		0.000
Control: Gender (dummy)	0.301	0.001	0.341	0.000	0.336	0.000
Control: SD Action in 2010	0.389	0.000	0.307	0.000	0.362	0.000
Have taken SD course (dummy)			0.307	0.000	0.248	0.003
Change in SD Knowledge					0.217	0.008
Model statistics						
F-value	28.672		20.344		18.048	
R2	0.283		0.370		0.412	
Adjusted R2	0.269		0.352		0.389	
Significance change	0.000		0.000		0.008	

5. Discussion

Students need to develop the ability to translate the knowledge of ESD into systemic and anticipatory critical thinking and actions (as highlighted by Rieckmann [5]). This study aimed at exploring the results of sustainability education, the impact of sustainability integration and the effect of sustainability courses in educational programs at the undergraduate level. With the help of students' gender and changes in their self-perceived sustainability knowledge, awareness and actions at the beginning and end of their studies, we wanted to find out which factors correlate with students' actions at the end of their studies.

There was a significant difference in students' self-perceived knowledge already in the beginning of the studies in 2010, *i.e.*, before they had had any sustainability courses. This could be based on different entrance requirements into the different engineering and nursing programs. To enter engineering, education students are required to have four mathematics courses and nursing students should take two mathematics courses. Nurses' natural science courses have more focus on environmental and sustainability issues than the pure physics and chemistry courses required of engineers according to the secondary education plans (see [44]) in addition to chemistry and physics. The different entrance requirements cannot, therefore, explain the differences in initial sustainability knowledge.

The results contradict previous research [23] claiming that females have stronger environmental awareness and knowledge. In this study, the students in programs with sustainability courses and higher initial self-perceived sustainability knowledge (2010) had fewer females (57%) compared to the programs without sustainability courses (66%).

An explanation might be that the students choose study programs that contribute to their sphere of interest, which shows in the initial knowledge.

There were also differences in knowledge at the end of the studies between the cohorts, and the differences grew. This implies that the knowledge gap for the students with sustainability courses was lower than for those who did not have sustainability courses. This shows, however, only moderately in actions in our study, possibly due to the short time span (see [33,45]). The small changes in action in spite of having knowledge agree with Hiller Connell and Kozar [34], since the students think that their daily activities on campus do not affect the environment in any way (see [20]).

The sustainability courses in the study programs are discipline-specific, which would explain the difference in their actions [35]. Sustainability integration can explain the increase in knowledge (see [36]), but the changes in the wider sustainability concept were not covered by this study. The changes in awareness are not significant, so we cannot conclude that they correspond to specific sustainability courses in the program as suggested by Zsóka [32].

The self-perceived actions of a student in 2013 conform to the actions of the same student in 2010 (probably based on habits), as was confirmed by the study. In spite of students acknowledging the need for radical change in the society for sustainability, such as the urgent need to protect fresh water resources, this awareness does not have significant effect on their actions, which shows in the small changes in actions between the years in the study, agreeing with other studies [15,19,46]. Although students' attitudes are not fully reflected in their actions, environmentally conscious actions correspond to the intensity of sustainability education in specific sustainability courses as claimed by Zsóka *et al.* [32]

Another observation was that the constant factor, being female, means more for sustainability activity than being a male. This agrees with previous studies [23,24], but cannot, in the Swedish context, be explained by a much stronger involvement in domestic activities, since the differences between the genders in this regard are quite small [45].

The test of the model by regression analysis shows that all four independent variable actions in 2010—gender, sustainability courses and change in knowledge—contribute significantly to sustainability actions (Figure 2). Therefore, based on the statistics, the model explains the variation in sustainability actions to a high degree and fits the data well.
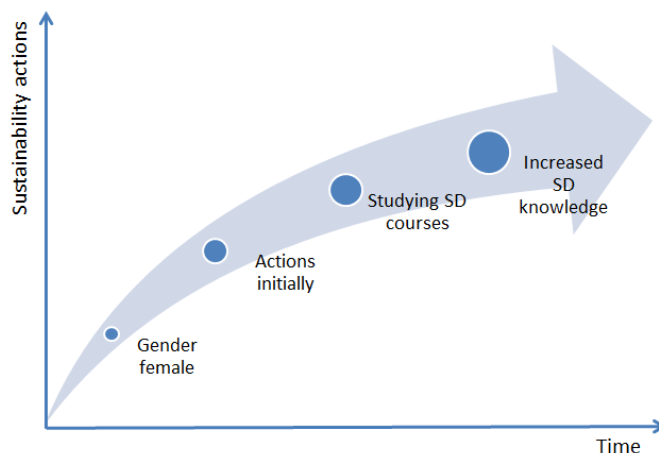

Figure 2. Influence of university studies in sustainability actions of students at the end of their studies.

The students in sustainability integrated programs and those whose programs in addition to integration would include specific sustainability courses showed differences in knowledge already in the beginning of their studies in 2010. The results do not support the expectation that knowledge would automatically result in increased awareness and actions, since the change is bound to take more time than the three years of undergraduate education allows, especially since the main focus of the studies is on education in a specific discipline. It may also be that there is a lack of coherence in the development of informational, emotional and behavioral sustainability attitudes [30].

This study shows that sustainability integration results in a significant increase in self-perceived knowledge. It is noteworthy that although each of the factors (students' self-perceived initial actions, gender, sustainability courses and change (increase) in self-perceived knowledge) makes a significant contribution to sustainability actions at the end of studies, the change in actions in total is not significant. This can be a result of students' more realistic perceptions of their actions at the end of three years of study, or the fact that since the mean values of actions in both years are about the same (Table 2), some students have lower self-perceived values at the end than in the beginning of their studies.

It is difficult to study the development of students´ self-perceived sustainability knowledge, awareness and actions based on education, because this development cannot be isolated from the society providing sustainability information via different channels. Another difficulty is exploring how the results of students studying specific sustainability courses or integrated sustainability in

their regular disciplinary courses differ from the results of students not exposed to "educational sustainability" during their studies. In this study, we have made an attempt to contribute to finding ways of isolating SD education from overall information received. Thus, there is a need to further develop methods to evaluate the results of education regarding sustainability.

6. Conclusions

This study aimed at exploring the results of education and the impact of sustainability integration and courses in educational programs at the undergraduate level. Given students' gender and changes in their self-perceived sustainability knowledge, awareness and actions at the beginning and end of their studies, we sought to discover which factors affect students' actions at the end of their studies. The conclusions are summarized below:

- The test model explains the variations in students self-perceived sustainability actions at the end of their studies well;
- The factors that contribute significantly to the students' self-perceived sustainability actions at the end of their studies are their sustainability actions at the beginning of the studies, being female, sustainability courses in programs and an increase in self-perceived sustainability knowledge; and
- The initial difference of students' self-perceived sustainability knowledge was surprising despite their similar backgrounds.

This research proposes a model describing which factors influence the results of education as self-perceived sustainability actions based on students' reports of their self-perceived sustainability knowledge, awareness, and actions at the beginning and end of their university studies. The student's gender and initial sustainability actions are factors that the student brings to the university.

The study shows that an increase in self-perceived sustainability knowledge, awareness and actions can be explored before and after university studies using the same questionnaire for identified students. The study results show changes that can encourage those working with ESD in universities, since students appear to have sincerely aimed at providing their self-perceptions at the time. The development shows that their self-confidence regarding sustainability knowledge has increased.

The study is limited by the extent of students' sustainability studies before they entered the university was not known. It is not possible to say how much of the change in the students' self-perceived sustainability knowledge, awareness and actions during the studies depends on education and how much on other sources such as the media. A limitation is also that the results show the students' self-perceived knowledge, awareness and actions and not, for example how they act in real-life situations. There could also be other variables that influence the students' sustainability actions that are not included in the study.

Further comparative studies among alumni who have worked for some time after their studies are proposed. Students from different disciplinary backgrounds in universities in different parts of the world, with and without integrated sustainability, and with specific sustainability courses could be included in a further explorative study. The questionnaire could be developed to focus on the wide sustainability perspective and complemented with interviews to gain a deeper understanding of the development including affective learning for sustainability.

Author Contributions: Kaisu Sammalisto designed the research with Tove Holm, compiled the results and wrote the major part of the paper. Agneta Sundström provided constructive critical comments on the study and the paper. Robin von Haartman prepared the statistical analyses and interpreted their results. Zhilei Yao contributed to refining the results of the pre-study in addition to developing the survey. All authors read and approved the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix

Sustainable Development Questionnaire (2013)

The University of Gävle educates leaders for the future, who can include sustainable development in their activities. We are interested in your opinions so please fill in the following questionnaire. We asked you to complete the questionnaire in the beginning of your studies.

Name:
E-mail:
Bachelor program:
You are A. Female B. Male

1. **Do you agree with the below statements?** Grade them on a scale from 1 to 5. 1. Strongly disagree 2. Disagree, 3. Undecided 4. Agree 5. Strongly agree

    a   I know a lot about sustainable development.
    b   The three dimensions of sustainable development are environmental, economic and social.
    c   I know some documents that deal with sustainable development.

2. **Do you agree with the below statements?** Grade them on a scale from 1 to 5. 1. Strongly disagree 2. Disagree 3. Undecided 4. Agree 5. Strongly agree

    a   A huge population puts a lot of pressure on the earth's resources.
    b   It is urgent to protect fresh water resources from pollution.
    c   The choice of personal lifestyle (e.g., saving water and electrical energy, waste recycling *etc.*) can make a contribution to sustainable development.
    d   Reports of damage that people cause to the environment are exaggerated.
    e   Studying about sustainable development can promote sustainability.

3. **How often do you do the following to contribute to sustainable development?** 1. Never, 2. Seldom, 3. Sometimes, 4. Often, 5. Always

    a   I sort my waste.
    b   I buy second hand (e.g., clothes, furniture, *etc.*)
    c   I talk with my family or friends about the current environmental situation.
    d   I try to save water, for example, when I take a shower.
    e   I attend activities about sustainable development (e.g., lectures about sustainable development)?
    f   I print reading materials from my computer.
    g   I use disposable products.
    h   I use public transportation.

The results from the survey will be used in research.

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