applied sciences

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Combining CS Unplugged and L2T2L to Bridge the Computing Illiteracy Gap of the Elderly Population: A Case Study

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Abstract: In the era where digital technologies are becoming increasingly prevalent, it is anticipated that a majority of the global population will have at least a basic understanding of informatics. However, empirical evidence suggests that a significant portion of the global population remains digitally illiterate. This phenomenon is particularly pronounced in the case of the senior adult population. In light of the aforementioned challenges, this work integrates Computer Science Unplugged exercises, based on games and recreational activities without the use of computers, and L2T2L, a learning-by-teaching methodology whereby university students learn and then, in turn, teach that learning to other populations in a cascading manner. A case study was conducted in Lima, Peru, with the participation of 140 volunteers from centres for the elderly. Thirty-five students and one teacher from the Universidad Científica del Sur were responsible for initiating the transfer of knowledge from the university to the senior citizens, with the assistance of twelve individuals responsible for their care. The results demonstrate that the participants attained a commendable level of comprehension when attempting to complete all of the assigned tasks. Furthermore, the efficacy of L2T2L is evident in its adaptability and suitability for scenarios beyond those for which it was originally designed.

Keywords: informatics; computer science unplugged; elderly; computing illiteracy; learning; learning by teaching

Academic Editors: Tomislav Jagušt, Peter Seow Sen Kee, Martina Holenko Dlab and Ana Sović Kržić

Received: 3 December 2024
Revised: 9 January 2025
Accepted: 15 January 2025
Published: 17 January 2025

Citation: Díaz-León, J.A.; Arbelaitz, O.; Larrañaga, M.; Arruarte, A. Combining CS Unplugged and L2T2L to Bridge the Computing Illiteracy Gap of the Elderly Population: A Case Study. *Appl. Sci.* **2025**, *15*, 919. https://doi.org/10.3390/app15020919

1. Introduction

At a global level, during the last decades, there are two facts that have converged and affected the evolution of the world population, as follows: the ageing of the population and the development of the information society.

By 2015, people over the age of 60 were the fastest growing group worldwide, with 901 million people aged 60 years [1]. This number is expected to increase to 1.4 billion in 2030 and to 2.1 billion in 2050. The size of the older population is estimated to grow extremely rapid in Latin America and the Caribbean, with an increase of more than 70% between 2015 and 2030 (https://www.cepal.org/es/enfoques/panorama-envejecimiento-tendencias-demograficas-america-latina-caribe?utm_source=chatgpt.com; accessed on 30 November 2024). Population ageing is a multidimensional process that must be studied from different perspectives, including demographic, biological, psychological, cultural, and social processes.

As regards the presence of information and communication technologies in society, everyday life is becoming increasingly digital, and all members of society are expected to adapt to and use digital technologies [2]. The use of digital technologies can bring many benefits to the elderly population, as follows: social interaction, personal autonomy when accessing information and culture, health monitoring, and increased motivation and self-esteem derived from maintaining an active mind. However, in a world where ageing has traditionally been seen as a process of decline, loss of function, and deterioration, where the so-called disengagement theory—which asserts that it is natural for the older people to withdraw from society and personal relationships as they age—is seen as acceptable, it is necessary to develop social construction theories of ageing that move away from this belief [3].

Demographic and technological changes in the world not only pose major challenges for the development of ageing policies, but also offer new opportunities and perspectives. Responding to the challenges of ageing is crucial for both governments and civil society to promote higher levels of active and successful ageing. In this context, education and learning play a key role in improving the quality of life and well-being of older people [4].

As in most countries, the ageing of the population has led to a significant increase in the proportion of older adults in Peru, where the specific study to be presented in this work is based. According to data from the National Institute of Statistics and Informatics (Instituto Nacional de Estadística e Informática, INEI) collected in the INEI report [5], in 2021, approximately 13.0% of Peru's population was aged 60 or over. As far as the educational level of this population is concerned, 13.4% have no or very little education, 36.8% have completed primary education, 26.8% have completed secondary education, and 23.0% have completed higher education (14.6% with a university degree and 8.4% with a non-university degree). Focusing on the gender gap, there is also a significant gap between men and women in terms of access to education. The INEI report [6] shows that only 19.6% of older women have reached a higher level of education, while the percentage of men in the same category is 26.7%. Regarding the management and use of information technologies, or the knowledge of what computers are and what benefits they can bring, the INEI report [7] shows that the management of information technologies among older women in Peru is limited. In 2021, only 8.5% of women aged 60 and over used the Internet.

There are studies that support the effectiveness of computer-based cognitive training programmes as intervention tools in preventing and delaying cognitive decline in old age [8]. A study on cognitive development in adulthood and old age [9] emphasises the importance of learning new subjects in older adults to improve their quality of life. Introducing computers to older people can have a positive impact on their cognitive functioning, mood, and social integration [10]. However, this group may face challenges when learning computer science concepts, particularly those with low educational levels [11]. Factors such as age, education level, income, and social isolation can significantly influence computer and Internet use among older people [12]. Techniques such as Computer Science Unplugged (CS Unplugged), in which computer science concepts are taught without the use of computers, can help to overcome some of the existing barriers to teaching computer science concepts to the older population [13].

In this context, the work carried out has a twofold objective, as follows:

- To validate the suitability of using unplugged computing activities to teach computing concepts to an adult population, particularly older people.
- To validate the adaptability of the L2T2L pedagogical strategy to transfer computing knowledge from university students to older adults. L2T2L (Learn to Teach to Learn) is a learning by teaching methodology that has students learn and then, in turn, teach that learning to other students, in a cascade starting from university [14]. Variants of L2T2L were previously used to transfer computing knowledge from university students to primary and secondary school students [14,15] or from university students to prisoners [16].

The case study presented in this article was conducted in centres for the elderly in Lima, Peru, during the 2023–2024 academic year with 140 volunteers. Through CS Unplugged exercises based on games and recreational activities, students from the Universidad Científica del Sur, Peru, initiated the teaching of computer concepts to the elderly without the use of computers. This study has not only shown the positive attitude of the elderly towards computing, but also the suitability of the combination of CS Unplugged and L2T2L to transfer computing skills from the university to the centres for the elderly. Initiatives such as the one presented in this work can significantly contribute to an improvement in the cognitive activities of the elderly and to re-education, improving the quality of life of this population in the community.

This article is structured as follows: Section 2 presents a review of the literature on teaching computing to older people, together with an introduction to CS Unplugged. Section 3 focuses on describing both the methodology used to transmit knowledge associated with certain topics of computing from the university to centres for the elderly and on detailing aspects related to its implementation. Section 4 elaborates on the results obtained. In Section 5, comparisons with the results of previous studies carried out with different populations of students and with inmates in prison are presented. Finally, Section 6 points out some conclusions and future lines of research.

2. Literature Review

This section covers two main topics. First, it looks at how computer education for older adults has been approached, and then briefly introduces the concept of unplugged computing (CS Unplugged).

2.1. Computer Education for the Elderly

Although several studies have been carried out with the aim of introducing computing concepts to the elderly population, it should be noted that there are more studies that have focused on analysing aspects of how this population uses technology, rather than on teaching what computing itself is and what its basic principles are. For example, literature reviews have been written to analyse the use of smart health devices by the older adult population [17,18], to review the impact of Internet use on the quality of life of this population [19], and to highlight the potential of computer-based foreign language learning programmes for cognitive training and brain plasticity [20]. It is true that teaching computer science to older people often requires the adaptation of software products created by educational developers [21] or the development of specialised educational programmes that require prior training of the personnel in charge of transmitting this information [22,23]. However, much of this transmission has been carried out through so-called warm experts—family members or friends [24,25]—and often through community services [26] or non-formal learning settings [27].

In the case of Europe, a number of studies and programmes have been developed to analyse the response of older people to digital development [28] or to introduce computer science topics to older adults. For example, the work presented in [11] explores the first encounters with programming of older people with low levels of formal education over a 6-month period in an adult education centre in a working-class neighbourhood of Barcelona. Pihlainen and colleagues [29] present the interdisciplinary ACCESS study, conducted in Austria, Finland, and Germany, which analyses the reasons why retired older adults participate in digital literacy opportunities. The work presented by Ramos García and colleagues [30] analyses the use of different educational approaches (intergenerational, peer-to-peer, and online) to teach digital skills to older people in four European countries. The European Commission has also funded projects with the aim of providing the adult population with digital skills. This is the case of programmes such as DISK digital skills for an ageing Europe (https://diskproject.eu/; accessed on 15 November 2024), MILEAGE Media and Information Literacy and Digital Competences Enhancement for Active Aging (https://mileageproject.eu/; accessed on 15 November 2024), TeleGrow (https://telegrow.erasmus.site/; accessed on 15 November 2024), SmarthHome4SENIORS (https://sh4seniors.erasmusplus.website/; accessed on 15 November 2024), E-engaged (https://engaged.altervista.org/; accessed on 15 November 2024), DIGITGERA (https://digitgera.eu/; accessed on 15 November 2024), and Skills to Connect (https://www.pourlasolidarite.eu/en/project/skills-connect-digital-skills-service-seniors), they are developed with different objectives, such as analysing the specific barriers that the digital environment poses to this population, creating platforms that bring together different training courses to improve memory and learning skills of older people, providing knowledge and skills to help professionals to be more effective in creating an interesting learning environment for older people, etc.

Studies have also been conducted in various countries in Asia and Oceania to understand the relationship between the older adult population and technology. These include Hong Kong [31], Taiwan [32], Australia [33,34], India [35], South Korea [36,37], and China [38]. Intercultural studies between different Asian countries have also been carried out, such as the one presented in [39] or the one presented in [40], in which people from Japan and Germany participated. Several programmes have been developed with the aim of teaching digital skills to older people. This is the case of the Digital Literacy Training for Seniors (https://officeforseniors.govt.nz/our-work/digital-inclusion/digital-literacy-training-for-seniors/; accessed on 15 November 2024) or Seniornet (https://seniornet.nz/; accessed on 15 November 2024) programmes developed in New Zealand and Singapore, respectively, through the Digital for Life programme (https://www.imda.gov.sg/about-imda/who-we-are/digital-for-life; accessed on 15 November 2024), and in Australia through the Be Connected programme (https://www.dss.gov.au/seniors/be-connected-improving-digital-literacy-for-older-australians; accessed on 15 November 2024), which is managed by the Australian government.

Although on a much smaller scale, there are also programmes developed on the African continent, such as the iGOGO—Gogos With Vuma programme [41], developed in South Africa. However, on this continent, most efforts are focused on bridging the digital divide between technologically developed and technologically developing countries, rather than on providing digital skills to the older population [42]. It should also be noted that their reality is different; moreover, the world's population is ageing, with the only exceptions being sub-Saharan Africa and parts of Oceania [43].

In the Americas, the digital divide between countries and between urban and rural areas is also significant. For example, much more has been carried out in the North than in the South to promote computer literacy among older people. In the case of Canada, for example, Marcotte [44] presents a detailed review of the barriers that exist and the programmes that are being implemented, with the aim of implementing successful digital literacy processes for the older adult population. Mullins [45] suggests practices that may be successful in achieving this goal. In the case of the United States, there are studies that analyse older people's attitudes towards technology and the different forms of social support that may be appropriate in this regard [46,47]. There are also numerous organisations and programmes that promote technology education for this population. This is the case of Older Adults Technology Services OATS (https://oats.org/; accessed on 15 November 2024), AARP (www.aarp.org; accessed on 15 November 2024), Senior Planet (https://seniorplanet.org/; accessed on 15 November 2024), SBSS (https://sbsstech.my.canva.site/welcome-to-tech-education; accessed on 15 November 2024), and GOAL (https://theprojectgoal.org/about/; accessed on 15 November 2024), among others. Continuing on the American continent, in [48], in addition to presenting a review of the state of the use of digital technologies by the older adult population in Latin America and the Caribbean, policies and programmes implemented to promote the inclusion of this group in society by using digital technologies are highlighted. However, in many countries and regions of Latin America, the aim is once again to close the existing digital divide between technologically developed areas and technologically developing areas [49].

Finally, it should be noted that virtually all of the works mentioned above consider computing only at the level of the user of applications and technology, and do not deal with the underlying concepts of computing as a science.

2.2. Computer Science Unplugged (CS Unplugged)

CS Unplugged [13] is based on teaching basic computing concepts and computational thinking skills without the use of digital devices through a constructivist approach to knowledge. The idea behind this initiative, originally conceived in the 1990s, was that young students could understand the ideas behind computing through activities and games. Since then, many organisations and projects have worked together to develop new materials and content for learning by doing–Computer Science for Fun [50], code.org unplugged [51], and Bebras [52], among others.

CS Unplugged was originally designed and implemented in a technologically developed environment, specifically at the University of Carterbury, New Zealand [53]. The idea behind the proposal was to implement a new way of teaching computing concepts in primary schools, with materials in English. Since then, CS Unplugged has become a multicultural and multilingual initiative, used in different educational settings and levels, and even beyond the formal education setting. Moreover, it has gone from being used only in technologically developed scenarios, where it was decided not to use computers, to being used in technologically developing areas and countries where computers are not available. There are even hybrid scenarios where CS Unplugged activities are combined with activities carried out with a digital device [54].

There are various literature reviews on the CS Unplugged approach, most of which support the use of unplugged computing mainly in formal education settings [55]. Specifically, most of the experiences correspond to primary and secondary education and to subjects directly related to computing and STEM education [56,57], or to the teaching of more specific content, such as the concept of algorithm [58].

However, the experience gained by the authors of this article supports the suitability of the CS Unplugged approach for other educational levels and scenarios. For example, in [14], university students in a technologically developed area were involved in transferring computing concepts from university to primary and secondary education. In [15], university students were involved in the transfer of computer concepts to primary and secondary levels in a rural environment and during the COVID-19 pandemic. Finally, in [16], the final population to receive training was an adult population incarcerated in a correctional centre. In a way, these experiences make the CS Unplugged technique a potential approach for learning computer concepts, not only by young people and in formal educational settings, but also by adults in non-formal educational scenarios. In addition, it should be mentioned that no references have been found for the application of CS Unplugged to the elderly population. The work presented in this article aims to demonstrate that CS Unplugged can also be valid for teaching computer science to the elderly in a non-formal educational setting carried out in centres for the elderly.

3. Materials and Methods

The methodology used in this proposal to transfer informatics knowledge to an older adult population, through CS Unplugged exercises and games, is based on a new adaptation of the Learn to Teach to Learn (L2T2L) methodology, previously used in both educational [14,15] and correctional settings [16].

This new variant of the L2T2L methodology (Figure 1) requires university teachers (Group 1) to initiate the process and transmit information about the methodology to be used to their students (Group 2). Furthermore, both groups, students (in groups of 5 people) and teachers, work together to study the content to be transmitted and prepare the materials to be used during the experience. Subsequently, the university students (Group 2) are responsible for delivering and transmitting the agreed materials and knowledge to the responsible individuals in the centres for the elderly (Group 3) and to the elderly population (Group 4).

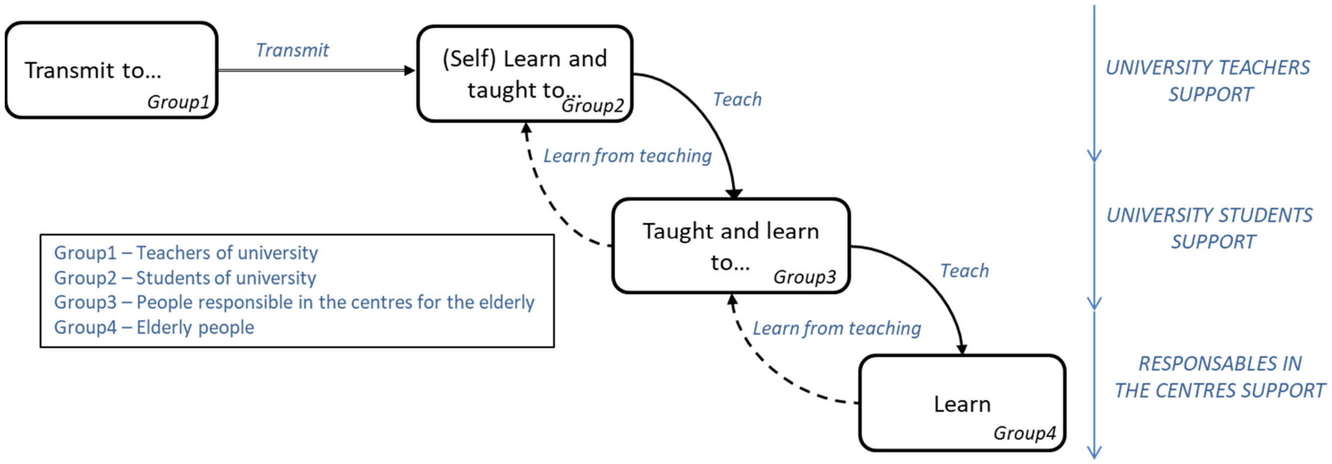

Figure 1. Pedagogic strategy.

The responsible staff at the centres for the elderly (Group 3) use the information and educational material provided by the university students (Group 2) to perform their task. The educational material includes exercises and activities based on CS Unplugged (http://csunplugged.org/; accessed on 10 October 2024), Computer Science for Fun (http://www.cs4fn.org/; accessed on 10 October 2024), code.org (https://code.org/; accessed on 10 October 2024), Scratch (https://scratch.mit.edu/; accessed on 10 October 2024), Bebras (http://bebras.org; accessed on 10 October 2024), and other resources, as described by Larraza-Mendiluze and colleagues [59], who covered mainly the following three topics: Introduction to computational thinking, Representation of information in computers, and Fundamentals of programming and algorithms. Therefore, in this new experience, in addition to using a new variant of the L2T2L methodology, the topics of previous experiences are also reused [14–16].

The experience was carried out in Lima, Peru, in the first semester of the 2023–2024 academic year. The collaboration of the Universidad Científica del Sur and 10 centres for the elderly (Hogar Canevaro, Gerontological Residential Care Center, Hogar San Vicente de Paúl, Casa de Soso Santa Rosa de Lima, Virgen del Carmen Residential Care Center, Hogar de Ancianos San José, San Pedro Residential Care Center, Hogar de Ancianos La Divina Misericordia, Hogar Canevaro, and Gerontological Residential Care Center) ensured the success of this project. A total of 140 elderly volunteers, all of them healthy and over 50 years old, took part in the project, including 71 men and 69 women. By age, there were 82 people over 60 (40 men and 42 women) and 58 people under 60 (28 men and 30 women). In addition, 35 university students participated in this study.

They were enrolled in the Thesis Seminar course, an optional and transversal course in the last year shared between 9 degrees (Business Administration—4 students-, International Business Administration—5 students-, Information Systems and Management Engineering—5 students, Business Systems Engineering—6 students, Economics and Business Engineering—4 students, Marketing and Administration—5 students, Accounting and Finance—3 students, Marketing and Advertising—2 students, and Network Administration and Computer Security—1 student). Twelve people responsible for the care of the elderly also participated in the experience at the centres for the elderly.

During the experience period, the university students, university teachers, individuals responsible for care in the centres for the elderly, and senior citizens were in charge of the tasks summarised in Table 1. The table specifies the group or groups of people in charge of performing each task, as well as the time period in which the task was performed.

Table 1. Timeline of task distribution.

	Month1	**Month2**	**Month3**	**Month4**	**Month5**
Training of university students	Group1 Group2	Group1 Group2	Group2	Group2	Group1 Group2
Recruitment of centres	Group2				
Recruitment of elderly volunteers	Group2 Group3				
Training of individuals responsible for care in the centre		Group2 Group3	Group2 Group3	Group2 Group3	Group2 Group3
Pre-test		Group 4			
Doing exercises		Group3 Group4	Group3 Group4	Group3 Group4	Group3 Group4
Post-test					Group4

The activities carried out ensured that the older adults not only learned about computers, but also promoted their cognitive skills [9,10]. Each of the 10 exercises developed by the elderly included knowledge of a topic related to computing, which allowed them to work on concepts such as the following: What are algorithms and what are they used for?; Binary codes; Break down, identify patterns, abstract, and generate an algorithm; What is computational thinking?; Search and sort data; Introduction to programming; Coding and iteration with blocks; and Conditional sentences and variables.

We evaluated the teaching methodology used and the level of transmission of computer concepts through the CS Unplugged contents by collecting data through surveys before, during, and after the experience.

To ascertain whether there was a change in the participants' perception of informatics following their experience of working with the CS Unplugged contents and completing all of the exercises and activities, the participants completed the same survey before commencing the experience and again after it had concluded. The survey (see Table 2) comprises 23 closed-ended statements with 5 values on a Likert scale of 1–5 (1—total disagreement; 5—total agreement). It is the same survey used in the initial scenario [14], with two slight modifications to two items: 11 and 15. Items 11 and 15 were modified as follows: in item 11, the verb tense of the sentence was altered from "When I grow up I want to work in informatics" to "I would like to work in informatics"; and, in item 15, the phrase "When I grow up I want to study informatics" was replaced with "I would like to continue to delve deeper into informatics".

Table 2. List of the closed statements included in the survey (adapted from [14]). The modified statements from the initial scenario are shaded, and the modifications are marked in bold.

Statement	Item
Using the Internet is central to informatics	1
Using text editors (Google Docs, Word...) is central to informatics	2
Installing software/programs is central to informatics	3
Programming is central to informatics	4
Being able to solve different problems is central to informatics	5
I think I am capable of studying informatics	6
Informatics is an area related to math	7
I am good at science	8
The computer scientist should be good at cooperation	9
The computer scientist is a nerd	10
I would like to work in informatics	11
Men are better than women at studying informatics	12
The computer scientist should have a mathematical way of thinking	13
Work in informatics requires long hours	14
I would like to continue to delve deeper into informatics	15
Working in informatics is fun	16
Computer science workers earn a lot of money	17
I am good at math	18
Work in informatics can be done without a computer	19
Informatics is a boring subject	20
Informatics is used in almost all professions	21
People who work in informatics should use their creativity	22
In general, I like informatics	23

We analysed the data collected during the case study and made comparisons with the results obtained in previous studies conducted in different contexts and scenarios. To fulfil this purpose, we used Cohen's D [60] to measure of effect size of the difference (the magnitude of the difference in standard deviation units) and Student's T test to measure the significance of the differences.

In addition to the aforementioned data collection methods, surveys were also employed to gather information about the CS Unplugged exercises. Upon completion of each CS Unplugged task, each senior responded to a brief three-question survey with the objective of assessing the difficulty of the exercises and the extent of task completion. To this end, the university students elected to repurpose the survey initially developed for a prior experience, wherein each question was answered on a Likert scale of 1 to 5 (1—nothing; 5—all/a lot) (see Table 3).

In order to enhance the quality of the findings and gain an external perspective on the learning outcomes of the students, the instructors were requested to assess the extent of learning they believed each of the students, older adults who had participated in the training, had achieved. The question posed was as follows: "Do you consider that the individual's knowledge of computers has improved?" Once more, the responses were provided on a Likert scale comprising 5 values (1 = a little, 2 = somewhat, 3 = regularly, 4 = quite a lot, 5 = a lot).

Table 3. List of short questions to assess exercise completion and understanding (from [16]).

Statement	Item
Where you able to finish the exercises?	1
How many exercises did you find to be complex?	2
Do you think you understood the concept?	3

4. Results

This section presents an analysis of the impact of the intervention on older adults analysing the change produced in their perception of informatics and their level of achievement, to confirm the efficacy of the methodology and materials employed, as well as to assess the extent to which the methodology can be applied in other contexts.

The analysis of older adults' perception of informatics will be conducted by classifying the survey items according to the subject matter with which they are concerned. The following items will be analysed: items 1, 2, 3, 4, 5, 19, and 21, which relate to knowledge of informatics; items 6, 8, and 18, which relate to self-perception or personal perception of knowledge; and items 7 and 13, which relate to knowledge of the relationship between informatics and mathematics. The remaining items pertain to the following areas: characteristics or profile of people working in informatics (items 9, 10, 14, 17, and 22), liking for informatics (items 11, 15, 16, 20, and 23), and gender stereotypes (item 12).

The reliability of the data collected in each questionnaire was found to be greater than 0.9, as determined by Cronbach's Alpha, which is deemed to be an acceptable level of reliability for this type of questionnaire [61,62].

In addition, a final analysis will examine the extent to which the exercises performed by this population of adults have been achieved and understood and their level of learning according to their supervisors' view.

4.1. Older Adults' Perceptions of Informatics Before the Experience

Table 4 illustrates the mean values obtained for the pre-test (preT column) and post-test (postT column) questionnaires in the 23 closed statements. The results of the pre-test indicate that older adults have a general understanding of informatics and its associated occupations, although, in some cases, their responses were not entirely accurate. For instance, the respondents exhibited a positive response to all queries pertaining to computer literacy, including the necessity of the Internet, the utilisation of text editors, the installation of programs, the processes of programming, and problem solving. In each case, the average score was approximately 3.5 or above, indicating a perspective that is likely shaped by user experience, or at the very least, external to informatics, given that not all statements are entirely accurate. The self-perception scores are somewhat lower; however, they nevertheless exceed 3 on average for all three questions, namely computer studies ability, science ability, and mathematical ability. However, in the case of knowledge of the relationship between informatics and mathematics, especially when asked whether those who work in computer science should have a mathematical mind, it was below 3. The questions corresponding to the characteristics of the people who work in informatics were also answered positively in general, with mean values that exceed 3, obtaining the lowest mean score, 3.16, in the case of question 14, working hours, and the highest mean score, 3.86, in the case of the use of creativity (item 22). The respondents also showed a liking for informatics, as they obtain scores that exceed 3.2 in items 15, 16, and 23, and, on the contrary, they stay close to 2.5 in the question of whether computers are boring. On the other hand, these same people showed a certain reluctance to work in informatics in the future, with an average value of 2.78 in item 11. Finally, gender stereotypes are not very noticeable since, in general, men are not considered better than women, obtaining an average value of 2.14 in item 12.

Table 4. Comparison of pre- and post-tests for older adults. Where the perception of informatics is analysed, statistical significance levels are marked with (**) when significant differences existed at significance level alpha = 0.01, and with (*) when the significance level was alpha 0.05. The effect size has been calculated using Cohen's D and has been marked in italics when the impact is small, and bold for medium impact.

CD	postT	preT	*p*-Value	t-Value	Statement	Item
0.25	4.07	3.82	0.06	−1.86	Using the Internet is central to informatics	1
0.09	3.63	3.53	0.48	−0.71	Using text editors is central to informatics	2
0.01	3.84	3.84	1	0	Installing software/programs is central to informatics	3
0.34	3.87 **	3.51	0.01	−2.62	Programming is central to informatics	4
0.13	3.51	3.36	0.3	−1.04	Being able to solve different problems is central to informatics	5
0.06	3.26	3.20	0.67	−0.43	I think I am capable of studying informatics	6
0.40	3.61 **	3.17	0	−3.08	Informatics is an area related to math	7
0.31	3.40 **	3.07	0.02	−2.36	I am good at science	8
0.11	3.72*	3.61	0.42	−0.81	The computer scientist should be good at cooperation	9
0.32	3.73 *	3.39	0.01	−2.45	The computer scientist is a nerd	10
0.31	3.12 **	2.78	0.02	−2.35	I would like to work in informatics	11
0.68	2.96 **	2.14	0	−5.28	Men are better than women at studying informatics	12
0.25	3.24	2.96	0.05	−2	The computer scientist should have a math way of thinking	13
0.49	3.65 **	3.16	0	−3.8	Work in informatics requires long hours	14
0.01	3.25	3.24	0.95	−0.07	I would like to continue to delve deeper into informatics	15
0.06	3.29	3.21	0.58	−0.56	Working in informatics is fun	16
0.31	3.67 *	3.34	0.02	−2.36	Computer science workers earn a lot of money	17
0.26	3.41 *	3.14	0.05	−1.95	I am good at math	18
0.61	2.96 **	2.16	0	−4.75	Work in informatics can be done without a computer	19
0.76	3.33 **	2.56	0	−5.82	Informatics is a boring subject	20
0.14	3.66	3.51	0.28	−1.07	Informatics is used in almost all professions	21
0.05	3.91	3.86	0.68	−0.41	People who work in informatics should use their creativity	22
0.05	3.59	3.53	0.64	−0.46	In general, I like informatics	23

4.2. Effect of Experience on Older Adults' Perception of Informatics

Table 4 illustrates the substantial alterations in numerous pivotal elements subsequent to the educational intervention. These outcomes indicate a notable transformation in the perception of older adults towards informatics, which has had a predominantly favourable impact on the participants.

In terms of computer literacy, the surveys conducted following the intervention indicate a tendency towards maintenance or slight increase, even in items such as the need for the Internet. However, no statistically significant differences were observed overall, but the magnitude of the effect according to Cohen's D were found to have a small size in some of the cases. Nevertheless, two cases emerge in which statistically significant differences are observed at the 99% level. The first of these is item 4, which inquires whether programming is essential in informatics. Here, the mean value of the response increases with small effect size according to Cohens' D, indicating that participants in the experience now possess a heightened awareness of computer work that extends beyond the mere user. The second case is item 19, which assesses the ability to work in informatics without using computers. Here, the mean value of the response increases with a medium effect size, indicating that the population is more aware of this fact.

The intervention has a positive effect on older adults' self-confidence, as evidenced by an overall increase in self-perception and statistically significant differences in the case of science and mathematics skills (items 8 and 18), with small effect sizes. Similarly, it seems that, after the experience, there is a more pronounced understanding of the relationship between informatics and mathematics, with statistically significant differences at 99% but a small effect size in the case of item 7.

Concerning the characteristics of individuals engaged in informatics, there is a statistically significant increase in the perception that collaboration is essential (item 9), the value of extensive study (item 10), the capacity to work long hours (item 14), and the potential for high remuneration (item 17), with small effect sizes in all cases. However, the perception of the intrinsic enjoyment of informatics (item 6) and the necessity for creativity (item 22) does not exhibit a similar magnitude of increase.

Conversely, there is a slight increase in the proportion of respondents who express a liking for informatics (items 15, 16, and 23), while the proportion who perceive it as boring increases significantly (item 20). There is also a notable rise in the number of respondents who indicate a preference for pursuing a career in informatics (item 11).

Ultimately, the results of the experiment indicate a statistically significant difference in the perception of men and women's abilities in informatics, with 99% confidence. This finding deviates considerably from the intervention's intended outcomes.

In conclusion, it can be stated that the intervention resulted in alterations to the manner in which older adults perceive informatics. In certain instances, these modifications are in a favourable direction, exemplified by an enhancement in self-perception, heightened awareness of the function of programming, and a stronger aspiration to pursue a career in informatics. However, there are also unanticipated consequences, including an increase in the conviction that men are more proficient in informatics than women are.

4.3. Level of Achievement and Understanding of the Tasks

The aim of the second phase of this study was to assess the level of understanding and success in solving the ten proposed computer science exercises.

Figure 2 shows a summary of comprehension and achievement level of the ten assignments proposed in the experience. Most of the older adults managed to complete the vast majority of the exercises, but not without difficulties, since in every task they found more than half of the exercises to be complicated. The data suggest that the overall level of understanding was good, as the average score in solving the exercises exceeded expectations. This finding is particularly relevant, as most of the participants had no prior knowledge of concepts such as algorithms, search, and loops, so these topics were completely new to them.

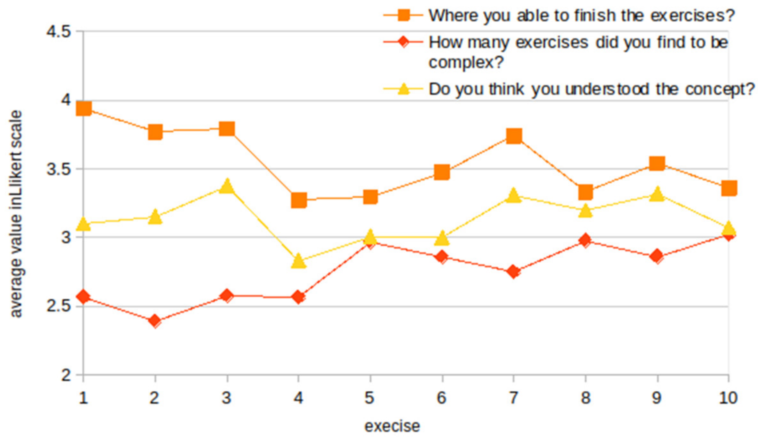

Figure 2. Achievement level and comprehension of the tasks.

The level of performance was not the same for all tasks, as some activities were found to be more difficult for the elderly. In particular, tasks 4, 8, and 10, related to algorithms, search, and loops, were more difficult to understand and solve. However, even in these cases, a satisfactory level of completion of the exercises was observed. Thanks to the support provided by the tutors, the older people were able to overcome the initial difficulties and successfully complete the exercises. This support was a key factor in the successful understanding of the exercises. Informatics allowed the seniors to access additional explanations and clarification of concepts that would otherwise have been more difficult to understand. The constant guidance and support provided during the completion of the exercises was instrumental in maintaining a high level of confidence in the older adults, thus facilitating the successful completion of some of the tasks.

The older adults' ability to overcome these challenges and complete the exercises, as well as their responses in the surveys, suggest that these types of activities not only improve their computer literacy, but also promote greater confidence in their ability to face technological challenges in an increasingly complex digital age. In addition, as a side effect, some cognitive skills were also promoted. For example, logical thinking and problem-solving activities fostered older people's ability to analyse situations, break down complex problems into manageable parts, and develop step-by-step solutions, which benefit them in making everyday decisions and solving practical challenges. Memory and attention are worked on, as practicing computer logic requires retaining key information and paying attention to detail. Solving computer problems involves exploring different approaches, which strengthens the ability to adapt to new situations and perspectives. Finally, understanding logical structures and algorithms improves the ability to identify patterns and make connections between concepts, useful in activities such as planning and organisation.

4.4. Learning Level of Older Adults According to Their Instructors

A survey was administered to the instructors involved in the educational process to ascertain their perceptions of the impact of the training on older adults. The survey concentrated on the extent of knowledge acquired by older adults in informatics-related topics and their capacity to apply it in practice (see Section 3).

The results demonstrate that improvement was perceived to be for 34.43% of the senior cohort fair *(regular)*, 40.98% of the seniors enhanced considerably *(quite a lot)*, and 11.48% substantially *(a lot)*. Conversely, only 12.30% of the students were reported to have had minimal *(a little)* improvement.

The results were also analysed according to age group. In the cohort of older adults between the ages of 50 and 64, 35.8% of the participants were classified as having experienced a moderate *(regular)* improvement, for 38% of them a notable enhancement was reported *(quite a lot)*, and, for 15%, a substantial *(a lot)* improvement was indicated. In the case of the group of older adults over 64 years of age, for 43.6% of the students, the improvement was considered quite significant *(quite a lot)*, for 32.7% it was considered fair *(regular)*, and for 14.5% it was considered slight *(a little)*. Overall, there was a favourable perception of improvement in their informatics literacy for both age groups. However, the older cohort (aged 64 and above) appeared to demonstrate a slightly lesser increase compared to the younger group.

The gender-based analysis revealed that, according to the supervisors, 29% of the male students were perceived to have had a considerable *(quite a lot)* improvement in informatics skills, while, for female students, this percentage was 21%. When combining categories, 47% of the female participants achieved a significant *(quite a lot)* or fair *(regular)* improvement, whereas the percentage was 45% for males. However, the distribution between both categories shows that the learning was considered greater for male participants (29 vs. 21 in significant improvement).

Additionally, the supervisors were queried about the necessity for modifications to the exercises or difficulties encountered when transmitting knowledge. While the materials were generally deemed adequate, some adaptations were proposed, including an increase in the font size and the inclusion of additional visual examples. Conversely, these suggestions appear logical given the age of the participants.

5. Discussion

The results prove that the proposed methodology is a viable tool for populations with minimal familiarity with technology. The older adults were able to complete the vast majority of the suggested tasks without much difficulty, gradually improving their understanding and learning.

A comparison to the effects in the participants' perception of informatics and achievement level in previous experiences [15,16] will assess the extent to which the adaptation of the methodology has been good and if it can be applied in other contexts.

5.1. Comparison Between the Attitude of Older Adults and Younger Rural Students

The first comparison has been carried out with results obtained in a previous experience conducted to introduce computer literacy from an early age during the pandemic with Peruvian students residing in disadvantaged areas [15]. In particular, the responses of older adults were compared with those of secondary school students. It was assumed that secondary education students were more mature than those in the primary stage, and, therefore, more similar to the target population (see Table 5 columns Secnd and CD_S).

The analysis of the entry point, or the test carried out prior to the experience, reveals that secondary school students exhibited a more positive response, with higher mean values, across all items. As a general trend, in some instances, older individuals demonstrated more accurate knowledge, while, in others, high school students exhibited this proficiency.

Table 5. Comparison of initial and final test results for older adults and schoolchildren. Statistical significance levels are marked with (**) when significant differences existed at significance level alpha = 0.01, and with (*) when the significance level was alpha 0.05. The effect size has been calculated using Cohen's D and has been marked in italics when the impact is small, bold for medium impact, and bold underlined for large impact.

Pre-Test					Post-Test					
CD_I	Inmat	CD_S	Secnd	Older	CD_I	Inmat	CD_S	Secnd	Older	It.
−1.89	**2.14** **	−0.11	3.96	4.07	0.00	4.07	0.14	4	3.82	1
0.89	2.57 **	−0.47	4.15 **	3.63	**−0.54**	4.21	**−0.54**	4.18 **	3.53	2
0.26	3.57	0.34	3.50 *	3.84	−0.25	4.14 *	0.24	3.55	3.84	3
−0.51	4.43	0.11	3.75	3.87	**−0.72**	4.36 **	0.02	3.48	3.51	4
−0.60	4.14	−0.32	3.85	3.51	**−0.75**	4.36 *	−0.3	3.75	3.36	5
−1.21	4.57 **	−0.15	3.44	3.26	**−0.55**	3.86 **	**−0.58**	3.89 **	3.20	6
−0.97	4.71 **	0.04	3.56	3.61	**−1.51**	5.00 **	−0.14	3.34	3.17	7
0.24	3.14	0.08	3.31	3.4	**−0.94**	4.29 *	−0.4	3.59 *	3.07	8
−0.12	3.86	−0.47	4.23 **	3.72	0.15	3.43 **	**−0.54**	4.27 **	3.61	9
2.33	1.14 **	−0.05	3.79	3.73	**−0.84**	4.43	−0.35	3.86 *	3.39	10
−0.13	3.29	**0.81**	2.06 *	3.12	**−1.16**	4.14 **	0.08	2.7	2.78	11
1.12	1.43 **	0.21	2.65 **	2.96	−2.31	4.93	−0.14	2.34	2.14	12
0.94	2.00 **	−0.01	3.25	3.24	1.60	1.14	−0.16	3.18	2.96	13
0.68	2.86 **	−0.29	4.02	3.65	0.78	2.29	**−0.76**	4.18 **	3.16	14
−0.36	3.71	0.01	3.23	3.25	0.25	2.93 **	−0.05	3.32	3.24	15
−0.59	4.00 *	−0.07	3.4	3.29	−1.35	4.79 **	−0.37	3.77 *	3.21	16
−0.03	3.71	−0.01	3.69	3.67	−0.90	4.36	−0.24	3.7	3.34	17
0.12	3.29	−0.08	3.54	3.41	−0.48	3.71	−0.38	3.75 *	3.14	18
0.56	2.14 *	0	2.96	2.96	−0.96	3.50	−0.23	2.59	2.16	19
2.02	1.29 **	0.33	2.79 *	3.33	0.22	2.29	−0.02	2.59	2.56	20
−1.23	4.86 **	−0.17	3.94	3.66	0.85	2.43 **	−0.37	4.18 *	3.51	21
−0.89	4.71 **	−0.38	4.50 *	3.91	−0.61	4.50 **	−0.48	4.66 **	3.86	22
−0.96	4.57 **	−0.24	4	3.59	−1.13	4.79 **	−0.28	4.02	3.51	23

Concerning the relationship between informatics and mathematics, the initial opinion was largely consistent across both groups, with notable differences only in two particular items. Secondary school students demonstrated a significantly higher level of belief regarding the need of text editors for professional work (item 2), while, on the contrary, also exhibited a heightened understanding of the pervasive presence of computer science in various fields (item 21).

In the case of the questions related to self-perception (items 6, 8, and 18), it appears that young people tend to exhibit a more optimistic perception of their abilities since, in all cases, they perceived themselves to be better with statistically significant differences before the intervention commenced.

With regard to the characteristics of individuals employed in the field of information technology, young people exhibited greater agreement with the statements presented in the items in all cases, even with statistically significant differences in four of the five items.

In contrast, the data indicate that the two groups hold similar views on the subject of informatics. Statistically significant differences were only identified in item 16, although the students also displayed a greater inclination towards the subject (item 23). Furthermore, the perception of the difference between men and women in informatics was found to be similar for both groups.

After the intervention, the number of statistically significant differences, their level of significance and the effect size decrease, so we could state that, as an effect of the learning process, the vision that different people have of informatics tends to homogenise.

As far as informatics literacy is concerned, the effect does not seem to be exactly the same in both populations. High school students have a better perception of people working in informatics as problem solvers, while older adults associate informatics more with programming. Knowledge of the relationship between informatics and mathematics is at the same level for both groups after the intervention.

In the case of the characteristics of people working in informatics, the intervention homogenises the measures, and statistically significant differences only appear in two items after the intervention. Young people are still more aware of the need for teamwork and the need for creativity, but the difference is now smaller.

On the other hand, in the items related to the liking for informatics, it seems that statistically significant differences appear after the intervention in cases that did not exist before, but they are somehow contradictory. Older people tend to think that informatics is boring, but, on the contrary, they show more interest in working in informatics in the future. Finally, the perception that men are better at computing than women increases among older people, but not among young people.

In conclusion, the results presented in Table 5 demonstrate that the educational intervention had a more pronounced impact on older adults compared to secondary school students. Older adults not only exhibited an improvement in their attitude towards informatics, but also demonstrated a more positive outlook on its relevance and usefulness in everyday life. Conversely, secondary school students already possessed a more favourable knowledge, which explains the more modest changes in their perception after the intervention.

5.2. Comparison of Attitudes of Older Adults and Prison Inmates

The second comparison was with a previous experience carried out to introduce informatics literacy in penitentiary centres in Peru [16] (see Table 5 columns Inmat and CD_I).

In terms of informatics literacy, the inmates responded positively to all but one item, item 21, which asks whether informatics is used in practically all occupations, where the mean is lower with statistically significant differences and a large effect size. It seems, therefore, that inmates have a lack of knowledge about the extent to which informatics has spread, although, on the other hand, inmates have more knowledge in other aspects, such as the centrality of programming, problem solving, etc., again with statistically significant differences. The initial self-perception is also greater for inmates, with statistically significant differences in two of the three items (6 and 8), with medium or large effect sizes in all cases.

With regard to the relationship between informatics and mathematics, the inmates gave controversial answers to both questions, so the comparison is probably not meaningful. Inmates and adults also have very different initial perceptions of the characteristics of people working in informatics. Inmates see informatics as a lucrative job that requires creativity and do not think that people working in informatics are nerds. Consistently, inmates have more positive attitudes towards informatics, with statistically significant differences and large effect sizes in items 11, 16, and 23, but they seem to be more reluctant to become more involved in informatics (item 15), also with statistically significant differences but a small effect. Finally, the inmates had a more sexist view, as their perception of the difference between men and women in informatics was found to be greater.

Although the intervention has a positive effect on both cohorts, it seems to have a greater effect on the incarcerated population. For example, in the case of knowledge of informatics, after the experience, they are more aware than elder people that the Internet or text editors are not central to informatics and that informatics is used in almost every profession (items 1, 2, and 21), with statistically significant differences and a large effect size. However, surprisingly, their perception of being able to work in informatics without a computer (item 21) decreases. If we compare the effect on self-perception, the intervention seems to have had a more positive effect on the older people in the case of science and maths, items 8 and 18, while it has a more positive effect on the inmates in item 6, ability to study informatics, increasing the effect size of the difference and maintaining significant differences. On the other hand, inmates do not seem to understand the requirement of a mathematical way of thinking (item 13), whereas older people perform better, with significant differences. In addition, inmates' attitudes towards informatics have improved more, generating statistically significant differences in items 16, 20, and 23. In addition, the impression that men are better at informatics than women (item 12) is drastically reduced in the case of inmates.

As a summary, although the older adults experienced significant improvements after the experience, the impact of the intervention on the inmates was significantly greater. The inmates saw informatics as fundamental to their social and professional reintegration, as evidenced by a significant increase in aspects such as informatics-related study skills, recognition of the importance of this discipline in all professions, and programming as an indispensable skill.

In contrast, older adults showed a more mature and formed perception of informatics prior to the intervention and less diversity of responses, and probably smaller improvement, in their post-intervention evaluation. In fact, when comparing the level of achievement of the exercises for inmates and the elderly population, the number of tasks that the inmates were able to complete was on average one point higher than those completed by the elderly adults (4.42 vs. 3.56); in addition, the level of understanding perception was also on average higher for the inmates (3.77 vs. 3.14), and the number of exercises found to be complex was more for the elderly adults (2.75 vs. 1.92). It is true that older adults had more difficulty in understanding abstract concepts such as algorithms and loops. However, their learning curve was positive, demonstrating that, with a gradual and adapted approach, it is possible to overcome these barriers and achieve knowledge improvement goals.

Finally, it can be concluded that adaptation works for the different populations and settings in which the combination of L2T2L has been used, and although in general it helps to homogenise informatics literacy after the intervention, there are differences that depend on the characteristics of the population to which it is applied. Therefore, after an initial intervention and analysis, a specific adaptation of educational materials that take into account the characteristics of the target group may prove beneficial. This could entail the incorporation of practical exercises and more illustrative examples in the case of older adults, potentially enhancing the comprehension of abstract informatics concepts and fostering a comparable level of understanding and knowledge across all participants.

5.3. Limitations of This Study

Although the presented study is based on a quite large sample size, and pre- and post-intervention surveys increase the reliability of the research, this study presents a limited generalisability of the findings as it was performed only in a particular scenario in Peru. Further experiments with senior populations in other settings around the world and the use of control groups would allow the results obtained to be generalised.

6. Conclusions

The case study presented in this paper has revealed that the combination of the L2T2L pedagogical strategy for conveying informatics concepts from the university to care homes for the elderly and CS Unplugged activities is an effective approach for teaching informatics concepts to elderly individuals residing in care centres. Furthermore, the viability of employing CS Unplugged activities with this demographic has been substantiated. The experience has served to replicate the favourable outcomes previously observed with the L2T2L methodology in other contexts, including primary and secondary educational institutions and correctional facilities. Similarly, it has been demonstrated that CS Unplugged activities represent a viable means of engagement for individuals who lack access to computers or who prefer not to use them, as well as for those who lack or have minimal familiarity with technology.

The analysis of the results obtained from the surveys conducted among the older adult population and those in charge of the care centres indicates a shift in perception among older adults regarding informatics, accompanied by an enhanced understanding of specific informatics concepts. This observation opens up an opportunity to expand educational programmes for older adults, incorporating a greater focus on technology and computational thinking, which can facilitate their digital inclusion.

Moreover, the pedagogical approach used in this research is replicable in other similar settings and could be adapted to teach not only informatics, but also other subjects that require the development of cognitive skills.

The initiative outlined in this work has the potential to significantly contribute to improvements in the cognitive activities of the elderly and to re-education, thereby enhancing the quality of life of this population in the community.

Author Contributions: Conceptualization, J.A.D.-L., O.A., M.L. and A.A.; Methodology, J.A.D.-L., O.A., M.L. and A.A.; Formal analysis, O.A.; Resources, J.A.D.-L.; Data curation, J.A.D.-L.; Writing—original draft, J.A.D.-L.; Writing—review & editing, O.A., M.L. and A.A.; Supervision, O.A. and A.A.; Funding acquisition, O.A. and A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Basque Government (ADIAN—Grant IT-1437-22) and by MCIN/AEI/10.13039/501100011033 and ERDF A way of making Europe (Grant PID2021-123087OB-I00 and Grant PID2021-127777OB-C21).

Institutional Review Board Statement: Approval of all ethical and experimental procedures and protocols was granted by CEISH (UPV/EHU) under Application No. M10/2022/126 (protocol date 23 May 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

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

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