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Sustainability and Educational Technology—A Description of the Teaching Self-Concept

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Abstract: The work of teaching is fundamental for achieving Agenda 2030, which defends the importance of improving quality in education (Sustainable Development Goal SDG 4), gender equality (SDG 5) and responsible consumption (SDG 12). Thus, the aim of the present study was to analyse teachers' self-perceived digital competence as regards their eco-responsible use of technology. A total of 259 teachers in Preschool, Primary and Secondary Education in the Valencian Community (Spain) completed the 14-item questionnaire designed and validated by Barragán et al. (2020). Added to this were two open questions. The data collected then underwent quantitative (descriptive and comparative) and qualitative (conventional and summative content) analysis. Notable among the results were the low levels of knowledge and training regarding the environmental impact of technologies and the use of preventive measures. In addition, differences were found as regards gender, with males having a more positive self-perception, especially those teaching in Secondary Education. The information about training they provided in their narratives supported the quantitative findings. Their voices also led to the uncovering of proposals on how to teach eco-responsible practices and attitudes regarding the use of Information and Communication Technology (ICT). Finally, teacher training was identified as the main problem but also the main solution. All efforts should therefore be directed towards training teachers in the eco-responsible use of ICT following a holistic approach to sustainability.

Keywords: educational technology; education for sustainable development; competency-based teaching; self-evaluation

1. Introduction

Since the 2015 Sustainable Development Summit, governments and institutions have implemented various strategies to promote more responsible environmental behaviors [1]. The meeting culminated in the establishment of 17 Sustainable Development Goals (SDGs) to be achieved by 2030. These goals are the result of an unprecedented agreement between all nations [2]. Among other ends, these general and global goals are directed towards: eradicating poverty, protecting the planet and ensuring prosperous development for all [3]. The objectives set include SDG 4, which defends the key role of education in building a just, inclusive and quality society. It is subdivided into seven partial targets and target 4.7 specifies the importance of developing sustainability education by advancing theoretical and practical knowledge in support of balanced environmental development [4]. While SDG 4 refers specifically to education, the relationship between this and the other objectives is evident bearing in mind that the achievement of each goal is dependent on education [5]. For example, SDG 12 points to the importance of using technological resources in a responsible manner. SDG 9 includes, among its specific goals, the urgent need to use technological resources efficiently, promoting clean and environmentally sound technologies. SDG 13, for its part, calls on education to raise awareness and empower society to prevent the aggravation of climate change [6].

The general nature of the SDGs requires a commitment from all the actors of the social fabric. In this sense, the willingness and training of people who work in the field of education, that is, teachers and principals, play a key role. Their actions have a clear impact on society: they develop students' awareness of sustainability and thus that of future citizens [4,7]. In fact, major international institutions have defended their key role [3,4,6], emphasizing the value of educational action regarding proposals of solutions to situations and actions that have an impact on sustainable development [8]. Examples include the various initiatives led by university institutions to promote the development of research, transversal educational experiences and the transfer of knowledge oriented towards sustainability [9–13]. These institutions play a critical role in achieving the aims of sustainable development and this gives them a high degree of social responsibility [14,15]. These initiatives, all of which focus on the developing sustainability, include scales to assess the contribution of educational digital resources to sustainable behavior [16], proposals to include the SDG in educational curriculums [17], teacher training program designs [12] and methodological strategies such as place-based learning to work on principles of Education for Sustainable Development (ESD) [18]. Research has also addressed other educational levels, as indicated in the Dieste et al. [17] study, focusing on the inclusion of the SDGs in the Primary and Secondary Education curriculum or schemes for the reuse of technological devices in educational settings [19]. All these works highlight the multidisciplinary strengths of ESD [18] and the impact of teacher training on the sustainable use of technology by future generations.

1.1. Technological Progress and Its Counterpart: The Importance of Eco-Responsibility

Today's information and knowledge society has brought about a widespread use of digital technology, cutting across all domains: the productive, economic, work, cultural spheres and so forth. The result is an excessive production of waste which is generating pollution problems [20]. For example, programmed obsolescence, which concerns most devices, often makes updating difficult and ineffective. Perceived obsolescence is an additional phenomenon: certain people consider their devices to be outdated, usually leading them to dispose of them shortly after use [21]. We must add to these factors a reduction in the price of technological products and the effectiveness of extensive marketing and advertising campaigns [19]. This early disposal of digital technology is reflected in an average duration of mobile device usage of approximately two years [22]. Thus, the main problem is not so much an excessive use of devices but rather the disposal of devices [23].

The SDGs are based on the premise that current needs should be met without compromising resources. This implies using technologies in an eco-responsible manner or directly choosing to use sustainable technologies. The latter are those for which less energy and fewer limited resources are used in their manufacturing, sales and consumption processes, those which do not pollute directly or indirectly and those that can be reused [24]. Eco-responsibility in the use of Information and Communication Technology (ICT) does not involve only the environmental dimension of sustainability but its other facets too, that is, the social and economic dimensions [5]. A lack of responsibility in this regard may have a negative effect on the achievement of the SDG, which could have very negative consequences for the world population [18]. Hence the idea of taking a holistic approach to sustainability in order to promote awareness among students. Such an approach, as Olsson et al. [25] point out, has positive effects on students' awareness of sustainability.

The advanced use of digital technology has also had an impact in the field of education: the catalogue of competencies that define a twenty-first century teacher has grown larger and the traditional understanding of literacy has taken on a new meaning. At the Spanish administrative level, the Agreement of the Sectoral Conference on Education on the framework of reference for digital teacher competence [26] was approved. In that document, the competence is divided into five broad dimensions and subdivided into further detailed ones. Specifically, competence 4.4 refers directly to environment protection: "Protecting the environment: taking into account the impact of technologies on the environment." This competence is divided, in turn, into three indicators, that, in general terms, focus on: the ability to save energy through ICT, to make adequate use of them so as to extend their useful life and to be able to establish channels of dissemination within the educational community itself for sustainable purposes. All this requires promoting the use of ICT while adopting a respectful and committed approach to the environment [27].

These strategies, however, should be supported by an analysis of educational needs and deficits to ensure that sustainable intervention proposals be as effective as possible [17]. Knowing which factors need to be improved when teaching will lead to more accurate environmental protection proposals. In addition, teachers play an essential role, both through their own actions and in how they teach their students. Thus their training is seen as a key element for change. In this respect the present becomes more promising from the moment a generalized increase in concern for environmental health is detected [28] with teachers showing favorable attitudes and great interest in including these contents in the curriculum [18,29].

1.2. Teacher Training to Raise Eco-Responsible Awareness When Using Technology

The question of teacher training in the development of digital skills, including the eco-responsible use of the associated resources, can no longer be avoided. According to Calero et al. [12] if one of our main global challenges is that of working towards sustainability, we should focus on teachers' initial and continuous training.

Teachers assume a big responsibility in the building of a sustainable society [30]. Indeed, they are training future citizens, who must learn to make appropriate use of digital technology in order to achieve sustainability [31,32]. To do so, these teachers need to be properly trained and in possession of the necessary resources to integrate educational models based on sustainability into their classrooms. They must also be a role model for students as eco-responsible teachers [33]. It has been established that training in sustainable development can change the way people think and contribute to developing attitudes that encourage the building of a fairer, healthier and more prosperous world [32].

Teachers should build self-perceptions of themselves as agents of change and direct their academic leadership towards this issue. Evans et al. [34] showed that the feeling of self-efficacy in ESD stems from the increase in knowledge and understanding of sustainability that results from the training they receive. Cleveland et al. [35], in turn, stressed that a belief in the possibility of changing the way things are has a considerable impact on environmental behavior. This aspect has also been studied by Watson et al. [36] and Meyer et al. [37]. It is therefore considered essential to acknowledge teachers' perception and vision regarding the concepts of sustainable development and ESD in order to bring the Agenda 2030 within reach [32]. Nevertheless, a number of studies also state that the presence of sustainability-related content is still scarce in the teacher's initial and continuous training programs. While it seems that this issue is starting to be included in teaching guides, concrete actions have not yet penetrated the classroom [38,39]. This fact supports the findings of several authors such as Green and Somerville [40] and Alvarez et al. [41], who conclude that teachers lack sufficient environmental competence to address the subject. The mastery of technological resources is limited to theoretical-practical training. However, concerns have arisen regarding a lack of knowledge about the environmental impact of digital resources and, consequently, possible prevention measures. What is needed, therefore, is to direct efforts towards designing and developing policies aimed at increasing teachers' commitment to this aspect by redesigning plans for teacher training so as to dedicate more time to these contents, identifying the drivers of and obstacles to the implementation of sustainability in the curriculum and encouraging research in this area [32,42].

Teachers' roles are essential to develop students' digital competence. Thus, to meet the objectives of the different spheres of action, not only is it necessary to make creative, critical and safe use of technologies but it is also necessary to learn about their eco-responsible usage. The latter requires recognizing the impact of technologies on the environment and establishing measures to minimize that impact. According to Plaza de la Hoz [43], ICT can empower students, provided they permit unlimited access to information and the creation of learning communities. In addition, their positive effects on student motivation have been recognized [44,45] together with their contribution to saving time [46]. This brings about an opportunity to develop their awareness of the impact these resources can have on the environment.

If the objective is to make teachers aware that they should contribute to sustainability by using technologies responsibly—thus turning teachers into role models and training them on how to address these issues—then it seems necessary to promote an experiential and collaborative training model [18,47–49], the same one they will use with their pupils [50,51]. Approaches that are merely theoretical should be dismissed and those based on applied knowledge should be adopted [52,53]. Such models should foreground the pedagogical aspects in order to foster, by including ICT in the classroom, the required methodological, cultural and ecological shift [54]. It would thus be possible to develop digital competence based on the following three pillars: technology, information and pedagogy [55]. This pillars form an active pedagogical approach can impact favorably on students' ICT self-efficacy [56].

Ultimately, we believe that a socio-constructivist teacher profile should be established, characterized by a high level of competence and a moral basis of action [57]. This profile would have the traits of a "hero": "smart, strong, caring, selfless, charismatic, resilient, reliable and inspiring" [58]. In this context, teachers must be aware of their responsibility and power to improve education and society through sustainable education and the construction of eco-awareness [33]. This can be achieved through a number of twenty-first century teaching skills, including the so-called digital competences [59,60]. In short, it is necessary for teachers to acquire sustainable digital skills in order to bring about changes in society [7,12,61,62]. Moreover, their self-perceptions influence how they organize and develop their professional activity and their ultimate commitment to a specific issue. Teachers' conscious self-perceptions of sustainable behavior regarding the use of ICT, hitherto insufficiently studied, will lead to the emergence of environmental awareness strategies and improvements in their digital teaching competence. Therefore, the aim of the study was to evaluate teachers' self-perception with respect to the eco-responsible use of technologies and their didactics proposals to develop this attitude in their pupils.

2. Materials and Methods

2.1. Objectives

The work aimed at fulfilling the following objectives: (1) to analyze and describe teachers' self-perceived digital competence regarding their eco-responsible use of technology; (2) to compare sustainable teaching digital profiles based on the sociodemographic variables of gender and educational stage; and (3) to interpret their proposals of teaching practices to reduce the environmental impact of technology.

2.2. Design

A mixed research paradigm approach was followed [63,64]. We considered that performing both a quantitative and qualitative analysis of the information would lead to a more accurate examination of the phenomenon, that is, teacher knowledge and training on the eco-responsible use of technology and its didactic application. We thus provide a descriptive and comparative overview of teacher knowledge and training on the eco-responsible use of technology. The latter is complemented with the conclusions drawn from the analysis and interpretation of the teachers' voices, while bearing in mind the contextual value of their discourse.

2.3. Participants

A sample of 259 teachers in active service in the Valencian Community (Spain) participated in this study. A total of 59.59% (144) were women and 40.4% (115) men. The female teachers' mean age was 39.60 ± 12.78 and the males' 41.49 ± 9.6. Regarding educational stages, a total of 49.42% of those surveyed worked in Secondary Education (128), 36.29% in Primary Education (94) and 13.9% in Preschool Education (36). With respect to the average number of years of teaching experience in each stage: 13.13 ± 9.56 for Preschool, 14.14 ± 10.28 for Primary and 13.67 ± 9.96 for Secondary. Finally, concerning the schools' types of ownership, 77.22% worked in state schools, 19.69% in semi-private schools and the remaining 3.08% in private schools. The selection was conducted based on convenience sampling, according to their availability to answer the questionnaire [65].

2.4. Data Collection Instrument and Process

We used the Barragán-Sánchez et al. [66] questionnaire which is designed to measure teachers' self-perceived digital competence regarding the eco-responsible use of technologies. This questionnaire is based on the "DIGCOMP: A Framework for Developing and Understanding Digital Competence in Europe" [67]. It was validated by its authors who indicated a high reliability coefficient (>0.9). The instrument also showed good internal consistency with the sample of this study (alpha value = 0.96), confirming the high reliability of the questionnaire [68]. It is made up of a total of 14 items, which were answered using an 8-point Likert scale (1 "Strongly Disagree" and 8 "Strongly Agree") in a one-dimensional scale to evaluate the eco-responsible use of technology.

To complement the quantitative data, two open questions are included in a separate section. In the first, the teachers were asked about what actions they believed they could implement in their daily practice as teachers to reduce the environmental impact of technologies. The second one aims at collecting their opinions as to which measures could help their students to develop technological eco-responsible awareness. Both questions were validated by two experts in educational research methodology.

Given the difficulty of collecting data under our current exceptional pandemic circumstances, teachers were asked to participate using the WhatsApp social network. The link to the questionnaire—created in Google Forms—was shared with Preschool, Primary and Secondary Education teachers via various contacts, linked to the Regional Department for Education, Culture and Sports and the Centers for Training, Innovation and Educational Resources of the Valencian Community. The criteria of frequency of use, speed and convenience of response of this social network were taken into account. The ethical aspects were respected and the regulations on this subject issued by the university to which the authors of this work belong were followed at all times; participants were informed of the objective of the study, as well as of the voluntary nature of their participation and the anonymity and confidentiality of the information provided. Participants were also asked for their consent for the scientific disclosure of the data. The questionnaire was accessible from mid-September to mid-October of the 2020/21 academic year. The teachers surveyed had to confirm they were on active duty for their answers to be accepted.

2.5. Data Analysis

In accordance with the quantitative paradigm, a descriptive and comparative analysis was performed using the non-parametric Kruskal Wallis and Mann Whitney U tests. The Mann Whitney U test was used to compare the differences according to the gender variable. To compare educational stages, we chose the Kruskal Wallis test, supplementing it with Dunn's post hoc test. In this way, we sought to analyze the possible differences in teachers' knowledge and training on the eco-responsible use of technologies. The data was processed using the JASP software (Version 11.1.0). The adopted qualitative approach consisted in interpreting the information using the AQUAD 7 software [69]. This tool was selected for its capacity to facilitate the interpretation and categorization of information into a series of units, designed to fulfil the study's third objective. Following several readings of the obtained narratives, an initial code and category framework was established. It was validated by the same experts who had previously validated the questionnaire. The analysis tool served as the basis for coding the information, which was finally organized into 2 categories and 12 codes. We chose to conduct a content analysis, which classifies oral or written information into units of meaning.

Specifically, a conventional and summative study was performed [70] once the framework was configured, based on the emerging information and taking into account the narratives' quantification. This latter strategy allowed us to evaluate latent meanings because it revealed the emphases present in participants' discourses concerning the different units of meaning. All narratives were identified with an alphanumeric code to ensure anonymity.

3. Results

Given the mixed nature of the study, we first present the quantitative findings of the study and then the qualitative results.

3.1. Quantitative Analysis Results: Description and Comparison of the Technologically Eco-Responsible Teacher Profile

Table 1 shows the descriptive results represented by mean, standard deviation and percentages grouped by the scores of Likert Scale (1–8, 1 "Strongly Disagree" and 8 "Strongly Agree"). It was generally found that although participants had heard of the environmental impact of technology, they did not have a clear understanding of it and this hindered their ability to define it and to identify the types of usages that produce an impact. The acute lack of training that they put forward could, for its part, explain the low scores they also obtained in their didactic competence to design initiatives to prevent the environmental impact of ICT, aimed at students and families. Similarly, they did not feel able to identify the actions that posed the greatest risks to the environment or the measures to stop them. The latter can be linked to the low scores they obtained regarding their confidence, as teachers, to help others to make a responsible use of ICT. Nor did they feel competent enough, from this standpoint, to provide information on the subject, to prevent the risks entailed by the irresponsible use of these resources and to establish appropriate prevention mechanisms.

Table 1. Descriptive data of the eco-responsible use of Information and Communication Technology (ICT) by teachers.

ITEMS	Mean	*SD*	1–2 (%)	3–4 (%)	5–6 (%)	7–8 (%)
1. I have heard about the environmental impact caused by using technologies.	5.22	2.07	12.36	25.48	27.41	34.75
2. I am clear about the environmental impact caused by using technologies	4.66	2.04	16.60	31.27	28.57	23.55
3. You could clearly define what the environmental impact caused by using technologies is	4.05	2.03	28.19	32.43	23.94	15.44
4. I have followed courses on the environmental impact caused by using technologies.	1.65	1.19	84.17	11.97	3.09	0.77
5. I would know how to perfectly define the technological uses that cause environmental impact.	3.63	1.93	33.20	33.20	24.71	8.88
6. With the knowledge that I currently have, I can prepare a didactic guide for students to prevent the environmental impact caused by the use of technologies	3.23	1.97	42.47	30.50	20.46	6.56
7. With the knowledge that I currently have, I can prepare a didactic guide for families, to prevent the environmental impact caused by using technologies	3.19	1.98	44.40	30.89	17.76	6.95
8. I consider myself capable of identifying the technological actions that cause the greatest environmental impact.	3.70	1.90	32.05	33.59	24.32	10.04
9. I am able to establish measures that reduce the environmental impact caused by the use of technologies.	4.00	2.01	26.64	34.75	23.94	14.67
10. I can help another person manage situations in which the use of technologies is creating a great environmental impact.	3.71	1.90	29.73	37.07	25.10	8.11

Table 1. *Cont.*

ITEMS	Mean	*SD*	1–2 (%)	3–4 (%)	5–6 (%)	7–8 (%)
11. As a teacher, I am able to inform students about the risks caused by the use of technologies for the environment	4.02	2.01	27.41	34.36	24.32	13.90
12. As a teacher, I am able to inform families about the risks caused by the use of technologies for the environment.	3.89	1.91	27.03	37.07	23.55	12.36
13. As a teacher, I am able to design actions to prevent the risks caused by the use of technologies for the environment aimed at students and families.	3.74	1.91	28.96	39.00	22.01	10.04
14. As a teacher, I would be able to establish a procedure to follow based on the use of technologies	4.05	1.89	23.55	37.07	25.87	13.51

3.1.1. Comparative Analysis Based on Gender

A comparative presentation of the results obtained from the questionnaires is given in Table 2. The data analysis is presented by mean rank. The difference between eco-responsible use of technology and gender was analyzed through the Mann–Whitney U test. The effect size (ES) was determined through eta squared test (η^2). Mann–Whitney U test revealed a statistically significant differences for all the items evaluated except for the first. We observed a higher mean rank for all items, in men's more positive self-perception, though to different degrees. We must thus acknowledge that both men and women received a reduced amount of training, had little related knowledge and barely felt ready to work on the subject in the classroom. In fact, a small ES was determined for most items, except for questions 5, 6, 7, 12 and 13 which obtained a medium ES.

Table 2. Results of the comparative analysis distributed by gender.

	Male (*n* = 115)	**Female (*n* = 144)**		
ITEMS	**Mean Rank**	**Mean Rank**	***U***	**η^2**
1. I have heard about the environmental impact caused by using technologies.	139.28	122.59	9370	0.012
2. I am clear about the environmental impact caused by using technologies	142.10	120.34	9671 *	0.021
3. You could clearly define what the environmental impact caused by using technologies is	147.84	115.75	10,332 ***	0.045
4. I have followed courses on the environmental impact caused by using technologies.	146.23	117.04	10,146 ***	0.037
5. I would know how to perfectly define the technological uses that cause environmental impact.	153.91	110.91	11,029 ***	0.081
6. With the knowledge that I currently have, I can prepare a didactic guide for students to prevent the environmental impact caused by the use of technologies	153.72	111.06	11,008 ***	0.08
7. With the knowledge that I currently have, I can prepare a didactic guide for families, to prevent the environmental impact caused by using technologies	152.16	112.31	10,828 ***	0.07
8. I consider myself capable of identifying the technological actions that cause the greatest environmental impact.	149.53	114.40	10,526 ***	0.054
9. I am able to establish measures that reduce the environmental impact caused by the use of technologies.	148.77	115.01	10,483 ***	0.052

Table 2. *Cont.*

	Male (n = 115)	Female (n = 144)		
ITEMS	**Mean Rank**	**Mean Rank**	U	η^2
10. I can help another person manage situations in which the use of technologies is creating a great environmental impact.	149.31	114.58	10,501 ***	0.053
11. As a teacher, I am able to inform students about the risks caused by the use of technologies for the environment	150.89	113.32	10,682 ***	0.062
12. As a teacher, I am able to inform families about the risks caused by the use of technologies for the environment.	150.46	113.66	10,632 ***	0.06
13. As a teacher, I am able to design actions to prevent the risks caused by the use of technologies for the environment aimed at students and families.	152.87	111.47	10,909 ***	0.074
14. As a teacher, I would be able to establish a procedure to follow based on the use of technologies	150.08	113.96	10,589 ***	0.057

Note 1: * $p < 0.05$, *** $p < 0.001$; Note 2: η^2 interpretation: small ≤ (0.01), medium ≤ (0.06) and large ≤ (0.14) effects.

3.1.2. Comparative Analysis Based on Educational Stage

Regarding the educational stage during which they taught, the Kruskal Wallis non-parametric statistical test was selected. Dunn's post hoc test was performed in order to compare the scores of the three educational levels. The data analysis is presented by mean rank, Chi Square (X^2) and ES. The ES was determined for Table 3, through the eta square test (η^2). The results revealed the existence of statistically significant differences between Secondary and Preschool for all the items evaluated, the scores obtained for Secondary education being higher. When comparing the Secondary and Primary stages, statistically significant differences were also found in the majority of the items, with higher scores in Secondary. Finally, the Preschool-Primary comparison yielded statistically significant differences with higher scores in all items for Primary, except for the numbers 1, 4, 6, 8 and 14 (Table 3). The ES was shown to be significantly larger in Secondary over Preschool for all items. A large ES was detected for item 5, related to the knowledge for defining the technological uses that cause environmental impact, between the three stages. The remaining items showed a medium and small effect for all educational stages assessed.

Table 3. Comparative results according to educational stage.

	Preschool (n = 37)	Primary (n = 97)	Secondary (n = 128)			
ITEMS	**Mean Rank**	**Mean Rank**	**Mean Rank**	X^2	η^2	**Comparison**
1	117.45	117.57	142.76	7.502	0.021	S ** > P, Pr
2	97.58	125.96	142.34	10.883	0.035	S ***, P ** > Pr
3	90.70	125.94	144.34	15.465	0.053	S *** > P * > Pr
4	107.04	124.14	140.94	9.548	0.029	S ** > P, Pr
5	84.68	123.01	148.23	22.467	0.08	S ** > P * > Pr
6	99.00	122.22	144.67	12.680	0.042	S ** > P, Pr
7	96.01	123.80	144.38	13.456	0.045	S *** > P * > Pr
8	101.62	123.57	142.92	10.043	0.031	S ** > P, Pr
9	93.96	125.08	144.03	13.738	0.044	S *** > P * > Pr
10	90.05	132.49	139.71	13.086	0.043	S ***, P ** > Pr
11	93.14	128.87	141.48	12.243	0.04	S ***, P ** > Pr
12	91.45	128.38	142.33	13.623	0.045	S ***, P ** > Pr
13	93.55	125.81	143.61	13.604	0.045	S *** > P ** > Pr
14	95.84	123.20	144.87	13.822	0.046	S ** > P, Pr

Note 1: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; Note 2: η^2 interpretation: small ≤ (0.01), medium ≤ (0.06) and large ≤ (0.14) effects.

3.1.3. Comparison According to Gender and Educational Stage

In order to specify the origin of the significant differences detected between gender and educational stage in Tables 2 and 3, the results according to gender in Primary and Secondary Education were compared in Table 4. We ruled out comparing the gender and stage of Preschool Education because only two men completed the questionnaire. The difference between eco-responsible use of technology by gender and educational stage was analyzed through the Mann–Whitney U test (Table 4). The ES was determined through eta squared test. The results showed significant differences according to gender only for the Secondary level, except in the case of the items 1, 2 and 3. Additionally, in the case of Secondary Education, a medium ES was detected to items 6, 7, 11, 12 and 13, being irrelevant for item 1 and 2 and small for remaining questions.

Table 4. Results of the comparative analysis based on teacher gender and educational stage.

	Secondary				Primary			
ITEM	Male (n = 86)	Females (n = 42)	U	η^2	Male (n = 27)	Female (n = 67)	U	η^2
1	66.12	61.18	1945.5	0.004	48.22	47.21	924	0.0
2	66.97	59.44	2018.5	0.009	47.39	47.54	901.5	0.0
3	68.02	57.30	2108.5	0.018	51.69	45.81	1017.5	0.009
4	69.53	54.19	2239 *	0.038	49.76	46.59	965.5	0.003
5	70.19	52.86	2295 **	0.048	51.44	45.91	1011	0.008
6	72.12	48.90	2461 ***	0.086	51.43	45.92	1010.5	0.008
7	71.92	49.30	2444 ***	0.082	49.02	46.89	945	0.001
8	70.35	52.52	2309 **	0.051	51.44	45.91	1011	0.008
9	70.42	52.38	2315 ***	0.052	49.98	46.50	971.5	0.003
10	70.48	52.26	2320 ***	0.053	52.30	45.57	1034	0.012
11	71.52	50.13	2409.5 ***	0.073	51.72	45.80	1018.5	0.01
12	71.71	49.74	2426 ***	0.077	51.13	46.04	1002.5	0.007
13	71.96	49.26	2447.5 ***	0.083	52.04	45.67	1027.5	0.011
14	70.20	52.83	2296 **	0.048	51.06	46.07	1000.5	0.007

Note 1: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; Note 2: η^2 interpretation: small ≤ (0.01), medium ≤ (0.06) and large ≤ (0.14) effects.

3.2. Results of the Qualitative Analysis: Contribution to the Development of Eco-Responsible Awareness

The results of the qualitative analysis are set out below. As shown in Table 5, the information is organized into two categories. The first presents the teaching actions that participants believe are effective in reducing the environmental impact of technologies and turn them into technologically eco-responsible teachers. The second includes the teaching proposals that they believe will develop their students' sense of ICT eco-responsibility. Both units of meaning encompass a set of codes that allow us to better understand the study's reality from a qualitative perspective. Each code is accompanied by the Absolute Frequency and its percentage (AF and AF(%)). The AF is understood as the number of times participants refer to each unit of meaning, its percentage being calculated as follows: AFx100/Total AF.

Worthy of note, of the total number of participants, 167 answered the open questions. During the analysis stage, those who did not respond to these questions were discarded, as well as those who said they were not knowledgeable enough to answer. A total of 57% were women, with the highest age percentages corresponding to the age ranges of 33–37 years (15%) and 43–47 years (17.4%). In relation to their professional experience, the highest percentages were found around the ranges of 10–14 years (20.4%) and 20–24 years (17.4%). Regarding the educational stages in which they were teaching, the percentage was higher during the ESO stage (46.7%) and lower for the Stages of Primary education (37.7%) and Preschool education (13.8%). Finally, there was a large majority of state sector professionals (77.8%).

Table 5. Descriptive data of research codes.

Categories	Codes	AF	AF (%)
1. Actions of the technologically eco-responsible teacher	1.1 The 3 R's (reduce, reuse and recycle)	102	28.2
	1.2 Training, information and reflection	41	11.3
	1.3 Responsible renewal of device	30	8.3
	1.4 Disconnecting devices	12	3.3
	1.5 Responsible consumption of applications and use of respectful materials	15	4.1
	1.6 Renewable energy	10	2.8
2. Teaching proposals: development of students' ICT eco-responsibility	2.1 Sensitisation and awareness	50	13.8
	2.2 Active methodologies and experiential learning	47	13
	2.3 Curriculum integration	26	7.2
	2.4 Setting the example	22	6.1
	2.5 Family information	5	1.4
	2.6 Tutorial action	2	0.6
Total		362	100

3.2.1. Category 1. Actions of the Technologicall Eco-Responsible Teacher

The first category includes codes referring to actions that participants consider to be distinctive of a technologically eco-responsible teacher. All of them were considered to reduce ICT's negative impact on the environment. As the results show, their narratives underscored the particular effectiveness of the rule of the 3 Rs. Thus, their contributions show that they consider it essential to reduce the use of technological devices to minimize the consumption of electricity. In addition, teachers strongly suggested that devices should be repaired to extend their service life and, if not possible, their components should be recycled and reused, as illustrated in the following narratives:

> *If possible, use refurbished technological products, minimise the use of electricity, put applications in low energy consumption mode, properly dispose of appliances that are no longer of use.* (Prof_036)

> *The actions that would define my teaching intervention would include avoiding making excessive use of electrical connections.* (Prof_167)

> *Promote the recycling of old equipment. Reuse components of other equipment to extend their use and efficiency.* (Prof_056)

Moreover, many recognized the importance of knowledge and reflecting on the subject, hence they repeatedly identified education as a necessary means to act eco-responsibly with regard to ICT:

> *Environmental awareness should be developed mainly through proper training.* (Prof_082)

> *We must learn more about the subject first. Otherwise, it's impossible to take action.* (Prof_098)

> *I think that first, I would need to be better trained, because I haven't received any training on the subject, though I have heard about the problem. So perhaps the first thing to do is to engage in self-reflection on what I can and cannot improve.* (Prof_105)

They also stressed that the list of actions of this teaching profile should include the ability to share information with other educational actors, especially with students' families:

> *Comprehensively inform citizens about what attitude they should adopt and its environmental impact.* (Prof_065)

> *Disseminate responsible use among families.* (Prof_068)

Furthermore, both inferential and descriptive data showed that the responsible renewal of devices became a recurring issue. In this regard, they indicated that it was necessary to properly maintain and care for these resources in order to extend their useful life and avoid making unnecessary purchases:

Change devices when they don't work anymore, not before. (Prof_023)

Take better care of the devices so that they have a longer service life. (Prof_086)

Extend computers' lifespan, using GNU-licensed software and operating systems (Ubuntu, Free Office . . .). (Prof_049)

They referred, however, less often to the other codes. Nevertheless, on a number of occasions, they were found to understand that it was relevant to disconnect technological devices when they were not being used to save energy:

Make sure I turn off all devices every day and unplug them over the weekend. (Prof_007)

Try to control the use of technologies in the classroom. For example: Not turning the light on and off (taking advantage of natural light, orienting the class in such and such a way), restrict the use of the projector within a time interval so that it is not on all the time . . . (Prof_042)

Turn off the computer and projector that are in the courtyard. (Prof_018)

Responsible consumption of applications as well as the use of renewable energy were also insisted upon, as shown in the following narratives:

Search for ICT products or tools that are produced taking into account environmental impacts, promote the use of renewable energies within such devices . . . (Prof_011)

Look for different resources that have a lesser environmental impact and that help to achieve the same goals. (Prof_026)

I could try to choose environmentally friendly companies or energy companies that get energy from renewable sources. I could also reduce consumption to what is necessary, reuse products and recycle (the 3Rs). (Prof_156)

3.2.2. Category 2. Teaching Proposals to Develop ICT Eco-Responsibility in Students

Unlike the previous category, the information included within this second unit of meaning category refers to the teaching approaches that participants believe have a positive impact on the development of their students' eco-responsible awareness, specifically, in terms of the use of technologies. Therefore, the codes in this category do not refer to the actions that teachers themselves apply to reduce the environmental impact of ICT but to those they perform with students to promote this attitude in them.

In this way, as shown by the inferential and descriptive data, on the one hand, they insisted on the importance of contributing to sensitization and awareness through information, mainly exposing them to the consequences of the irresponsible use of these resources:

Knowing the negative impacts of the misuse of technologies on our lives. (Prof_026)

Raising students' awareness of the need to reduce their intensive use of video games, to turn off lights and electronic devices when not in use . . . that is, developing activities that make them more conscious of the need for environmental protection. (Prof_106)

On the other, they considered that talks or the viewing of films and documentaries provided a means to transmit this information and to spark reflections:

Awareness-raising talks. (Prof_005)

I think the best way is to play videos that show where coltan, for example or other materials with which ICT are produced come from. (Prof_167)

They also recognize the effectiveness of adopting active teaching methods, as they promote experiential learning and make it possible to contribute to the development of key skills. They agreed on the need for students to cultivate this responsible attitude, by perceiving its relevance through investigation, experimentation, debates, analysis or participation in workshops. Thus, the students themselves draw conclusions on the relevance of their behavior, in this sense, for the common good:

Have a solar battery in the classroom, encourage students to make the most of their tablet time and to value every battery charge. (Prof_012)

Through solidarity eco markets that include recycling, repair and reuse centres or workshops. (Prof_040)

Awareness-raising through educational projects, collective intervention programmes and content processing adopting a transversal approach. (Prof_100)

Conducting journalistic reports or discussions on the environmental effects of ICT. (Prof_149)

Moreover, they confirmed, with a low percentage of frequency (AF%−7.2), that these contents need to be integrated into the curriculum. Some of them reflected on how they might include this information in their subjects:

The subject of biology presents an opportunity to work on these contents. In fact, I include them in the curriculum. (Prof_113)

Through documentaries on the subject … In chemistry I can talk about the chemical elements used in electronics and the impact of their extraction … (Prof_057)

However, a majority believed in a transversal approach to the question:

Working transversally across all disciplines or including a subject dedicated to environmental protection. (Prof_054)

Adopting a transversal approach together with specific learning activities. (Prof_090)

They also agreed that the teacher must set the example to ensure consistency between discourse and practice, thus promoting learning by osmosis:

The best way is to be an example, that is, doing it myself, then working in class and creating habits, conscience/conscience, building group cohesion around those goals. (Prof_001)

We simply have to raise awareness by setting an example trough daily actions and explaining the reasons for an eco-responsible environment. (Prof_164)

By being a role model. As I said, it is difficult to raise students' awareness without prior analysis of what we do wrong as teachers. (Prof_151)

In addition, they valued families' involvement in learning these contents, as supported by the following narrative:

Being an example for students, trying to introduce it as transversal content throughout the year. It would also be nice to create some kind of a challenge in which we could include families (e.g., hold a contest in which they have to look for an original way to make eco-responsible use of technologies at home). (Prof_042)

Holding reflection days with families. (Prof_070)

Finally and with a very low frequency (AF%−0.6), they pointed out that the subject could also be worked at through tutoring initiatives:

In tutoring sessions, you can work on the topic by engaging in activities of reflection or games. (Prof_127)

4. Discussion

The objective of this study was to evaluate teachers' self-perceptions as eco-responsible users of ICT in order to generate a sustainable digital competence teacher profile, based on various aspects such as gender and educational stage. The aim was also to interpret participants' voiced proposals of actions that they regarded as distinctive of a technologically eco-responsible teacher as well as the practices to foster the development of this attitude in students.

4.1. The Need for Teacher Training on the Eco-Responsible Use of ICT and Its Teaching

Our study was based on digital competences, in accordance with Romero-García et al. [71]. Previous studies on teachers' self-perceptions of such skills, have found low levels of competence [40,72,73], as well as training needs in this regard [38,39,74]. Indeed, these competences are key for 21st century teachers [75], who must guide their practices towards teaching a sustainable use of ICT [24]. That is why we focused our study on learning about teachers' self-perceived digital competence with respect to the eco-responsible use of these resources. Quantitative results confirmed low self-perception levels of eco-responsible digital teacher profiles, especially concerning teacher training and the competence to design classroom experiences on the subject [40,41]. While it is true that teachers heard about the environmental impact of technologies, as highlighted also by other researchers [76,77], it is equally true that they did not clearly identify the technological uses that originate the impact or its implications [23]. The information they received is perhaps what allows them to identify actions proper to technologically eco-responsible teachers, such as the 3 Rs (reduce, recycle and reuse), the responsible consumption of applications and the use of respectful materials or renewable energies. However, their voices confirm the limited knowledge and training they showed in the descriptive study, insisting on the need to be trained both on the eco-responsible use of ICT in the classroom and how to teach it. It seems that the training is again perceived as the main problem and the main solution: therefore, this profile, based on an active and critical digital citizenship [78], could and should be promoted by teachers' initial and continuous training centers [12].

4.2. Positive Self-Perception of Males in the Eco-Responsible Use of ICT

Significant gender differences were found among the teachers in the study, which is in line with the results found in other papers. Kilinc and Aydin [79], for example, found that female and male teachers had different perceptions of the concept of sustainable development. The females focused more on the environmental, educational, social and political dimension, while the males leant more towards the environmental, economic and energy dimension. In general terms, results indicated women had a lower self-perception of themselves regarding: (a) their degree of knowledge about the environmental impact of ICT; (b) the true possibility of applying this knowledge when teaching; (c) recognizing the necessary teaching skills to reduce environmental impact and; (d) the ability to educate the educational community in the eco-sustainable use of ICT. The differences reported were small except for the capacity to define the technological uses that cause environmental impact and design didactics activities to inform about the risks caused by the use of technologies and how to prevent their environmental impact.

These results must be considered from a dual gender perspective. On the one hand the use and mastery of ICT and, on the other, environmental awareness. Starting with this latter aspect, substantial evidence confirms that women have played a primordial role in sustainable development [80,81] and they value questions related to sustainable development more strongly [82,83], a relevant fact in our study. Thus, in the absence of clear evidence of lesser environmental awareness in women, the results obtained could be partially explained by the existence of a digital gender gap. This gap is understood as the differences between the sexes in the use of technological devices [84]. One of the reasons for this gap is the intention to use technology [85], as women are more strongly influenced by perceived ease of use than men. Some studies have indicated the existence of a certain gender bias in the use of ICT tools, these tools being considered as more masculine in nature [86], both in work environments [87] and in training environments [88]. Therefore, the gender differences found in the study regarding the eco-sustainable use of ICT could be a consequence of the digital gender gap and not of women's lower environmental awareness [89]. In fact the study by Al-Sadee [90] showed women have more knowledge of and a more favorable attitude towards sustainable development.

4.3. Assessment of Differences According to the Stage: Secondary School Teachers Mark the Difference

Regarding the differences according to educational stage, they are especially relevant in the vast majority of questions. The reported differences are more noticeable as the level of education increases. Gender was found to be a significant factor among teachers of Secondary Education, with men in this collective obtaining the highest scores in their self-perception of technological eco-responsibility, especially connected with their didactic competence. However, no gender-based differences were found between teachers at primary level. These general findings lead us to ask where the root of this situation might be found. A partial explanation could be the diverse content worked on at each stage. In addition, several studies have indicated that teachers at higher educational levels show a greater mastery of technological resources [91]. The fact that there is usually a greater number of resources available in Secondary Education than in Primary Education could also play a part [92].

It is notable that, although the collective of male Secondary teachers describes themselves as being significantly more knowledgeable of the environmental impact caused by ICT with a greater capacity to apply this knowledge in their teaching and to be able to educate the educational community in the eco-sustainable use of ICT than women, no statistically significant differences were found between Primary and Secondary teachers as regards the capacity to help others to manage situations in which the use of technologies has a great environmental impact and to pass on this knowledge. These questions have an effect on the ability to train and inform students and families about the appropriate use of ICT [93]. Indeed, these items along with recognition of the environmental impact caused by the use of technologies are the only ones in which no significant differences can be seen between the two stages. These results (apart from the items highlighted, Secondary teachers score higher in didactic competence) would support the idea that in this case self-concept on this topic strengthens didactic competence, since according to the training model, Secondary education teachers receive less didactic training than those teaching in lower stages. It should be noted that Secondary education teacher training in Spain conforms to a consecutive models (psychopedagogical training is subsequent and diachronic with initial training in specific disciplinary content) [94].

Significant differences were also detected between the Primary and Preschool Education stages, the former obtaining generally higher scores. These results could be explained not so much by the educational stage—it has been proven that what affects more the use of ICT is rather pedagogical competence and professional experience [90], as by the complexity of the contents for being understood in the earliest stages. Thus, the key to overcoming these differences could depend on the curriculum and teacher training of this stage about these contents [71]. This idea was also confirmed by the data extracted from the questionnaire, since the item designed to measure the training followed by teachers in this area received the lowest score.

4.4. Building the Profile of the Technologically Eco-Responsible Teacher Based on Participants' Voices

The aspects discussed above allow us to generate a teaching profile regarding the sustainable use of ICT, that is, a series of characteristics that was complemented by the study's third objective. This objective was to interpret the proposals put forward by teachers to reduce the environmental impact of technology through their teaching practice. This latter objective was fulfilled and led to relevant proposals of actions proper to technologically eco-responsible teachers as well as educational suggestions on how to develop ICT eco-responsibility in students. Among the actions that were conducted in the classroom, teachers insisted notably on the 3R's, as well as the relevance of disconnecting devices, of consuming responsibly or of using renewable energy. Regarding the development of didactic proposals to promote ICT eco-responsibility attitudes in students, the teachers emphasized the importance of sensitizing and educating students by providing information [95–97]. The teachers highlighted the relevance of using active methods so as to promote meaningful, praxis-orientated, contextual and dialogical learning [53,98,99]. At the same time, they were committed to integrating these contents into the curriculum [100] and to becoming clear role models [101,102].

The study's limitations notably include its sample size, which could reduce the work's generalizability. Moreover, although three educational stages were considered, it would be interesting to increase the number of stages. While the analyzed sample focused on the Autonomous Community of Valencia, it would be relevant to repeat the study with a larger sample of teachers and educational levels, including Higher Education. Nevertheless, the results do provide an overview that may help to bring teacher training into line at a practical, political and curricular level.

Another limitation of the study could be its use of a single measurement scale. It would be a good idea to take this point into account in future studies.

5. Conclusions

We can conclude that teachers at non-university educational stages consider that they do not have a high level of digital competence regarding the eco-responsible use of ICT. Therefore, given that sustainable development is becoming a necessity in our environment [102], we recommend the implementation of teacher training programs. In fact, based on the qualitative analysis performed, teachers pointed to the following pillars: sensitization and awareness, active methodologies and experience learning, integration into the curriculum, informing families and tutorial action [51]. In addition, we found that the male teachers' self-perceived eco-sustainable digital competence was greater than the women at the same teaching stage. In this regard, we suggest the need for programs and studies aimed at making this digital gender inequality disappear. In addition, we confirmed the relationship between the higher teaching stage and self-perception in the mastery and use of ICT, Secondary school teachers being more eco-responsible than Primary teachers and the latter, more than Preschool teachers.

Finally: we believe governments and institutions should promote training on the sustainable use of educational technology as significant deficiencies were detected among Preschool, Primary and Secondary Education teachers. It would be necessary to direct efforts towards the construction of a training model based on a holistic approach to sustainability.

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