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Communications in Computer and Information Science 1425

Advanced Virtual Environments and Education

Third International Workshop, WAVE 2021
Fortaleza, Brazil, March 21–24, 2021
Revised Selected Papers

Springer

Communications in Computer and Information Science 1425

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ISSN 1865-0929 ISSN 1865-0937 (electronic)
Communications in Computer and Information Science
ISBN 978-3-031-07017-4 ISBN 978-3-031-07018-1 (eBook)
https://doi.org/10.1007/978-3-031-07018-1

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

WAVE^2, the Workshop on Advanced Virtual Environments and Education, organized jointly by the Special Commission on Computers in Education of the Brazilian Computer Society (SBC) and the Brazilian Association of Distance Education (ABED), provides a forum for world-class research around relevant issues of Brazilian education, particularly in the open and distance modalities, contributing to the advancement of international knowledge on these topics.

The aim of WAVE^2 is to stimulate and promote innovation and entrepreneurship in the field of computing for open and distance education. Considering the transdisciplinary nature of this field, SBC and ABED understand that the collaboration between researchers from related communities progressively promotes research and technological innovation in the sector. The objectives of WAVE^2 are as follows:

- To expand the visibility, recognition, and impact of research related to improving the quality of open and distance learning and the use of technology in teaching in the various areas of knowledge;
- To foster interdisciplinary cooperation networks;
- To contribute to the training of young researchers from related areas who wish to join interdisciplinary networks;
- To be recognized as an event of excellence in stimulating interdisciplinary cooperation;
- To serve as a strategic point for the establishment and consolidation of international cooperation networks;
- To attract the best researchers from the areas related to the event, matching its relevance and impact to similar international events;
- To promote a consistent epistemology for interdisciplinary approaches concerning the human practice of technology-mediated teaching;
- To promote debate and the advancement of high-level knowledge on topics of high-impact and social relevance associated with open and distance education; and
- To orient a research agenda, proposing topics of interest and establishing connections between related areas.

The workshop's target audience brings together entrepreneurs, designers, researchers, technologists, and experts in a multidisciplinary forum to collaboratively define the various skills, methods, techniques, processes, and structures needed to foster the evolution of new learning environment concepts and stimulate targeted research.

The workshop themes address, in a central way, the relations between the human, social, and technological dimensions of didactic processes mediated by computational platforms, encouraging a rigorous theoretical and methodological approach. The papers included in this volume clearly represent advances in the frontiers of knowledge about human phenomena occurring in technology-mediated teaching modalities, particularly in distance interactions, contributing to the advancement of education, psychology, design, computer science, and the like.

The first edition of WAVE^2 took place in Florianópolis, Brazil, within the program of the 24th ABED International Congress on Distance Education (CIAED 2018). The second edition took place in Poços de Caldas, Brazil, within the program of CIAED 2019. The third edition of WAVE^2 was scheduled to take place during September 13–16, 2020, at the Federal University of Ceará, Brazil, together with the 26th ABED International Congress on Distance Education; however, it was postponed until March 2021 due to the ongoing COVID-19 pandemic. In this third edition (WAVE^2 2021), we discussed the topic "Exploring the Variety of Active Strategies in Distance Learning".

In this special issue, we present the full papers accepted in the Full Innovation category. These papers present results with substantial advances in technological innovation, including empirical or theoretical aspects, discussions on the state of the art and technique, scientific and design methodologies, and evaluations of the effectiveness of products that foster academic discussion and interaction with the public in the open and distance education sector. In total, we received 27 submissions, of which 12 were selected following a double-blind peer review process, giving an acceptance rate of 44%.

In the first paper, "Emergency Remote Learning one year later - what changed?", Luciana Oliveira, Arminda Sequeira, Anabela Mesquita, Adriana Oliveira, and Paulino Silva analyze emergency remote learning (ERL) experiences during the first confinement caused by COVID-19 pandemic. They developed a close-ended questionnaire to understand how higher education students experienced this situation, examining six issues that may impact the learning experience: educational and organizational issues, technological and working conditions, and social, family-related, psychological, and financial issues. The results show that while the improvements were mainly related to contextual aspects, such as family dynamics, working conditions, and financial safety, the negative impacts were primarily felt in the input and process elements that concern the remote learning environment and social interactions with teachers and peers. The set of persistent issues reveals a scenario of the perpetuation of the problems/concerns detected since the first confinement, such as sleeping disorders, exhaustion, lack of engagement in classes, and lack of motivation.

In their paper "Collaborative Content Construction: A Pedagogical Architecture to Support Distance Education" David Brito Ramos, Ilmara Monteverde Martins Ramos, Alberto Castro, and Elaine Harada Teixeira de Oliveira propose a pedagogical architecture called Collaborative Content Construction, which relies on the collective construction of knowledge through relational pedagogy, supported by the genetic epistemology of Jean Piaget. Pedagogical architectures represent a way of contributing to innovation in the use of technological support in learning. Their proposal includes a methodology that simultaneously builds, collectively and interactively, knowledge, and leads to the development of materials that benefit participants even after the end of the activity. They expect the resulting learning material to be more attractive to the students since it would be developed by their peers.

Hayet Kerras, Susana Bautista, Danilo Santos Piñeros Perea, and María Dolores de Miguel Gómez discuss the gender pay gap in the labor market. This gender pay inequality is conditioned by several other gender gaps that are observed from childhood and that develop throughout the evolution of the professional life of the human being. They analyze the behavior of four Mediterranean countries: France, Spain, Morocco,

and Algeria, aiming to define the elements that impact the creation of wage gaps. A general analysis is made to observe how both the gender secondary education gap and gender labor force gap influence the gender pay gap.

A phygital educational scenario is discussed in "Scratch + CNC: Mixing Physical and Digital Worlds" by Dirceu Antonio Maraschin Junior, Anderson Eugênio Souza Gutierres, and Tiago Thompsen Primo. The work presents the development of an extension for Scratch 3.0 capable of interacting with a computer numeric control (CNC) machine. With this, a proposal of cooperation between two environments in the learning context is created, combining programming in blocks with equipment able to provide outputs in physical objects. The intention is to provide a physical-virtual environment where learners can experience a tangible interaction beyond the computer screen. The objective is the design of technological components to foment the "maker" culture through the use of computer-controlled machines in schools, groups, or labs.

Leandro Flórez-Aristizábal and Fernando Moreira, in their "Case Study: A CSCL Approach for Object-Oriented Programming Learning" paper, explore the emerging experiences during a collective object-oriented programming (OOP) learning situation. Students were invited to play different roles while solving software-based problems (from requirements specification to software development). Eight students took part in this study following each of the stages proposed in the approach and the results show that even though this is still a good starting point, some changes need to be made to achieve better results.

José Figueiredo and Francisco J. García-Peñalvo present "HProgramming: A Helping Tool for Teach and Learn Programming". It provides plans and activities created by the teacher. The students complete a set of exercises framed with the plane defined by the teacher, and practice at their own pace and as often as deemed necessary, with consideration of the respective immediate feedback. The results obtained, and the opinions expressed by the students, indicate that the HTProgramming application is a good tool to help teachers and students to minimize the difficulties of teaching and learning introductory programming, and it will be a good contribution to demystifying the problem of teaching and learning programming for the entire science community interested in this area.

In "Assessment methods determining the higher education students' academic success", Joana Martinho Costa, Sónia Araújo, Mohammad Soliman, and Maria José Sousa analyze the extent to which assessment methods have a substantial impact on approval rates of students. In doing so, 797 averages of course grades from a Portuguese higher education institution were collected in different academic years. The significant effect of the course field, laboratories, projects, mini-tests, group work, individual work, frequencies, exercises, and presentations on the final averages of the courses was evaluated based on the modeling of structural equations. The results showed that the use of laboratories, presentations, and individual and group-based work/tasks are the most explanatory elements (25%) for positive averages. These results reinforce the importance of active learning strategies to promote students' engagement and achievement.

In "HCI 2020 Master's Degree Study: A Review", Gabriel M. Ramirez, Yenny A. Méndez, Antoni Granollers, Andrés F. Millán, Claudio C. González, and Fernando Moreira present an exhaustive review of the state of university masters or graduate

programs in the discipline of human-computer interaction (HCI) and related areas up to 2020. The objective of the study is to determine what universities are teaching worldwide, how this compares with the needs of companies or organizations, and if there is a congruence between what is being taught at a global level in higher education and the requirements of organizations. The review identifies what other institutions are doing, the needs of the market and organizations, and how this contrasts with the authors' own experiences and ideas to propose a graduate program.

The main goal of Liren Su, José Martins, Manuel Au-Yong-Oliveira, Ramiro Gonçalves, and Frederico Branco's study, "Are the Mobile Applications of Portuguese Higher Education Institutions Accessible?", is to assess accessibility in mobile applications of the education sector. An evaluation model is suggested and used to assess the accessibility of 46 official mobile applications related to 23 universities and institutes of Portugal. The applications were analyzed from two perspectives, which are the inherent properties of the applications and the user experience of different disability categories, using automatic and manual testing methods. The results of the accessibility testing showed that the status of web accessibility of mobile applications in the higher education sector in Portugal is unsatisfactory. The study concludes that most apps have multiple accessibility issues and they are extremely unfriendly to users with visual impairments, and the authors propose a series of accessibility recommendations for mobile applications.

In "An educational digital game for the development of Phonological Awareness", Vinícius Oliveira Damasceno, Cibelle Albuquerque de la Higuera Amato, and Valéria Farinazzo Martins address the phonological awareness phenomena as an ability to perceive the sounds contained in words and present the Educational Quiz - Phonological Awareness, a game developed and tested with nine professionals in the speech therapy field and with eight children in speech therapy sessions.

Nazaret Gómez del Río, Carina S. González-González, Yeray Barrios Fleitas, Pedro A. Toledo Delgado, Francisco J. García Peñalvo, and Fernando Moreira, in "Using exergames to promote healthy habits in schools", present an educational intervention project to promote healthy lifestyle habits using active video games and gamified activities as a motivational tool towards healthier habits. They describe the workshops carried out in different primary schools using an active video game called TANGO:H and other gamified tools. The results evidence a very high level of satisfaction with the intervention itself and the active video game.

On behalf of the organizers, SBC and ABED, we would like to thank everyone who helped to make WAVE^2 2021 a successful event, bringing together researchers of the two communities and the like to raise the international impact and relevance of Brazilian research on aspects related to open and distance education.

Alex S. Gomes
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Learning Scenarios and Grouping Methods

Emergency Remote Learning One Year Later - What Changed?

Luciana Oliveira(✉), Arminda Sequeira, Anabela Mesquita, Adriana Oliveira, and Paulino Silva

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Abstract. During the first confinement caused by COVID-19 pandemic education shifted to what was coined as Emergency Remote Learning/Instruction/Teaching, trying to balance the need to continue the provision of educational content and the enormous challenges of coping with multiple issues that an unforeseen, unplanned, and urgent situation brought worldwide. At that period, we developed research to understand how HE students were living this situation for what we built a close-ended questionnaire comprising six dimensions of issues that may impact ERL: educational and organizational issues, technological and working conditions, social, family-related, psychological, and financial issues. Previous results, collected right after the first month of ERL revealed that the most severe problems reside in the pedagogical and psychological domains. The present research followed the evolution of the situation and confronts research results obtained during the first confinement with the conditions and students' perception that we collected during the second confinement and its multidomain repercussions. The current results show that while the improvements reside mainly in contextual aspects, such as the family dynamics, working conditions, and financial safety, the worsening is primarily felt in the input and process element issues which concern the remote learning environment and social interactions with teachers and peers. However, the set of persistent issues reveals a scenario of perpetuation of the problems/concerns detected in the first confinement, such as sleeping disorders, exhaustion, lack of engaging classes, and lack of motivation.

Keywords: Remote learning · Comparative analysis · Higher education · Students' perceptions · CIPP Model

1 Introduction

March 2020 will remain as a global landmark date that established the first global health crisis that would change the world as we knew it and determined a mandatory confinement worldwide as a measure to contain the spread of the COVID19 disease. The situation determined that all education shifted to Emergency Remote Learning/Instruction/Teaching. As Hodges et al. [1] defined, ERT consists as a "temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances".

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 3–14, 2022.
https://doi.org/10.1007/978-3-031-07018-1_1

The process "involves the use of fully remote teaching solutions for instruction or education that would, otherwise, be delivered face-to-face" and "return[ing] to that format once the crisis or emergency" is over. As such, the main goal of ERT consists of providing temporary access to instruction and instructional support, in synchronous and asynchronous formats, in reliable ways during a particular moment and is essentially a shift of delivery modes, methods, and media which are progressively adjusted to the available settings, resources, and limitations of organizations, teachers and students [2]. As the situation called for immediate actions, HEI focused on ensuring the continuity of the provision of the services for whatever means available, setting up an operational instructional approach. This emergency approach revealed some level of unawareness of the impacts of the situation on the students' wellbeing and mental health, which can be understood given the urgency of the situation.

As the confinement period extended, people began to realize the potential risks for the wellbeing, namely mental health, of the confinement and other sanitary measures, could have on the population in general and on the HE students in particular. That was a time when a significant number of publications emerged presenting multiple Covid19-related research topics, from all over the world, with a special focus on the mental health of individuals and families [3–11]. Another stream of research focused on understanding the overall sentiment of the population through the analysis of emoji posts following news publication especially on social media platforms [12].

In Portugal, the mandatory confinement and the closure of schools occurred from the March 12th, 2020, until the end of the school year, for basic and secondary education cycles and determined the need to implement emergency responses which, in the absence of contingency plans, pushed organizations and teachers to focus on easy-to-implement operational solutions that facilitate the continuing of the delivery of instructional contents and support to students, as it happened all over the world. After a thorough analysis of the situation and being conscious of the multiple potential impacts that could emerge from it, we performed a research that aimed to evaluate the impacts of the confinement situation and remote learning effects on HE students' experience, exploring multilevel repercussions of the situation. For that purpose, we developed a six-dimension model to assess the student's perceptions, focusing on the educational/pedagogical, technological, and working conditions, social, family-related, psychological, and financial issues. Results obtained reveal that the most impactful problems focus on the pedagogical and psychological domains [2].

Further ahead, we used the CIPP (Context, Input, Process, and Product) model to establish a 46 variable analysis based on the students' responses which confirmed the crucial importance of motivation and engagement in online classes as learning enablers or constrainers. These also shape the students' perception of the role that online classes play in helping them to stay more positive during ERL [13].

The second mandatory confinement in Portugal started on January 21st, 2021, being gradually reopened as soon as the sanitary conditions allowed. On March 15th, the 1st cycle of basic education returned to face-to-face classes; the 2nd cycle of basic education and the secondary cycle returned to in-person classes on April 5th, 2021. HEI partially returned to having in-person classes on April 19th, 2021, but most of the HE institutions decided that only part of the classes returned to fully face-to-face.

This 2nd confinement determined the return, once again, to remote learning/teaching/instruction, and it became imperative that we reassessed the students' perceptions regarding the context, input, and process elements of the CIPP Model.

As such, the present research aims to follow the evolution of the remote learning situation in Portugal, as by providing the follow up of the situation will allow to confront the results obtained during the 1st confinement (May 2020) and the ones obtained during the 2nd confinement (May 2021), figuring out the potential positive and negative evolution of the multidomain assessment, enabling an in-depth reflection and drawing conclusions about the adaptation curve.

The basic underlying reasoning that shaped the former and present research is that the learning/teaching/instruction process is complex and multidimensional, consisting of interrelations that need to be understood and explained in order to assess the conditions that influence students' performance and wellbeing. School closures and subsequent confinements due to the COVID-19 outbreak have affected 87% of the world's students physically, socially, and psychologically [14, 15], yet the consequences, namely social distancing and isolation, the lack of interaction with peers, and with extended family, the stress caused by news about the disease and panic actions or limit situations abundantly broadcasted, and the lack of adequate support from families, from community and HEI, among other reasons, caused a wide range of psychological disturbances on students [16, 17].

At this point, our purpose was to combine methodologically the structure of data collection used in our previous research consisting of a six-dimension model of issues that may impact ERL covering the fields of educational and organizational issues; technological and working conditions; social, family-related; psychological and financial issues framed in the CIPP model.

In the next section, we present some of the basic underpinnings of the CIPP Model while mostly remitting to our previous studies and move on to presenting our findings and discussion of the results.

2 The CIPP Model

In this paper, as in previous research [13], we use the CIPP model – Context, Input, Process, and Product evaluations [18] to reflect on the circumstances and impacting Emergency Remote Learning. We have focused on analyzing critical aspects contained in the CIPP model's context, input, and process elements, leaving the product element out, according to what is recommended by Hodges [1] for remote learning settings. We make some final remarks regarding the product element as a result of the comparison between the first and second confinements, highlighting future institutional interventions that we consider relevant.

The context assesses needs, problems, assets, and opportunities, as well as relevant contextual conditions and dynamics (e.g., institutional, social, financial, and governmental aspects). The input evaluation focuses on how it should be done and assesses competing strategies, and the work plans and budgets of the selected approach (e.g., technology infrastructure, software, faculty support, faculty professional development, learning resources such as access to libraries). The process evaluation considers if the

program is being done and consists of monitoring, documenting, assessing, and reporting on the implementation of plans (e.g., how processes can be adapted to this new reality, quality of teaching, and learning). Finally, the product evaluation sees if the program succeeded and it identifies and assesses costs and outcomes – intended and unintended short term and long term (e.g., course completion rates, aggregated grade analyses, feedback).

3 Methods and Procedures

The adopted methodology consists of comparative survey-based research. We build on previous exploratory research, which was characterized by employing a single data collection method to obtain an initial view of the key issues in the CIPP Model. Provided the scarceness of literature and systematization on the socio-educational impacts of the current confinement period on student's lives and on how they are responding to implemented ERL solutions, we proposed an evaluation instrument [2], comprised of 67 items organized in six dimensions of issues (educational and organizational, technological and working conditions, social, family-related, psychological, and financial issues) matched with the CIPP Model elements context, input, and process [13].

The survey was disseminated among students enrolled in HEI in Northern Portugal, through social media channels, namely in institutional public pages and open groups in May 2020 (student group 1) and in May 2021 (student group 2). Since the questionnaires were anonymous, it was not possible to track which students have answered both surveys. However, given that the dissemination strategy and channels were the same for both moments, we assume that the likelihood of having students answering both surveys is high. The items on the scale were anchored at 1 = never, 2 = rarely, 3 = frequently, and 4 = always. The survey data were downloaded and transferred into IBM SPSS Statistics 26.0 statistical analysis software package for analysis. Higher scores represent the higher frequency of the item.

4 Results

The sample demographics for both periods are presented in Table 1. The entire sample is composed of 762 answers to the questionnaire, divided into two groups. The first group of students (G1) answered the questionnaire in May 2020 (n = 359), and the second group (G2) answered it in May 2021 (n = 403).

Regarding the commonalities among both groups (χ^2 test), the majority of respondents are female (>70%), more than 31% received a financial aid scholarship, they have unlimited access to the Internet (≈78%), and more than 94% were attending online classes in May (p = n.s.). There are, however, some statistically significant differences between G1 and G1. Most of the students are aged 18–22 years old in both groups, but students from G2 are, on average, 1.5 years older ($t(760) = 4.016$; $p < .001$). Also, in both groups, most are non-working students, but this percentage is 9.3% higher in G2 ($\chi^2(2) = 8.718; p < .05$). The percentage of students that were compelled to return home (family residence) during ERL in G2 is about half (21.1%) of that recorded for G1 (41.8%) ($\chi^2(2) = 38.624; p < .001$). Similarly, and expectedly, the number of students

Table 1. Sample demographics ($N = 762$)

	G1 (May 2020)		*G2 (May 2021)*		*Full sample*	
	n	*%*	*n*	*%*	*n*	*%*
	359	47.1	403	52.9	762	100
Gender						
Female	268	74.7	291	72.2	559	73.4
Male	91	25.3	112	27.8	203	26.6
Age						
18–22 years	298	83	285	70.7	583	76.5
23–27 years	41	11.4	66	16.4	107	14
≥28 years	20	5.6	52	12.9	72	9.4
Status						
Non-working student	281	78.3	278	69	559	73.4
Working student	72	20	118	29.3	190	24.9
Financial aid						
Currently receiving	131	36.5	129	32	260	34.1
Believes will need in future	*99*	*75.6*	*86*	*66.7*	*185*	*71.2*
Currently not receiving	218	60.7	263	65.3	481	63.1
Believes will need in future	*56*	*25.7*	*36*	*13.7*	*92*	*19.1*
Returned home during confinement	150	41.8	85	21.1	235	30.8
Unlimited access to Internet	280	78	315	78.2	595	78.1
Attending online learning	340	94.7	391	97	**731**	95.9
First time attending online learning	*330*	*91.9*	*174*	*43.2*	*504*	*66.1*

attending online for the first time has drastically decreased from 91.9% in G1 to 43.2% in G2 ($\chi^2(2) = 201.678; p < .001$), although it is still substantial.

In the following sections, we present the sets of unchanged, improved, and worsened issues between the two groups regarding the CIPP model's context, input, and process elements, considering only the students attending online learning (n = 731). We focus on statistically significant equal/unequal variances.

4.1 Persistent Aspects

We identified seventeen persistent aspects (equal variances) among the two groups (Levene's test > .05) regarding the context, input, and process elements of the CIPP Model, presented in Table 2.

Regarding the family context, both groups report frequently having a proper workstation with the ideal conditions to participate in online classes in a favorable environment. In both groups, students also report frequently trying to keep a work/study routine while

Table 2. Unchanged issues ($n = 731$)

CIPP Model element/aspects category	*G1 (n = 340)*		*G2 (n = 391)*		
	M	*SD*	*M*	*SD*	*t-value*
Context/Family context					
Having a proper workstation with the ideal conditions to participate in online classes/work	3.19	.917	3.39	.895	2.860**
The family environment facilitates the participation in online classes/work	3.09	.981	3.28	.903	2.654**
Context/Working conditions					
Keeping up with a work/study routine	2.97	.788	3.12	.764	2.654**
Context/Financial context					
Ability to save money on school supplies	2.22	1.213	2.40	1.246	1.983***
Context/Wellbeing					
Having more sleep disorders	2.90	1.056	2.61	1.044	−3.781*
Having more time to practice hobbies	2.66	.879	2.45	.959	−3.121**
Devoting time to workout	2.71	.957	2.50	1.020	−2.181**
Input/Remote learning environment					
Motivation to participate in online classes	2.47	.936	2.31	.984	2.264***
Online classes are more tiring than face-to-face classes	2.86	1.045	3.04	1.048	2.352***
Input/Educational resources					
Gained access to more educational resources/materials	2.50	1.018	2.71	1.047	2.748**
Teachers started using more creative and diverse resources/materials	2.43	.864	2.62	.960	2.862**
Participation in online evaluation moments	3	9.61	3.39	.789	5.920*
Requested that assessment regime was changed	1.56	1.142	1.74	1.191	2.145***
The evaluation components of courses were changed and are less beneficial	2.65	1.112	2.42	1.143	−2.791**
Process/Social interactions with teachers/School					
Teachers care about my personal wellbeing	3.21	.812	2.93	.953	-4.339*
Received clear information from school regarding the functioning of online classes	2.96	.806	3.14	.835	3.074**
Process/Social interactions with peers					
Keeping contact with school friends/colleagues	3.34	.682	3.11	.825	-4.033*

* $p < .001$; ** $p < .01$; *** $p < .05$.

rarely being able to save money on school supplies. There are slight decreases in the averages of G2 regarding the wellbeing aspects; however, in both groups, students report frequent sleep disorders and rarely having more time for hobbies and exercise.

Concerning the remote learning environment, students keep feeling rarely motivated to participate (with a slight decrease in G2) and frequently more tired (with a slight increase in G2) in online classes. The access to a greater amount and diversity of educational resources has a slight increase in G2 but with a moderate frequency in both groups. Students kept rarely making changes to their assessment regime, frequently participating in online evaluation moments, and, on average, there were still some changes in the evaluation components of courses that were less beneficial to them.

In the process elements, there is a slight decrease in G2 concerning the frequency of support/interaction with teachers, but both groups reveal that teachers frequently care about their personal wellbeing and send clear information regarding the functioning of online classes. Likewise, with a slight decrease in G2, both groups report frequently keeping in contact with their school friends/colleagues.

4.2 Improved Aspects

We identified ten aspects in which the variation of averages, even if slight, among the two groups (Levene's test $<.05$) allowed us to detect improvements statistically significant in G2, depicted in Table 3.

The limitations felt in the family environment based on general disturbances and the need to share the workspace, and the computer decreased in G2. Students in this group also report a higher frequency in having the necessary equipment to attend online classes. Regarding their financial context, the students in G2 are slightly less concerned about the worsening of their financial situation, which also results in a less frequent notion that their permanence in higher education is risked due to financial struggles. In previous research, we have detected that students were frequently overwhelmed with work derived from online classes. This has also decreased in G2, despite still rarely being the same as in face-to-face classes. The teachers also shared information about the functioning of online classes more frequently, denoting increased communication in G2. For this group, there was also a decrease in the frequency in the possibility to pursue a continuous assessment method, which students tend to prefer.

Pertaining to social interactions, students in G2 are even less preoccupied about their privacy in online classes - despite several accounts of students unwillingness to turn on their video cameras or microphones during videoconferencing-based classes, namely in Zoom meetings [19, 20] - and, although they miss their school friends frequently, this feeling has also decreased in G2.

4.3 Worsened Aspects

We identified ten aspects in which the variation of averages, even if slight, among the two groups (Levene's test $<.05$) allowed us to detect the worsening issues with statistical significance in G2, depicted in Table 4.

Referring to the contextual element, in G2, students report an increased frequency of need to buy equipment/devices to participate in online classes. This group also reports a

Table 3. Improved issues ($n = 731$)

CIPP Model element/Aspects category	*G1 (n = 340)*		*G2 (n = 391)*		
	M	*SD*	*M*	*SD*	*t-value*
Context/Family context					
Need to share workspace with other people	2.04	1.043	1.80	.997	−3.205**
The work/study environment is disturbed by other people who live in the same house	2.19	.930	2.01	.927	−2.505***
Context/Working conditions					
Having all the necessary equipment for online classes/work	3.63	.583	3.76	.525	3.153**
Need to share the computer/device used for online classes	1.63	.971	1.35	.759	−4.316*
Context/Financial context					
Worried about the worsening of one's financial situation	2.85	.973	2.37	1.170	−6.051*
The stay in higher education is at risk, for financial reasons	1.60	1.104	1.43	.976	−2.232***
Input/Remote learning environment					
Teachers sent clear information about online classes	3.17	.686	3.43	.698	5.209*
Workload is the same as in in-person classes	2.10	.959	2.47	1.059	4.969*
Input/Educational resources					
Was taken the possibility to pursue continuous assessment	1.93	1.424	1.49	.992	−4.729*
Process/Social interactions with teachers/school					
Worried about one's privacy in online classes	2.19	1.133	1.91	1.018	−3.428*
Process/Social interactions with peers					
Miss school friends/colleagues	3.47	.818	3.19	.961	−4.276*

* $p < .001$; ** $p < .01$; *** $p < .05$.

lower frequency of saving money in transportation, which might be linked to an increase in mobility as confinement measures are less strict. In both groups, students indicate almost never receiving psychological and moral support from the school, and this has worsened for G2.

In the input element that refers to the learning environment and learning resources, both groups indicate frequently participating in interactive classes, but the frequency is lower for G2. The potential of online classes to keep students more positive during confinements is rarely encountered in both groups and has also decreased for G2.

In the process element, students identify a less frequent commitment of the school board to their welfare and academic success in G2, despite being nearly frequent for

Table 4. Worsened issues ($n = 731$)

CIPP Model element/Aspects category	*G1 (n = 340)*		*G2 (n = 391)*		
	M	*SD*	*M*	*SD*	*t-value*
Context/Working conditions					
Need to buy equipment/devices to participate in online classes/work	1.34	.850	1.69	1.064	4.927*
Context/Financial context					
Save money in transportation	3.73	.671	3.30	1.032	−6.846*
Context/Wellbeing					
Received psychological and moral support from school	1.80	1.286	1.43	1.060	−4.176*
Input/Remote learning environment					
Online classes are interactive, allowing to participate	3.02	.809	2.77	.845	−4.004*
Online classes help to stay more positive during this phase	2.59	1.073	2.26	1.171	−4.077*
Process/Social interactions with teachers/school					
The school board is committed to students' welfare and academic success	3.02	.889	2.77	1.003	−3.553*
Feeling closer to teachers	2.81	.912	2.51	.960	−4.332*
Process/Social interactions with peers					
Worsened relationships with friends/colleagues	2.05	.973	2.48	1.107	5.638*
Well-being depends on keeping in contact with friends/colleagues from school	2.88	.950	2.69	1.032	−2.575***

* $p < .001$; ** $p < .01$; *** $p < .05$.

both groups. The second group of students also feels less frequently closer to their teachers. This is also felt in other relationships. Despite rarely feeling a worsening in the relationships with their school friends (both groups), their frequency is visibly increased among G2 students. There is also a decrease, in G2, in the frequency of belief that one's wellbeing depends on keeping in contact with one's school friends/colleagues. We consider this to be a worsened aspect because the school environment is primarily a social space. This might, however, result from the maintenance of contacts with school friends, which remains unchanged, as identified in Table 2.

5 Discussion and Conclusion

According to the statistical significance established criteria, we found a set of 17 aspects that remaining the same, the second set of 10 items revealing improvements and a third set of 10 worsened aspects.

While the improvements (Table 3) reside mainly in contextual aspects, such as the family dynamics, working conditions, and financial safety, the worsening (Table 4) is mostly felt in the input and process elements' issues which concern to the remote learning environment and social interactions with teacher and peers. However, the set of persistent (unchanged) issues (Table 2) reveals a scenario more prone to the perpetuation of the problems/concerns detected in May 2020 than to a continuation of optimistic circumstances. The exception is relying, once more, on the contextual aspects, such as the family dynamics, working conditions, and financial safety, but not on the contextual aspects regarding the students' wellbeing.

Our analysis reveals the persistence of frequent sleep disorders and rarely having time for hobbies or working out (contextual), together with a persistent lack of motivation to engage in remote learning and persistent exhaustion (input). This, according to MacMahon, Leggett [21], might actually be a two-way problem. Teachers' ability to notice verbal and nonverbal behavior and interactions of students is reduced in remote learning. These social behaviors give vital insight into student knowledge, engagement, emotions, and motivation. Students, on the other hand, may feel socially isolated, cut off from their friends and classmates, who are crucial in developing good affect, motivation, and learning control.

This also reinforces the global awareness of the current physical, social, and psychological problems being faced by students, as noted by Tang, Xiang [14], and teachers [22, 23]. In fact, among the set of worsened aspects, it is possible to observe a significant reduction of the online classes' potential to help students stay more positive during confinement, as well as on the classes' ability to offer participative and interactive moments. This has also resulted in students feeling less close to their teachers and believing that the school board is less committed to their academic success, despite frequently reporting (and persistently) sensing that teachers care about their wellbeing and receiving clear information from the teachers and school regarding the functioning of online classes.

There is no doubt that the social dimension was heavily affected. Although students report a small reduction of the worsening of relationships with peers, the frequency in which this occurs is still relevant, particularly considering the decreased perception that one's wellbeing depends on social interactions within the school. We believe that it could indicate that students may be adjusting to a lifestyle in which they accommodate to isolation and undervalue social interactions, which, in turn, may worsen their psychological wellbeing and their role in the social ecosystem of the school and society. It may also signify that the notion of wellbeing has been altered, and this type of contact has been replaced with something else or that isolation is becoming increasingly comfortable.

Our analysis has allowed us to understand that the socialization potential of remote learning has been undoubtedly insufficient and to reflect upon several forces pushing its depression: the need to comply with the established curricula leaving little space for pure socialization, the overall lack of teacher's preparedness to instantly adjust to and manage remote instruction, the lack of institutional readiness and infrastructures, the students reluctancy to engage in video conferencing classes and/or to acquire the necessary autonomy to manage self-paced learning, to name a few. However, it should be noted that, according to our data, the main difficulties reside less on the contextual aspects that are somewhat controllable by the students (family, working conditions, and

income) than on the aspects that pertain to the domains in which education institutions are expected to have an active intervention. For instance, one of the most aggravating aspects that we identified reside in the reduction of the psychological and moral support provided to students, either in the form of support emails or psychology appointments.

The lack of guidelines for implementing distance learning, lack of infrastructure, lack of competencies, and security-related problems were some of the challenges met during the pandemic by the vast majority of education institutions. As a consequence, organizational models for remote learning are now being proposed in the literature [24], in order to prevent and minimize future problems. This, however, should not exclude the need to develop additional measures to compensate and minimize the long-term problems and effects that are and will be felt as a consequence of the first and second confinements, as, for instance, there might be a long way in recovering students' psychological wellbeing, motivation, intrapersonal skills and their trust in the education system.

The authors acknowledge that this work is not without limitations. Although we clearly state that we present a comparative study, since the surveys are anonymous, there is no way to determine how many students have answered both surveys and how their specific circumstances have changed.

As future work we suggest that a similar study takes place at the end of the first semester of the next academic year (2021–2022. At that time, supposedly, classes will be face-to-face again, and it would be interesting to understand if the more problematic situations described in this paper were improved or not.

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Collaborative Content Construction
A Pedagogical Architecture to Support Distance Education

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Abstract. This work presents a proposal of pedagogical architecture called Collaborative Content Construction, which relies on the collective construction of knowledge through relational pedagogy, supported by the genetic epistemology of Jean Piaget. Pedagogical architectures represent a way of contributing to innovation in the use of technological support in learning. This proposal includes a methodology that simultaneously builds, collectively and interactively, knowledge, and also leads to the development of materials that benefit participants even after the end of the activity, because in addition to learning in the process, we expect resulting learning material to be more attractive to the students since it would be developed by their peers.

Keywords: Pedagogical Architecture · Collaboration · Constructivism

1 Introduction

To reformulate the practices of the teaching-learning process, teachers seek to use methodologies that can provide the best results in learning. Currently, the idea of teaching is not limited to just helping to assimilate content but to make students reflect critically on what they learn and envision their participation in solving real problems. The training of students starts to increasingly value proactivity, the ability to work in groups, and to solve problems. In this context, student-centered methodologies have been highlighted.

Composing virtual environments with the simple application of traditional classroom methods in the context of online education can be considered inadequate. It is necessary to add the technology factor when designing the method, bringing true conformity with the reality of education today.

From this need, the Pedagogical Architectures (PAs) arise, in which the learning strategy includes technological support as part of it and not just a separate/external support. PAs are like learning structures that integrate pedagogical approach, technologies, and time and space conception [1].

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 15–25, 2022.
https://doi.org/10.1007/978-3-031-07018-1_2

In this work, a proposal for a PA that uses technologies to support the relationship between participating students is presented, as well as to maintain a historical and sequential record of the actions taken to facilitate the assessment of the steps performed.

The objective of this PA is the cooperative production of content using the agenda, as the journalism style. Under the mastery of a theme aligned with the teacher's learning purposes, groups of students select sub-themes, these can be pre-selected by the teacher, if necessary.

Each group must carry out previous research on the sub-themes of other groups and, for each of them, suggest an agenda, from which they want more details, which must be related to the sub-theme.

Then the group that received the agenda, analyzes them, and checks if they proceed. Then, the group must produce content to be presented that incorporates, but is not restricted to, the suggested agenda. The other groups evaluate the production of colleagues, according to the agenda they suggested. The teacher specifies deadlines for each phase, follows step by step until the end of the activity.

The PA was developed thinking about the need to join pre-determined themes/contents (by the school system/curriculum/teacher), to the independence in the choice of research topics made possible by PAs such as "Learning Projects (LP)".

The rest of the article follows this structure: Sect. 2 presents the related work, Sect. 3 presents the vision of the proposed PA, which is detailed in Sect. 4. Then, a practical example is presented as validation in Sect. 5, and finally, Sect. 6 presents the final considerations.

2 Related Work

The proposal by [2] presented a PA called APAME that uses educational makerspaces for the construction of knowledge. APAME aims to produce physical artifacts from the development of skills and competencies acquired in the areas of design, computing, and engineering.

The research of [3] consists of a PA to represent digital learning portfolios that are used for the systematic recording of impressions and reflections on guiding themes, as well as to determine the collective and individual effort in the formation of knowledge.

Reinoso et al. [4] proposed an PA called APMSII (Pedagogical Architecture for assembling an intelligent irrigation system) for the construction of a smart irrigation system. APMSII aims to build knowledge through skills and competencies that students will acquire when building solutions using experimental robotics in real-world cases.

The work of Marcon et al. [5] reports the use of Facebook as part of a PA, where an online group was created for discussions related to the content worked on by the participants. The study concluded that the analyzed social network can be a PA since it is intensively mediated by the teacher.

Biancardi et al. [6] presented a PA for cooperative knowledge building. In this PA teacher selects a set of materials called Study Objects (SO). Students selects one SO and make a product, for example, a report about it. After peer review, students make groups considering the SO in common. The groups make a new product. Teacher analyzes the new productions and give feedback for products and students' participation.

Given the above, it appears that several PAs contribute to the knowledge construction and that it is important to think about aligning pedagogical planning with technologies. This research presents a PA entitled Collaborative Content Construction, which is based on the collective construction of knowledge through relational pedagogy, supported by Piaget's genetic epistemology [7]. Following are more details on the proposed PA.

3 The Pedagogical Architecture Collaborative Content Construction

The proposed PA is based on constructivist principles, where there is no greater weight for the subject or object, but a balance between them. Thus, the principles of relational methodology centered on the subject's action/reflection on the object are followed.

In summary, the PA proposes the following dynamic, as shown in Fig. 1. The teacher defines a general study theme, under which students will work. Groups of 3 to 5 students are created. Then, each group selects a sub-theme with which they want to work.

Once the sub-themes are established, each group must carry out previous research on the sub-themes of the other groups and, for each of them, suggest an agenda, of which they want more details, such as the explanation of a concept or phenomenon, for example, that must be related to the sub-theme.

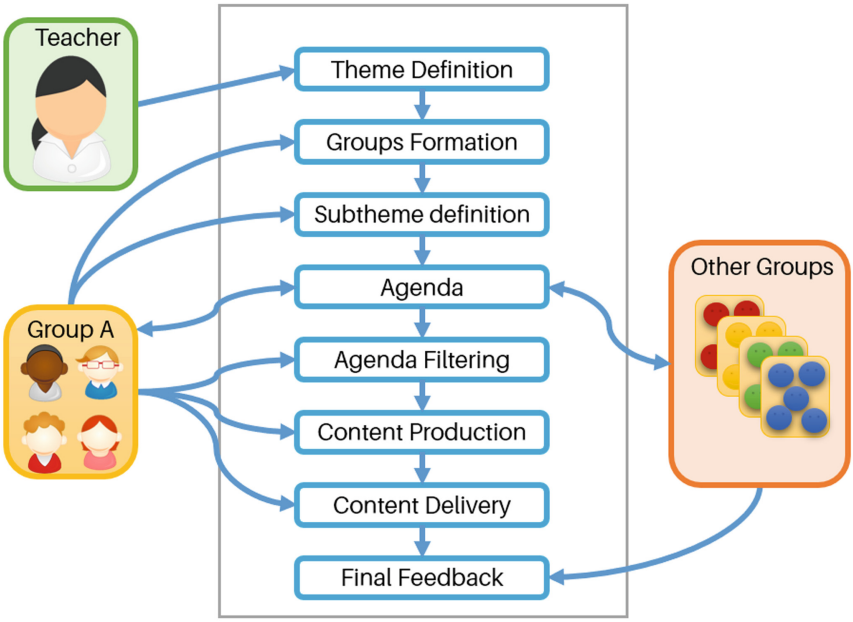

Fig. 1. PA collaborative content construction structure.

Then the group that received the agenda, analyzes them, and checks if they proceed, justifying if they reject any agenda item. Then, the group must produce content to be presented that incorporates, but is not restricted to, the approved agenda.

Preferably in a fluid way and presenting examples closer to their realities, if applicable. The teacher decides what the presentation format will be, it can be, for example, audiovisual or an article. The other groups evaluate the production of colleagues, as a whole and according to the agenda they suggested. The teacher evaluates in general the coherence and adherence of what was presented concerning the theme of the work. The teacher can also specify deadlines for each stage of the PA as well as monitor/evaluate students in each one. At the end of the activity, the teacher discloses the notes and the final considerations.

4 Elements of Collaborative Content Construction

4.1 Knowledge Domain

The domain of "Collaborative Content Construction" is not limited to a certain area of knowledge, but given its interaction proposal, this AP requires attention when choosing the umbrella theme, it should consider the size of the class, if the theme is limited it will be difficult to choose subthemes, if it is too broad, it may happen that the work of the groups does not become complementary. If this is the case, ideally, the teacher should launch some key subthemes for the choice of groups.

The proposed PA is strongly based on research, reading, interpretation, and writing actions. The teacher must pay attention to the choice of the theme so that its subthemes are not hierarchical to the point of requiring more work from one group and less from another. There should be always a necessary balance of effort between the teams.

4.2 Educational Objectives

Following the constructivist principles, this PA aims to support the construction of content interactively and collaboratively. Not only is the student's participation important, but his/her opinion is essential. At the stage where he/she can suggest agenda items, the PA allows that, even in the face of issues, even if already well established, he/she has an opinion, and that opinion will be heard and will be part of the final product.

If there are no agenda suggestions, the process does not proceed. This reinforces the importance of cooperative attitudes in the learning process. PA allows you to learn during the content construction process and share what you have learned with other colleagues at the end.

4.3 Previous Knowledge

In the proposed PA, prior knowledge is necessary mainly in two moments: sub-theme selection and agenda suggestion. First, Students are the generators of the material itself, and when choosing the sub-theme in which they will work together they will also use their prior knowledge on the subject.

Then, when suggesting an agenda, they analyze what they know and what they would like to know in greater depth, helping other teams to compose materials that best correspond to the expectations of their audience, which are the students themselves.

4.4 Interactionist-Problematizing Dynamics

Participants work in groups of 3 to 5 individuals. The sub-theme selection can occur in two ways: 1) previously, the teacher selects sub-themes, and the teams are allowed only to choose among them; 2) each group chooses a sub-theme of work adhering to the main theme.

In the second case, the teacher must be careful so that the sub-themes are not contained in each other. That is, a subtopic A cannot be contained in subtopic B, nor the opposite, but there can be partial intersections. For both cases, the teacher will specify a time for each group to exchange ideas and choose their subtopic better.

After choosing the sub-themes, students will check the sub-themes of the other teams and carry out individual research on them. At this point, each team member must suggest an agenda item, such that the number of different agenda items must be equal to the number of team members. Communication within the team is paramount so that there are no repeated agendas. Example: a team with five members should suggest five different agenda items for each group. This is an individual stage of the PA.

After all the teams have finalized the agenda suggestion, each team must carry out a process to filter its agenda. The agenda items that do not fit the sub-theme should be rejected and justified as to why. The repeated agenda item must also be refused. Communication within the team is paramount so that there are no repeated agenda items.

The next step is to generate the learning content. For this, the group considers its sub-theme, research, and suggestions from the agenda. The entire agenda must be included in the generated content. It is up to the teacher to decide the format in which the final content will be provided, for example, an article or an audiovisual product.

4.5 Distributed Pedagogical Mediations

There are no impediments when exchanging ideas between participants from different teams. However, the records of the agenda suggested in the technological support of the PA that will have greater weight in the evaluation of the interaction between groups. The teacher should always check that the sub-themes are under the umbrella theme, if the sub-theme is not aligned, the rest of the process will be compromised.

The teacher should also find out, for example, if the sub-theme chosen by the group is not very extensive concerning the time available for the activity. Students can consult the teacher at any time, except in the guideline suggestion phase, which must be carried out individually.

4.6 Procedural and Cooperative Assessment of Learning

The teacher can assess whether students cooperate with teams, for example, rejected agenda item may indicate that the student did not perform his/her role correctly. In the final delivery of the content, the teacher can assess whether the team correctly covered the subtopic. This is also a time for each student to check if his/her agenda item suggestion, when accepted, was included in the content or not and if it was answered satisfactorily.

At the end of the AP application, the contribution of all participants will be evaluated. The evaluation considers the final product, the collaboration of the participants through the suggestions made, and the use of the received agenda.

4.7 Computational Support

Collaborative work always becomes more complex when one participant depends on another to be able to start his/her contribution. Computational support can be applied both to serve as a repository for the contributions of the teams, as well as to monitor and to delimit the participation of the groups, avoiding possible setbacks and actions that are not allowed. The proposed computational support consists of an online virtual system, where students and teachers are registered. The environment has two profile, student, and teacher, which allow the monitoring and recording of all steps of the PA.

The teacher profile has the following features:

- Registration of the theme and sub-theme.
- Group management; assignment of students to groups.
- Assignment/confirmation of sub-themes.
- Viewing agenda suggestions; visualization of the final product and each group's forum.
- Control of start and end dates for each stage of the PA including the deadline for sending the product.
- The final feedback of the activity.

In the student module, the functionalities are:

- Registration of the sub-theme.
- Registration of the group, individual registration of agenda, where the student sees only the suggestions given by his/her group (in order not to repeat the suggestion).
- Filtering of the suggestions received, in case of rejection of the agenda, a justification field must be filled.
- Access to the group's forum to exchange ideas.
- Submission of the final product.
- Individual evaluation of the content/final product of the other groups and feedback from the teacher.

5 Validation with a Practical Example

We present the computational support called AC^3 (*Ambiente para a Construção Colaborativa de Conteúdo* (in Portuguese) - Environment for Collaborative Content Construction) that manages the activities of the PA and a practical example of how to use it with a form of validation. The sequence below represents the point of view of a single group, but the same behavior is replicated for any group in the PA.

Figure 2 presents a partial view of the tool applied to a computing class, in the discipline of Artificial Intelligence (AI). To facilitate understanding, only two groups

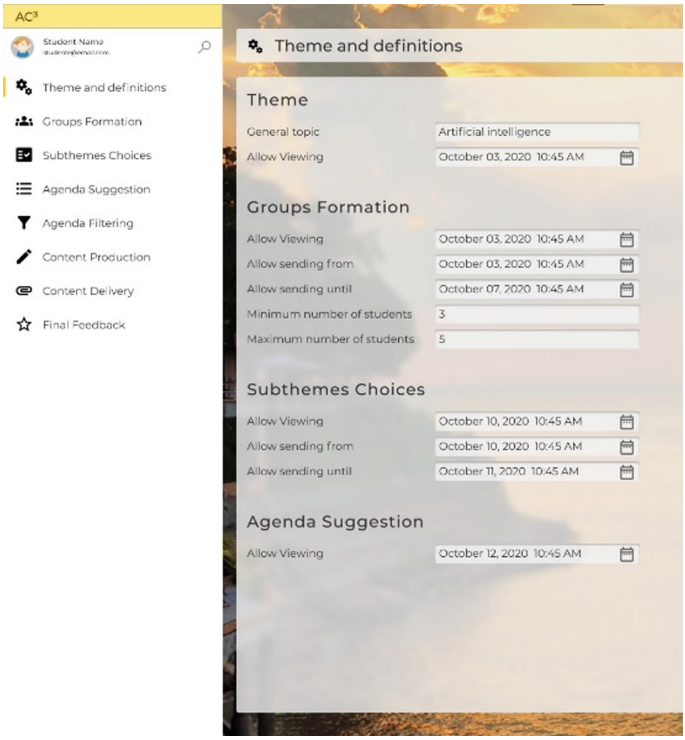

Fig. 2. Partial view of AC^3 showing general definitions.

with three members each will be considered. The groups will deliver an audiovisual presentation at the end of the PA.

As shown in Fig. 2, in 'Theme and definitions' the teacher launched AI research as a general theme. Still, the same figure shows the delimitation of the deadlines for each stage and the limits, minimum and maximum, of participants per group. Then, in the 'Groups Formation', students make groups and inform each other who will be the representative of the group. Figure 3 shows the visualization after the formation of groups A and B, with their respective representatives, Student 3, and Student 2.

In the subtopic selection phase, group A chose Robotics, while group B chose Computer Vision. The representative is responsible for registering the group theme in the tool. As shown in Fig. 4, the teacher receives the subthemes and evaluates whether he approves or not, for example, both were approved.

Once the deadline for choosing the sub-theme has ended, the 'Suggestion of agenda' will be enabled. Figure 5 presents the option where a student in group B can send an agenda item to the group A. This phase is individual.

As each student sends his/her suggestion, therefore, each group received an agenda with three items. Group A received as agenda suggestions: use of Lego, main robotics competitions, industrial use of robotics. Group B, on the other hand, received as agenda: detection of animals, assistance to blind people, weather forecast.

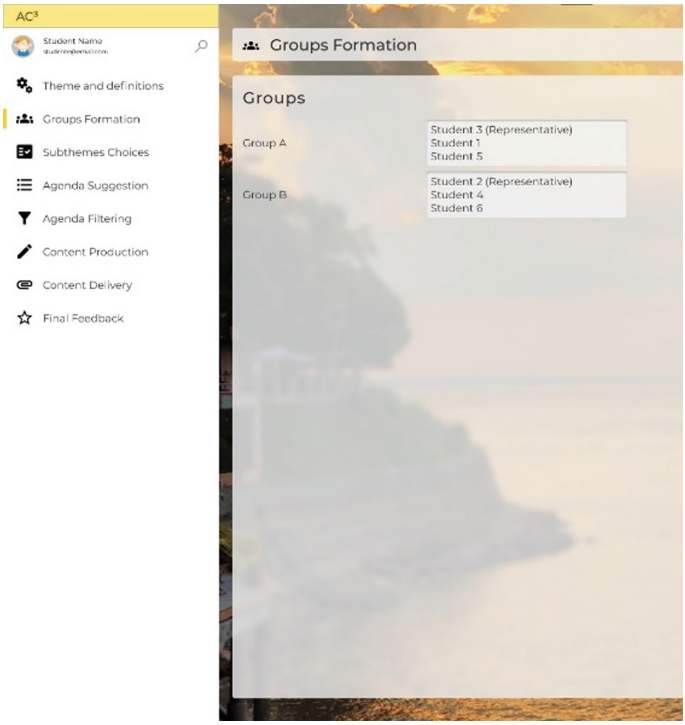

Fig. 3. View of the groups formed.

Then, students access the option 'Agenda Filtering', as seen in Fig. 6. Group A accepted all suggestions. Group B, on the other hand, rejected the 'weather forecast' agenda justifying that it is more focused on data mining. In the tool, the teacher can see which student suggested the agenda item that was refused. Groups can view the agendas of other groups, but they can only approve or disapprove their agendas. After the filtering of the agenda is complete, the content elaboration phase begins. The groups, in possession of the agenda, begin the work of developing the final product and can interact in the option 'Content Development'. In the end, the representative of each group sends the file containing the product created using the 'Content Delivery' option. The teacher evaluates all content presented, while students evaluate how their suggested agenda was presented. The assessment of students must be carried out in the system. The teacher will later post the notes that will be visible in the 'Final Feedback' option.

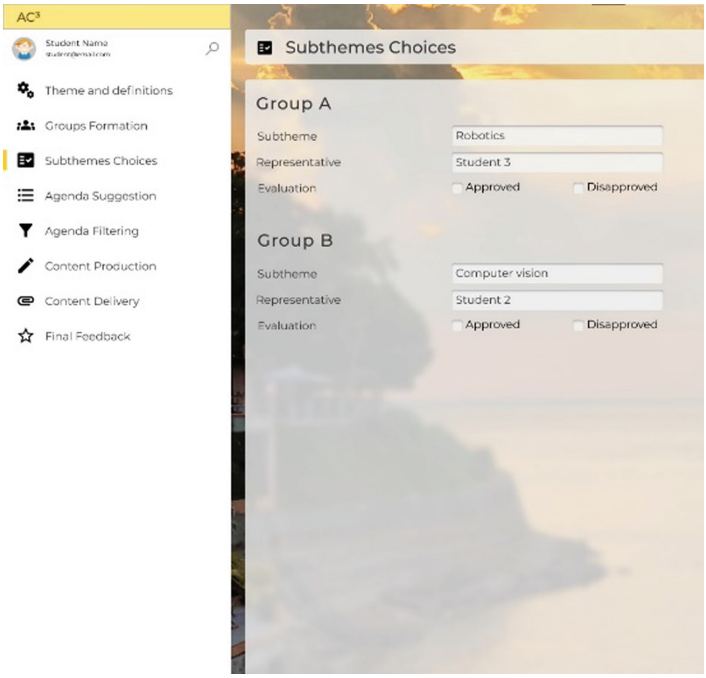

Fig. 4. Subthemes approval (teacher options).

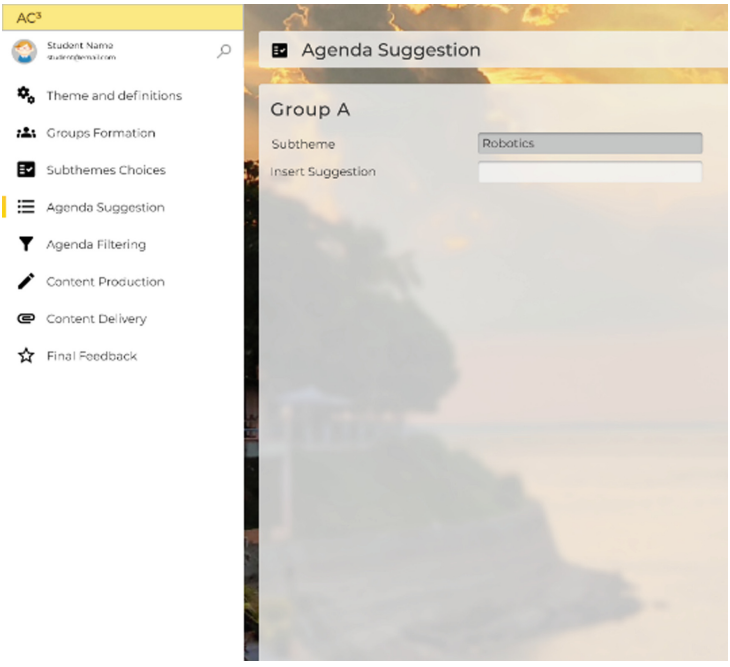

Fig. 5. The agenda suggestion.

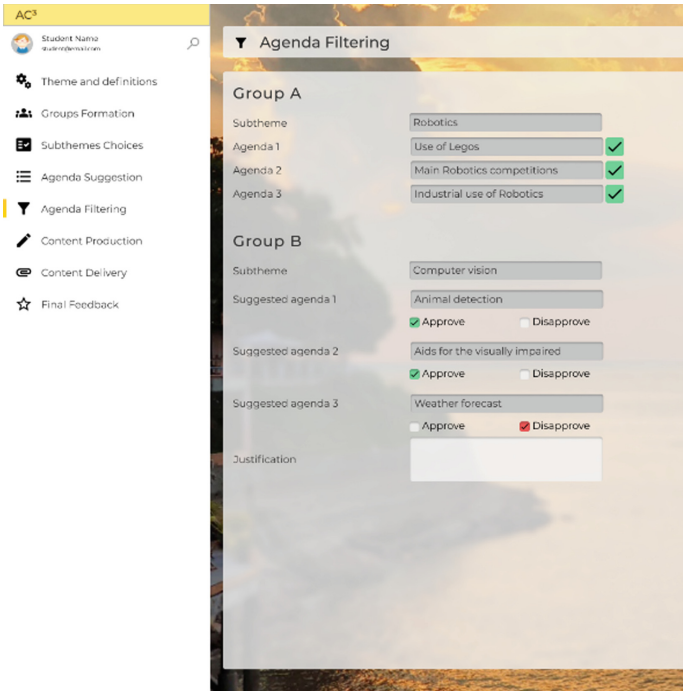

Fig. 6. Agenda filtering.

6 Final Considerations

This work presented a PA proposal entitled "Collaborative Content Construction", based on relational pedagogy. In the proposed PA, students are led to act collaboratively and, at the same time, to have their opinion as an essential key to the process of product creation and evaluation. So, they can also understand how they are assessed and what criteria were used. Students are expected to appreciate the final product, as it is created by themselves. The next steps in this investigation include a case study in a real use situation where, in the end, students will also be invited to evaluate the various stages of PA, identifying possibilities for improvement. As for technological support, it will be possible to identify adjustments to existing resources, for example, frequency of alerts to participating students whenever a stage approaches the end, in addition to the adequacy of other features.

Acknowledgment. This research was supported by the Foundation for Research Support of the State of Amazonas (FAPEAM) [PROINT/AM Program, 003/2018]; the Coordination for the Improvement of Higher Education Personnel - Brazil (CAPES) – Finance Code 001; and the Federal Institute of Education, Science, and Technology of Amazonas (IFAM).

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Is the Gender Pay Gap an Outcome of Other Gender Gap?

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Abstract. Promoting gender equal pay in the labor market represents one of the foundations that allow the socioeconomic development of all the countries that achieve them. However, this gender equal pay is conditioned by several other gender gaps that are observed since childhood and that develop throughout the evolution of the professional life of the human being. Unfortunately, despite the positive changes that have affected humanity at the social and economic level in recent decades, gender segregations continue to exist and limit women and prevent them from enjoying the same training and professional opportunities as men and consequently cause an imbalance in the pay of their abilities. The objective of this study is to define the elements that impact the creation of wage gaps; therefore, a general analysis is made to observe how both gender secondary education gap and gender labor force gap influence the gender equal pay gap. We will then analyze the behavior of four Mediterranean countries, which are: France, Spain, Morocco and Algeria based on these elements.

Keywords: Gender equality · Glass ceiling · Unequal pay · Labor force · Secondary education

1 Introduction

Women have made substantial headway in education and employment in recent decades, but there is still room for improvement because of occupational segregations and pay gaps. In fact, several gender inequalities in wage setting for identical jobs have been observed among employers in recent years [1–3]. These segregations have also been seen in other stages of women's lives, from taking them out of education to burdening them with domestic responsibilities that restrict their ability to work long hours in demanding professions.

The original version of this chapter was revised: The author's name has been changed as "Danilo Santos Piñeros Perea" and typesetting errors in figs 1, 2 and 3. have been corrected. The correction to this chapter is available at https://doi.org/10.1007/978-3-031-07018-1_12

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 26–41, 2022.
https://doi.org/10.1007/978-3-031-07018-1_3

According to the [4], women worldwide earn on average 20% less per month than men for jobs of the same nature. The same source noted that without targeted action, the pay gap will not disappear for at least 71 years from now.

Access to education and employment is today one of the greatest barriers preventing women from accessing the same earnings as men, even when they contribute the same economic values to society. The [5] trade union notes that the underlying causes of gender pay gaps are numerous and complex and simply reflect inequalities linked to education and the labour market.

Meurs et al. (2010) [6], meanwhile, say that gender pay differences can be explained by factors such as gaps in education levels, positing that education and experience are two determinants of employee pay and specifying that women's progress in education should reduce gender pay gaps. But the authors explain that this element is not the only one influencing pay gaps since, even when women have the same or an even better educational attainment as men, the time they are forced to take off work due to motherhood prevents them from building up the same employment history as their male counterparts. These two elements form the baseline for the achievement of equal pay, since women and men are educated differently from childhood on, and their professional paths are designed from the time they enter secondary education. Indeed, it is in high school where adolescents face one of the critical first decisions, i.e., choosing their academic orientation (science or humanities), which subsequently determines their professional one. However, this choice is not always personal and reflective and can involve many other elements, such as the conscious or unconscious influence of parents or other family members, social stereotypes imposing a division of education and careers by gender, pressure due to the obligation to make a quick decision, or a lack of references in one field or another [6, 7]. This dependency leads us to believe there is a correlation between the gender gap in secondary education and the pay gap, on the one hand, and between the gender gap in workforce participation and the pay gap, on the other, across 78 countries. This is the focus of our research work, where we unpack this problem for four Mediterranean countries, namely France, Spain, Morocco, and Algeria. Our hypotheses are as follows:

H0: There is no correlation between the gender gap in secondary education and gender gap in workforce participation variables and the gender pay gap.
H1: There is a correlation between the gender gap in secondary education variable and the gender pay gap.
H2: There is a correlation between the gender gap in workforce participation variable and the gender pay gap.
H3: There is a correlation between the gender gap in secondary education and gender gap in workforce participation variables together with the gender pay gap.

2 Literature Review

Although the four societies are all developing and leaving some social and cultural inequalities behind, there are still many aspects to change. These include stereotypes around the design of education and the idea of 'jobs for women' and 'jobs for men',

conditioned by the physical abilities of each gender and their family responsibilities, which ultimately prevent women from reaching senior positions.

According to the European Commission (2014) [8], the gender pay gap represents the average difference between male and female workers' gross hourly earnings. Gross earnings refer to payments made directly to an employee before applying any deduction on income or for social security. The same report found that women in the European Union earn, on average, 16% less per hour than men, and pointed out that this gap exists even though women outperform men academically. Goldin (2019) [9] says this pay inequality is measured by quantifying the earnings of all the women who work a year full-time in a particular country and all the men who do the same, establishing an average for each.

It should be emphasised that the pay gap penalises women not only during their working life but also after they retire, since it results in lower pensions than men and a higher risk of poverty [8, 10].

These gaps between what men and women make exist even when adjusting for other factors like experience, roles, location and education. As Osuna and Rodríguez (2015) [11] put it: "*Women and men still tend to work in different types of jobs and focus on different industries. Furthermore, women hold lower-value, lower-paying jobs within the same sector and/or company*" (p.36). Women also often have no choice but to accept jobs with more flexible hours so they can balance work and family requirements. This has been referred to as the double or triple working day and compounds inequality of opportunity and occupational segregation.

Other authors say the gender pay gap is down to women having interrupted and discontinuous work paths that negatively impact career development [12–15].

According to the human capital hypothesis posited by Becker (1975) [16], educational attainment, work experience and on-the-job training are powerful determinants of productivity and, indeed, individual earnings. Experience in the job market influences wage determination and this penalises women who have taken time out on maternity leave, for childcare responsibilities and to care for elderly relatives. The combination of paid work time (public sphere) and unpaid work time (private, domestic sphere) is a further obstacle enabling men to move further up the career ladder [11, 17].

Trade unions play a decisive role in the fight against wage discrimination as they are responsible for defending gender equality in the labour market through agreements that determine fair pay conditions. These difficulties are directly linked to the existence of a prior segregation that plagues education and training because of stereotypes. In this regard, de-Felipe (2019) [18] says there is a strong correlation between this discrimination and the gender pay gap and indicates that increasing wages and improving working conditions in sectors where women prevail could have the effect of encouraging more men into these professions and, in turn, addressing the problem of occupational segregation between the sexes.

Finally, the CES (2016) [19] government advisory body also warns about the existence of a positive correlation between educational attainment and workforce participation, especially among women. It says that female labour-force engagement increases the higher the level of education, especially in the case of university graduates, while men's participation is high regardless of educational background.

3 Material and Methods

3.1 Research Design

The purpose of this work is to confirm our hypotheses and test the existence of a correlation between the two independent variables and the dependent variable defined below in this section.

To this end, statistical data was first collected and then processed to perform two simple linear regressions and a robust multiple linear regression.

Gil (2018) [20] defines linear regression as a useful method to predict a quantitative response Y starting from a single independent or predictor variable X, assuming there is an approximately linear relationship between X and Y. Mathematically, this linear relationship is represented as:

$$\boldsymbol{Y} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{X}_1 + \boldsymbol{\epsilon}$$

Where:

Y: It is the dependent variable
X: It is the independent variable

$\boldsymbol{\beta}_0$ (constant, ordered at origin, expected value of Y when $X = 0$) and $\boldsymbol{\beta}_1$ (slope, mean increase in Y associated with an increase in X of one unit) are two unknown parameters in the model.

We assume that the residual or error ϵ (difference between what is observed and what is estimated by the model) is a random, independent component of X.

Multiple linear regression is an extension of simple linear regression where we can include more than one independent variable at a time [21].

$$\boldsymbol{Y} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{X}_1 + \boldsymbol{\beta}_2 \boldsymbol{X}_{2+\ldots\cdots+} \boldsymbol{\epsilon}$$

In the event of having more than one independent or predictor variable, we could posit that one option would be to fit a regression model to each one separately. However, this approach might not be entirely satisfactory since each regression equation would ignore the effect on the other variables when estimating regression coefficients.

Also, if the predictors were correlated with each other, it could lead to erroneous estimates, unlike if the adjustment is made separately. Therefore, one advantage of multiple linear regression is that it evaluates the effect of each independent variable in the presence of the rest, avoiding the confusion that can occur when the observed association between a predictor variable and the dependent variable, or response, is fully or partially explained by another variable (confounder) [20].

As for the robust multiple linear-regression model, its objective is to exclude outliers and anomalies. The statistical coefficients are subsequently analysed, and the Pearson correlation coefficient is chosen from among them. This is the correlation used most and

which represents a measure of linear dependence that confirms the significance of the correlation between these variables or the degree to which they are associated [20–22].

Definition of the Pearson Correlation Coefficient
The PCC is obtained by dividing the covariance of two variables by the product of their standard deviations.

Let X and Y be two random variables in a population; the PCC denoted by ρ X, Y is defined as:

$$\rho_{X,Y}=\frac{\sigma_{XY}}{\sigma_X\sigma_Y}=\frac{Cov(X,Y)}{\sqrt{Var(X)Var(Y)}}$$

Where:

σ_{XY} is the covariance of (X,Y)
σ_X is the standard deviation of variable X
σ_Y is the standard deviation of variable Y

Similarly, we can calculate this coefficient on a sample statistic denoted by rxy as:

$$r_{X,Y}=\frac{\sum x_i y_i-n\overline{xy}}{(n-1)S_xS_y}=\frac{n\sum x_i y_i-\sum x_i\sum y_i}{\sqrt{n\sum x_i^2-(\sum x_i)2}\sqrt{n\sum y_i^2-(\sum y_i)2}}$$

The value of the correlation index varies in the interval [−1.1], the sign indicating the direction of the relationship:

If $r = 1$, there is a perfect positive correlation. The index indicates a total dependence between the two variables called a direct relationship: when one increases, the other also increases in constant proportion.

If $r = -1$, there is a perfect negative correlation. The index indicates a total dependence between the two variables called an inverse relationship: when one increases, the other decreases in a constant proportion.

If $r = 0$, there is no linear relationship but this does not necessarily mean the variables are independent: there may still be non-linear relationships between the two variables studied.

If $0 < r < 1$, there is a positive correlation.

If $-1 < r < 0$, there is a negative correlation.

In effect, as in the case of the simple linear regression, the true β0, β1.., β-p coefficients are unknown, so they must also be estimated.

Imprecision in estimated regression coefficients is related to reducible error (model bias), unlike irreducible error or random ε in the model, which is related to the degree of uncertainty associated with how much each individual point differs from the true regression line or, to put it another way, the difference between what is observed and what is estimated by the model.

One of the measures most often used to determine how well a model fits in simple and multiple regressions is R^2 (coefficient of determination). This coefficient corresponds to the square of the correlation between the independent variable in the case of simple linear regressions and the square of the correlation between the response variable and the fitted linear model.

On the other hand, based on the standard error calculation, we can obtain the confidence intervals for each of the estimators. A 95% confidence interval defines a range of values that you can be 95% certain contains the true unknown population parameter. In the case of a linear regression, this interval for β0 and β1 takes the following form:

$$\hat{\beta}_0 \pm t_{df}^{\alpha/2} SE(\hat{\beta}_0)$$

$$\hat{\beta}_1 \pm t_{df}^{\alpha/2} SE(\hat{\beta}_1)$$

3.2 Data Collection Instruments

This study considered primary source data taken from scientific journals and government agencies, including:

- **Internet:** All statistical data for the macroeconomic variables used in this study was obtained from World Economic Forum web pages.
- **Document Analysis:** We analysed tests, monographs and scientific works on paper and electronic format explaining macroeconomic concepts to check that the equations found were related to the theory and economic phenomena explained to date.

3.3 Data Processing

After collecting this data on a country-wide basis with the aid of Microsoft Excel software, the data was first explored visually, then debugged and a complete database was created and filtered to save countries with complete data only. To ensure data standardisation, it was processed, and adjustments were made for years by extrapolation over time. This process also included verification of value concordance around consistency and quality. This stage let us consolidate the comprehensive program database and ensure its reliability. Mathworks MATLAB® processing software was used. This is a complete computing environment that enables information processing, display and applications.

3.4 Definition of the Hypotheses

Having stated the problem, posed the research questions and hypotheses, and established the cause-effect relationship model structuring this research work, we would state that this study is exploratory, descriptive, causal/correlational and explanatory of the impacts of the variables. The hypothesis of most interest is that Y (gender pay gap) is independent of the variables x1 (gender gap in secondary education) and x2 (gender gap in workforce participation). But this hypothesis considers four possibilities:

Hypothesis 0:
H0: This hypothesis considers there is no correlation between our three variables.

In this regard, the CEOE (2019) [23], an institution representing the Spanish business community, says that, despite progress on equal work in recent decades, the gender pay gap is yet to be resolved.

Requena (2020) [24] notes that educational attainment is unrelated to gender pay gaps, since women are often better educated than men but paid less.

Hypotheses 1 and 2:
H1: The first hypothesis considers the first variable only (secondary education gap):

$$\boldsymbol{GPG} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{X}_1$$

H2: The second hypothesis considers the second variable only (workforce participation gap):
eqe

$$\boldsymbol{GOG} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{\beta} \boldsymbol{X}_2$$

Several authors have commented on the correlation proposed in hypothesis H1, including Conde (2016) [25]; Anghel et al. (2018) [26], indicating that the rise in secondary-education attainment differences between women and men has a clear impact on the pay gap. These authors say that the higher the level of education the lower the pay gap.

Conversely, the ILO (2018 b) [27] trade union supports the existence of the correlation predicted in hypothesis H2 and points out that one of the most important gaps affecting the gender pay gap is horizontal or occupational segregation, i.e., the non-uniform distribution of men and women in each production sector and which concentrates the presence of women in jobs characterised by worse pay and lower social standing.

Hypothesis 3:
H3: The third hypothesis considers the two variables together:

$$\boldsymbol{GPG} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 \boldsymbol{\beta} \boldsymbol{X}_1 + \boldsymbol{\beta}_2 \boldsymbol{X}_2$$

Our third hypothesis, H3, is supported by Karamessini and Loakimoglou (2007) [28] who argue that there is a very close relationship between these three variables, since an unskilled worker without a certain level of education can only be employed in some specific jobs and is limited in terms of workforce participation, making them less valuable than people with more skills and meaning they earn lower wages.

More recently, Cebrian and Moreno (2015) [29] have noted that the gender pay gap is divided into the following: one part explained by differences in productivity due to educational attainment or employment history, and another part that is unexplained and is a waste that is sometimes called a measure of discrimination.

3.5 Definition of Variables

Drawing from the review of the state-of-the-art developed in the previous section, we deduced that the dependent and independent variables, which are quantitative and describe the model, were (Table 1):

Table 1. Definition of variables

Variables	Definitions
SERG	Secondary Education Rate Gap: The difference between the secondary education rate for men (SERM) and the secondary education rate for women (SERW), where: $SERM = \frac{Secondary\ Education\ Men}{Total\ men} * 100$ $SERW = \frac{Secondary\ Education\ Women}{Total\ Women} * 100$
LFPRG	Labor Force Participation Rate Gap: The difference between the workforce participation rate for men (WPRM) and the workforce participation rate for women (WPRW), where: $LFPRW = \frac{Workforce\ participation of\ women}{Total women} * 100$ $LFPRM = \frac{Workforce\ participation\ of\ men}{Total\ men} * 100$
GPG	Gender Pay Gap: The difference between men's income (MI) and women's income (WI), where: $GPG = \frac{WPRM - WPRW}{Men's\ income} * 100$

Source: Authors' own work

3.6 Approach of the Models

This section describes the econometric technique most used to find the coefficients of equations describing relationships between studied variables. In research, regression analysis is very often applied to provide a response or obtain a Y result (dependent variable) influenced by one or more independent variables. In our case, the linear regression models were two simple types and one multiple types. The two simple regression models relating variable Y to another explanatory variable were as follows:

$$GPG = \beta_0 + \beta_1 SERG_i$$

$$GPG = \beta_0 + \beta_2 WPRG_i$$

As for the multiple linear regression model relating variable Y to several explanatory variables, it had the following form:

$$GPG = \beta_0 + \beta_1 SERG_i + \beta_2 WPRG_i$$

Where:

GPG: Gender Pay Gap
SERG: Secondary Education Rate Gap
LFPRG: Labor Force Participation Rate Gap

3.7 Application of Regressions to a Set of Countries

The selected variables were chosen for an international context and four Mediterranean countries were also singled out: France, Spain, Morocco, and Algeria. The aim was to

analyse where these countries lie within the 78 chosen countries and how they behave around gender gaps in accordance with the cultural, social, economic, and political aspects of each. The choice of these four countries was mainly due to their historical relationships, since the two on the northern shore of the Mediterranean (France and Spain) have had responsibilities in the two on the southern shore (Morocco and Algeria), giving them cultures that are at once both very similar and markedly different.

4 Results Analysis

This section compared three types of gaps: the secondary-education gender gap, the workforce participation gap and the gender pay gap. The results can be summarised in the following table:

Table 2. Models of robust linear regressions

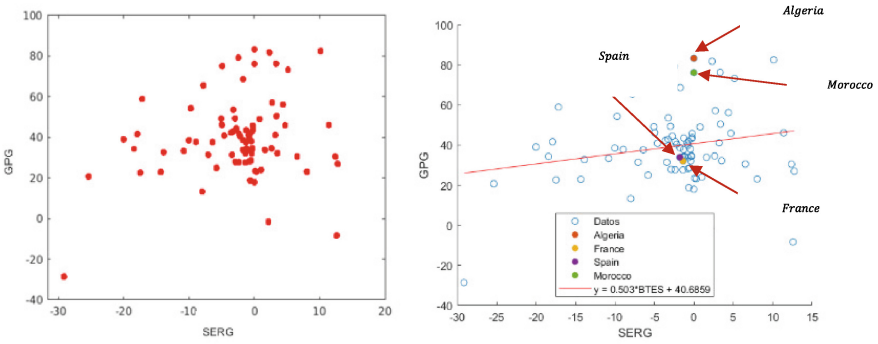
	Variable	Coefficient	Standard Error	t-Stat	pValue
Model 1	X: SERG	0,50	0.22	0.72	0.47
	Intercept	40.67	1.80	21.60	$2.3276_e - 35$
	Number of observations: 78, Error degrees of freedom: 75 Root Mean Squared Error: 15.64 R-squared: 0.01, Adjusted R-squared: −0.002 F-Statistic vs. constant model: 085, p-value = 0.36				
Model 2	X: LFPRG	0.88	0.08	11,62	$1.0712_e - 18$
	Intercept	21.89	1.93	11,82	$4.5303_e - 19$
	Number of observations: 78, Error degrees of freedom: 75 Root Mean Squared Error: 10.2 R-squared: 0,64, Adjusted R-squared: 0,63 F-Statistic vs. constant model: 136, p-value = 8.35−19				
Model 3	X1: SERG	0.30	0.15	1.98	0.05
	X2: WRPG	0.89	0.08	1.98	$1.7034_e - 17$
	Intercept	23,60	2.046	11,53	2.7689e − 18
	Number of observations: 78, Error degrees of freedom: 75 Root Mean Squared Error: 10.4 R-squared: 0,64, Adjusted R-squared: 0,63 F-Statistic vs. constant model: 65.6, p-value = 3.39−17				

Source: Authors' own compilation based on data from the World Economic Forum (2020) [30]

4.1 Correlation Between Gender Pay Gap and Gender Gap in Secondary Education (H1)

We analysed our first hypothesis, looking at the gender pay gap and the gender gap in secondary education, i.e., the difference between the percentage of girls and boys in

lower and upper secondary education. This education level was identified in line with level 2–3 of the International Standard Classification of Education (ISCED), defined as the stage of education preparing for both first labour market entry and post-secondary non-tertiary and tertiary education. According to UNESCO (2011) [31], this stage of education is designed for learning at an intermediate level of complexity, distinguishing between lower and upper secondary education.



(A) Analysis of the 78 countries

(B) Behavioural analysis of France, Spain, Morocco and Algeria

Fig. 1. Influence of the gender gap in secondary education on the gender pay gap. **Source:** Authors' own compilation based on data from the World Economic Forum (2020) [30].

In Fig. 1(A) there is extensive dispersion that does not appear as a straight line; however, the dots track upwards, indicating the existence of a significant correlation between our two variables. Furthermore, our p-value is greater than the low p-value (0.05), and not confirming hypothesis H1 of a correlation between the gender gap in secondary education and the gender pay gap.

We then analysed the behaviour of each of four countries (France, Spain, Morocco, Algeria) within the set of countries considered. Figure 1(B) shows the two North African and the two European countries performing differently. This is due to the substantial gender pay gap in Morocco and Algeria. We also see that these two countries are aligned in an almost parallel position, indicating some similarity in terms of secondary education.

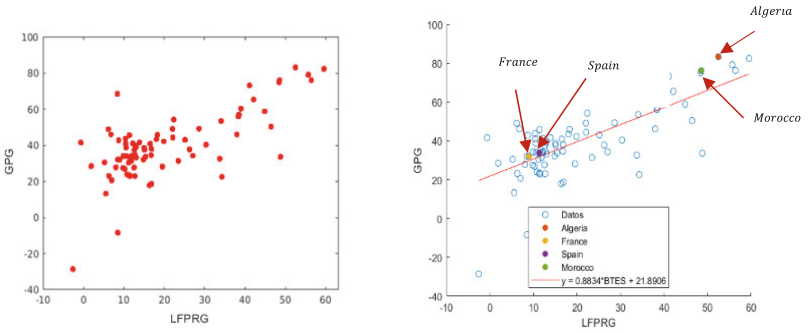
It also shows that France and Spain are very close to the adjusted regression line, while the other two countries are a long way from it. This leads us to conclude that the two European countries are adjusting to parity, while the other two lags. The equation also puts the gender gap coefficient in secondary education at 0.503.

$$GPG = 0.05 * SERG + 40.67$$

This indicates that for each additional unit of SERG, the GPG can be expected to rise by an average of 0.5.

4.2 Correlation Between Gender Pay Gap and Gender Gap in Workforce Participation (H2)

The existing correlation results between gender pay gap and gender gap in workforce participation is a measure of the proportion of a country's active working-age population (18–65 years of age) available to engage in the production of goods and services [32]. Indeed, the workforce is the sum of the number of people employed and the number of people unemployed [33].



(A) Analysis of the 78 countries

(B) Behavioural analysis of France, Spain, Morocco, Algeria

Fig. 2. Influence of the gender gap in workforce participation on the gender pay gap. **Source:** Authors' own compilation based on data from the World Economic Forum (2020) [30].

Figure 2(A) very clearly illustrates a positive correlation between the gender gap in workforce participation and the gender pay gap. This correlation is much more significant than the previous one. Indeed, the PCC is positive and closer to one, and the Fig shows a straight line. The p-value for this variable is lower than the low p-value (0.05), thus confirming hypothesis H2, i.e., of a correlation between gender gap in workforce participation and gender pay gap.

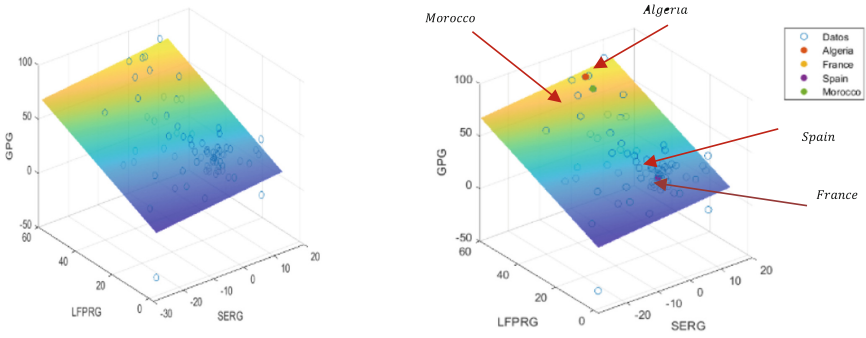
As for Fig. 2(B), we see that not only do France and Spain have very low gender gaps compared to Morocco and Algeria, but they are also closer to our adjustment line, while the two North African countries are further away from it, indicating a greater workforce participation disparity and gender pay-gap inequality (the latter more visible for Algeria than Morocco). The equation also puts the gender gap coefficient in secondary education at 0.88.

$$\boldsymbol{GPG = 0.88 * WPRG + 21.89}$$

This indicates that for each additional unit of LFPRG, the GPG can be expected to rise by an average of 0.88.

4.3 Correlation Between Gender Pay Gap and the Gender Gap in Secondary Education Together with the Gender Gap in Workforce Participation (H3)

This analysis was performed to corroborate hypothesis H3, indicating whether the gender pay gap depends on or is influenced by gender gaps in secondary education and workforce participation.



(A) Analysis of the 78 countries

(B) Behavioural analysis of France, Spain, Morocco and Algeria

Fig. 3. Representation of the robust linear regression model. **Source:** Authors' own compilation based on data from the World Economic Forum (2020) [30].

Figure 3(A) shows the representation of the multiple linear regression considering the two variables at the same time and pointing to the existence of a positive correlation between the three variables. This endpoint also confirms hypothesis H3 and consequently rejects our null hypothesis H0.

Figure 3(B), like the previous ones, visibly highlights the positioning of the two North African countries and their two European counterparts.

The equation also shows that the gender gap coefficient in secondary education is 0.30 and the gender gap coefficient in workforce participation is 0.88.

$$\boldsymbol{GPG = 0.30 * SERG + 0.88 * WPRG + 23,59}$$

This indicates that for each additional unit of SERG, the GPG can be expected to rise by an average of 0.30 and that for each unit of the LFPRG, the GPG can be expected to rise by an average of 0.88.

Based on figures obtained via the statistical analysis of the data, we can see that:

- GPG has a significant correlation with SERG and LFPRG, with a PCC of 0.30 and 0.88, respectively. Although the correlation between GPG and SERG may seem low, it is considered a significant correlation because the p-value is 0.04, i.e., lower than the significance level the calculation was made with (0.05).

With the previous model and in accordance with the data analysed, we could explain 64% of the GPG data, and the averages and confidence intervals are presented with a confidence level of 95% for each of the three variables.

5 Discussion

Our results suggest there is no significant correlation between the gender gap in secondary education and the gender pay gap, thus rejecting hypothesis H1. This lack of correlation could be justified by the fact that education alone is not enough to secure pay parity and is only one factor among others that influence it.

As for the result regarding the relationship between gender gap in workforce participation and gender pay gap, we are led to conclude that hypothesis H2 is true: the smaller the gender gap in workforce participation, the smaller the gender pay gap. This is explained by women's greater involvement in informal sectors and submerged economies compared to men, which does not put them in a good position to negotiate wages. However, it is also influenced by other factors such as a lack of self-confidence, lack of a work-life balance leading them to choose positions with fewer responsibilities or in lower-paid sectors, as well as the time they take off work during their career [34] which means they do not develop the same employment history as men. Even when they hold down the same job, they do not get the same allowances and do not dare ask for them.

On the other hand, our result indicates there is also an inverse influence consisting of the gender pay gap impacting women's integration in the work world. This is due to the tough decision mothers must make when they do not have enough resources to ensure the care of their children, e.g., for nurseries, and therefore stop work since otherwise their pay would go on childcare. Kaipper (2018) [35] points out that mothers who cannot afford to take on a nanny or pay for a nursery give up work, some even before they go on maternity leave.

After all, we found the correlation between gender pay gap and the two elements together had a 63.6% significance, confirming hypothesis H3 and rejecting null hypothesis H0. This endpoint speaks to the complementary nature between guaranteeing parity across education and employment for delivering gender pay equality. On the other hand, Araújo (2014) [36] indicates that the pay gap is generated in the job market due to the diversity of the workforce in relation to educational attainment, profession, age, gender, activity sector and area of residence.

Finally, we unpacked the particularities presented by the countries studied, where several disparities were detected in Algeria and Morocco. These segregations are due to various social and cultural factors causing women to live in the shadow of men. In effect, traditions, social pressure, stereotypes, parental level of education and the values parents convey play an important role in women's emancipation and men's insights around equality. Arab culture has generally imposed a style of family management in use among the population that reduces women to fragile beings requiring constant protection by the dominant male gender (fathers, brothers, husbands, uncles, grandfathers...).

This is explained by the fact that their financial and social autonomy and independence date back only a few decades and they still have some way to go to achieve total parity. In this regard, Casballo et al. (2018) [37] indicate that maintenance is a right of

the wife and an obligation for the husband laid down in Islamic law and the provisions of various Arab laws.

Indeed, traditional culture prevails in many villages across Northwest Africa, with women preferring to stay home to care for children and the elderly rather than take their place in the world of work. In the case of Algeria, for example, this situation is accounted for by the 'black decade' (period of terrorism) it experienced between 1989 and 2001, where women were forced to stay home since it became quite dangerous to be out on the streets.

As for the result we got for Morocco, it can be explained by Moroccan women's involvement in the rural world, where they are generally considered to be helpers rather than employees and do not benefit from either social protection or official pay. Berlanda (2013) [38] points out that Moroccan women do most of the domestic and farming work and manage the family economy, while getting no payment for it.

6 Takeaways

In light of the results of this study, we can confirm the existence of a direct relationship between the three analysed gaps. These results are justified by the complementary nature of the elements forming a vicious circle, since without an education you cannot work and without work you cannot earn a living. The same goes the other way round: without financial resources you cannot access education or the same job opportunities.

The comparative study among the countries also enabled us to see their behaviour in terms of secondary education, workforce participation and pay gap and how socioeconomic, cultural, and religious factors influence each of them.

This work also led us to reassess the importance of onboarding women across all areas starting from childhood to raise awareness around the importance of diversity. Grant Thornton (2017) [39] says diversity is key to business success since a mixture of men and women at the helm makes a company better prepared for all eventualities.

It is therefore essential to set the challenge of circumventing structural barriers and ensuring wage parity by promoting the work-life balance. Indeed, business strategies must power human values and leverage technological progress to make them a partner that guarantees diversity, inclusion, and the achievement of added economic values [40]. Tackling the pay gap is no mean feat, but it can be achieved with the involvement of all actors in society ensuring equal access to development opportunities at work and creating an inclusive culture across all companies.

Empowering women to take on more responsibilities and reviewing recruitment processes would help shore up human resource policies from all kinds of exclusion and segregation.

Finally, equal treatment of employees influences corporate loyalty and performance (wellbeing in society and quality work), thus generating profits for the company and the entire country.

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Applications and Scenarios, Phigital, CS Education and Assessment

Scratch + CNC: Mixing Physical and Digital Worlds

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Abstract. It is already known that the retention of knowledge occurs more effectively when there is experimentation, there being an association between the understanding of what has been conceptually learned and a real experience. In this context, this work proposes the development of an extension for Scratch 3.0 capable of interacting with a CNC (Computer Numeric Control) machine. With this, a proposal of cooperation between two environments in the learning context is created, combining programming in blocks with equipment able to provide outputs in physical objects. Therefore, it is intended to provide a physical-virtual environment where the learner can have a tangible result beyond the computer screen, adding learning skills. In addition, the objective is the development of technological components to foment the "maker" culture through the use of computer-controlled machines in schools, groups, or labs.

Keywords: Creative learning · Scratch · Computational thinking

1 Introduction

In the Brazilian context, there is a great challenge in reference to the progress of education in relation to the indices achieved in the last years, an even greater challenge when comparing public and private education. According to data from the "*Todos pela Educação*" (or "All for Education") movement, about 70% of students were expected to reach the adequate learning goal by the year 2020 for students in the final years of elementary education in municipal and state schools in a perspective aligned with five objectives: assistance, literacy, performance, completion and direct investment. However, the monitoring report on the goals of the National Education Plan, produced by Inep [5], shows that only 20% of the objectives were fulfilled in relation to the measures that should have been implemented by 2017 (the law has planned phases until the year 2024). Indices generated by PISA (Programme for International Student Assessment) 2018 based on around eleven thousand students from 597 schools show that 68.1% of 15-year-old students do not have a basic level in mathematics, while 55% do not have a basic level in science and 50% in reading [4]. This demonstrates some

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 45–54, 2022.
https://doi.org/10.1007/978-3-031-07018-1_4

of the need for changes in the teaching-learning process motivated by the wish to raise engagement rates not only for students but also for educators and the school community.

The globalized world inserts the technology in everyday life directly or indirectly, but it does not occur in the same way within the classroom in most Brazilian schools, and when it happens the greatest potential is not extracted. Thus, despite the latest advances in the offer of technology to transform teaching and learning in the traditional classroom environment [6,12,20], there is a general concern about the effectiveness of current approaches, which fail to generate clear evidence that technology produces results that contribute to the educational environment. Therefore, it is noticed that there are failures in the educational model, where the technological evolution was not inserted in the school context, occurring a gradual reduction in the engagement of the learners faces to the educational methodologies used, which become obsolete.

It is needed encouragement for change to happen even in front of the difficulties and in this process, we believe that the first steps (even if small) reflect more actions that generate positive results and best practices. In this thought, the present work has as an objective to propose the development of an extension to the programming environment in blocks Scratch version 3.0, allowing interaction with a computer-controlled machine from which they can be concretized in different materials and in different ways what has been programmed in the tool, such as 2D figures, geometric shapes, traces and free drawings.

We intend to achieve different competencies listed in Common National Curriculum Base (in direct translation for "*Base Nacional Comum Curricular*", implemented in the year 2020) [3] linked to the educational context and other aspects of the Creative Learning Methodology [14,25]. We want to connect concepts already covered in the classroom such as physics and mathematics, for example, to develop logical thinking through programming (computational thinking [23]) related to the process of assembly and running of the machine (electronics, robotics, etc.), adding the "maker spirit". This whole set of experiences serves as a base for the development of a methodology of teaching and learning in which many abilities can be emerged involving many learners, besides that the creativity will be imminent and the development is possible with low cost of resources, allowing even greater versatility to the project.

2 Learning Environment

The usage of technologies as support to the process of teaching and learning is not recent. It aims to stimulate teachers and learners through technological components that help in materialization of abstract concepts in concrete phenomena that support the continuous improvement of the teaching-learning process. New challenges to be overcome arise constantly with the demand for new approaches as a reflection of social changes and the evolution of technology to more complex systems. For Jonassen [11], the learning comes from problems that need to be solved as students learn and understand while they are solving. In this

same idea, [16,23] define computational thinking as the capacity that an individual has to initiate a process of elaboration and solution of problems. The logic of programming allows the coherent articulation of the information in a logical sequence that makes possible the resolution of problems, being one of the fundamental knowledge for the construction of computational thinking [15]. The biggest challenge to be overcome in the current classroom model involves introducing transversal computational thinking collaborative projects involving different disciplines, teachers and so on [9].

However, these teachings are passed in isolation most of the time, without contextualization and relation with other areas of knowledge and problems of the real world, damaging the process of understanding the applicability of these concepts in the everyday of the learner. Practice that contradicts David Ausubel's Significant Learning theory, with a concept of Derivative Subscription [2], for example.

Thus, computational thinking can assist in the development of adjacent skills such as (i) abstract thinking, with different levels of subjectivity in understanding the problem; (ii) logical thinking, in the formulation and elimination of hypotheses; (iii) algorithmic thinking, constructing solutions to problems in different steps to arrive at the most efficient and effective solution; (iv) scalable thinking, dividing a problem into smaller parts to compose a complex solution [1]. Linked to this, the Fig. 1 illustrates a percentage quantification in view of the forms of learning estimated by Glasser [10] where, after two weeks, it can be observed that active methodologies in activities cause greater impact in the retention of knowledge.

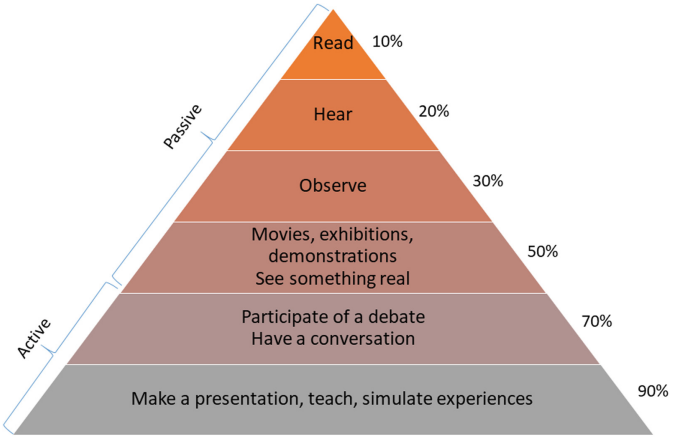

Fig. 1. Levels of retention of knowledge, adapted from [10].

In this sense, research has been carried out to introduce concepts of computation in the context of Brazilian primary and secondary education. Parallel

to this comes the promotion of Creative Learning initiated by [14] through the concept of constructionism, having its in-depth research by [17]. Based on the adoption of the four P's (Projects, Peers, Passion, and Play), aiming at stimulating students by placing them at the center of the educational process, enabling them to plan, create and test in real situations of daily life, acting actively before before social problems and the themes that involve them [8,21]. On the other hand, the growth of the maker movement and maker spaces has engaged more peoples in the use of digital manufacturing tools than ever before [22]. Aligned with this idea, we will present the extension proposal in the next section.

3 The Proposal

Motivated by the previous discussion, we want to put into practice the development of this proposal, extending the computational thinking approach to creative computing. For that, we will develop an extension for the Scratch 3.0 block programming language to generate the positioning file (G-Code) in the object construction process through a computer-controlled machine, allowing the user to transform what was programmed into a real object.

The Fig. 2 shows the desired development scheme of this extension, we can see the Scratch tool as the main module of the system and the physical object as the final product of the process.

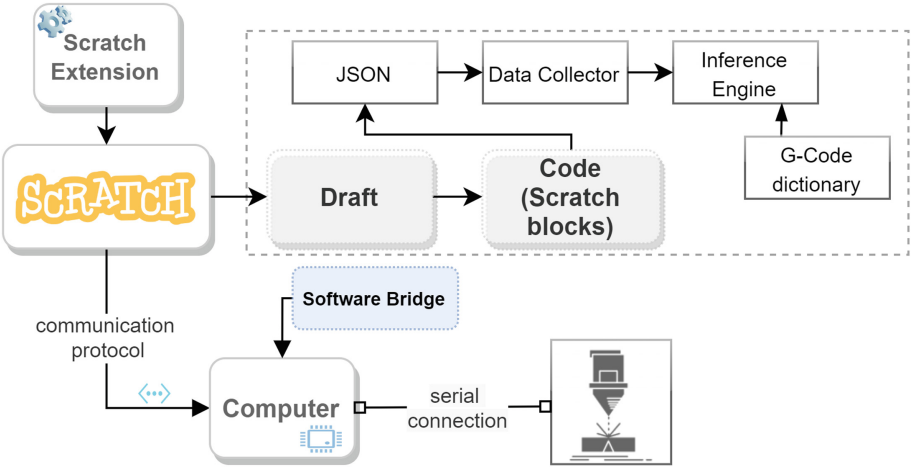

Fig. 2. Scratch extension scheme. three main layers: the first comprises the tool Scratch; the second is the extension responsible for translating what was programmed in blocks to g-code; thirdly, the layer of control and communication with the machine.

From this, we describe the other technological components:

i. Scratch extension: este componente compreende uma camada lógica, responsável pela transformação dos do código em blocos programado na interface do Scratch em G-code.
   - Scratch data collect: all the block programming performed in the Scratch workspace interacts with the *scratch-blocks* and *scratch-vm* modules. Through since last, all code is constructed and executed from the blocks, being normalized to a *JSON* structure, where each event can be accessed and interpreted independently. Thus, a structure is needed for the correct collection and processing of necessary information:
     - data collector: this module should be responsible for collecting properly the relevant information present in *JSON* structure built by the Scratch tool in backend;
     - inference engine: should select and apply the most appropriate rule in each step as the application is executed, constituting the previous step to the translation to *G-Code*;
     - code translation: from the access to the *JSON* structure, the code must be translated into another format that can be interpreted by the CNC machine interface (*G-Code*) according to a dictionary.

ii. Computer component: hardware unit that interfaces between Scratch and the computer-controlled machine. This can be a desktop or even a Raspberry Pi.
   - Software bridge: software component responsible for communication between interfaces. After collecting and processing the code generated in Scratch, it is necessary to send to the CNC machine the code that will represent the drawing in coordinates. This communication must take place through a protocol which can be HTTP or WebSocket. So far, WebSocket has chosen to promote full-duplex communication channels over a single TCP connection;
   - Serial interface: communication between the control unit (computer with bridge software) and the computer-controlled machine. This is a normal USB connection that takes the processed commands to the lowest level control unit present on the CNC machine.

iii. Object creation: the final step of the process will be object production as the materialization of the drawing made in the Scratch in an perspective of physical-virtual interaction.

4 Tools

4.1 Scratch

Scratch is a visual programming language that was developed by a partnership between MIT and University of California, Los Angeles (UCLA). This is not the first environment and programming language intended for beginner programmers. There is a rich history of different tools for this purpose [13]. Scratch is

based on the ideas of Logo [7], but replaces the code typed with a "drag and drop" approach inspired by LogoBlocks [24] and Etoys. The tool emphasizes media manipulation by supporting programming activities that are of interest to young people, such as creating animated stories, games, and interactive presentations. Originally designed as a rich media programming environment to introduce and motivate school programming [18,19]. Programs are built by assembling stacks of colored command blocks that eliminate syntax problems and encourage the exploration of the environment. The Fig. 3 exemplifies the use of Scratch with very simple programming containing a loop repeat and commands that indicate the character to move and present a message on the screen. The third version of Scratch was developed together with the Google Blockly[1] team to redesign the programming blocks for their newest version. Scratch extensions allow interaction with external hardware and information outside of Scratch through new developer-built blocks for the visual programming language Scratch. However, now there are two mechanisms to extend Scratch 3.0, either with *http* requests or JavaScript as indicated by the wiki[2]. There are four types of extensions that can define everything from Scratch's core library (Core, Team, Official, and Unofficial), to unofficial extensions that can be loaded from a remote URL.

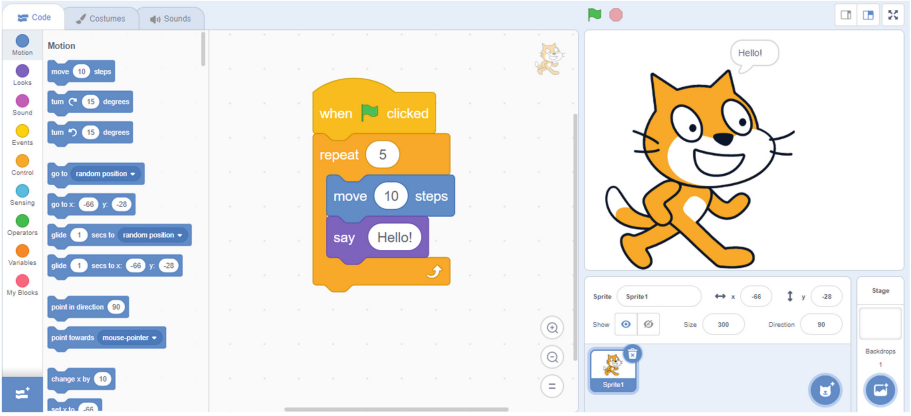

Fig. 3. Interface of the Scratch editor. On the left the programming blocks, in the center the programming area and on the right the output with the character performing the commands.

4.2 CNC

Initially, in the 1940 s MIT created the NC (Numerical Control) which later evolved into CNC with the advent of computing. The computerized numerical

[1] https://developers.google.com/blockly.
[2] https://en.scratch-wiki.info/wiki/Scratch_Extension#Scratch_3.0.

control by itself comprises a system that allows control of machines through a specific code called *G-Code*, through which it can interact simultaneously with electronic and mechanical components, such as the axles moved by motors and the operating head.

Any workflow involving a computer-programmed machine involves several steps from designing to manufacturing the object itself. For example, if we want to mark a 2D image using a laser CNC the flow would start with an image vectoring tool, configure the machine working area, vectorize the image, generate the G-Code path and save it, transfer it to the machine that contains a firmware capable of interpreting the code generated in controls to move the platform movement motors, turning the laser on and off. This example is illustrated in Fig. 4. Used mainly in the large-scale industry, this technology is not restricted to the industrial context but has become part of a range of smaller applications that can be built indoors, reusing materials and diversifying the applications as machines that can draw, paint and write combining mechanical parts for drive and electronics for control like the Arduino, ESP32, Raspberry Pi or other which can be easily integrated into the project. The Fig. 5 shows the CNC built completely with reused materials (electronic scrap) such as threaded bars, stepper motors, wood, and Arduino Nano for the control module containing the control firmware.

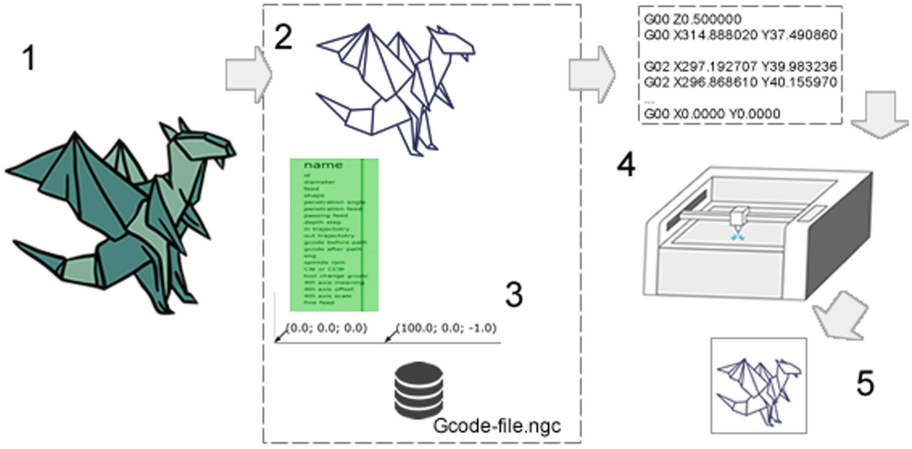

Fig. 4. Workflow to perform laser marking. (1) Trace bitmap of figure; (2) set orientation points; (3) generate g-code path and save .ngc file; (4) transfer code to machine; (5) work performance.

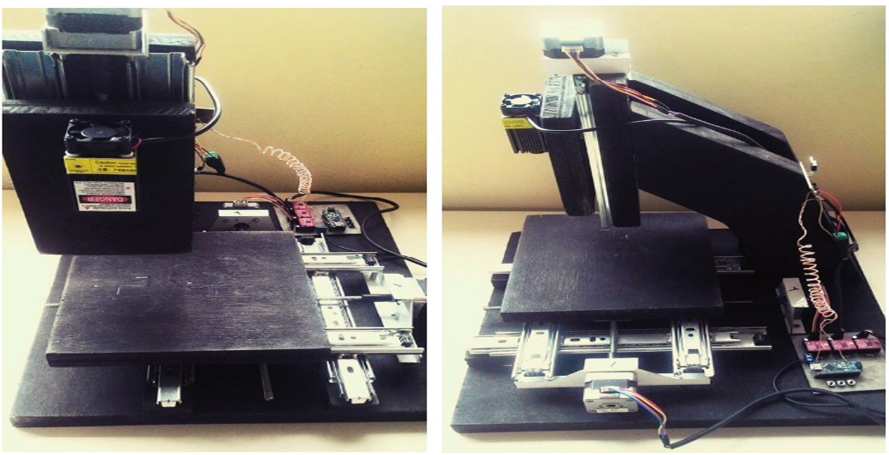

Fig. 5. Laser CNC handmade in university laboratory.

5 Considerations

The discourse of this paper begins by presenting worrying data about the low performance of students in the Brazilian educational context. We strongly believe among the reasons is the application of obsolete methodologies and little or no introduction of technology in the classroom, this contact is motivating for generations of connected young people. Furthermore, the application of a new educational model (the BNCC) provides for a more effective introduction of technology to the teaching-learning process, including programming.

This article presents the proposal to implement an extension to the Scratch 3.0 block programming tool. The main objective is to integrate the block programming system in a computer-controlled machine, allowing the user to have the experience of transforming what was programmed into a physical object.

Furthermore, many teaching-learning skills can be associated with the set: (a) understanding of coordinates (operation of machine axes according to commands); (b) electronics concepts (by machine components); (c) programming logic (understanding block programming to generate the desired output); (d) multiple dimensions (lines and geometric shapes in 2D) among others. For the hardware component of the machine we can list possibilities such as (i) creation of drawings from mathematical functions; (ii) printing characters cut out of the student's drawing to compose a board game, for example; (iii) markings on the wood, paper, and other materials; (iv) the construction of the machine itself, which, as shown, can be created with relatively simple and inexpensive materials and relatively low complexity for tutors with computer knowledge.

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Case Study: A CSCL Approach for Object-Oriented Programming Learning

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Abstract. A Computer-Supported Collaborative Learning (CSCL) approach was designed for the Systems Seminar course of the Systems Engineering program at University Antonio José Camacho (UNIAJC) in Cali (Colombia) [1]. The purpose was to make Object-Oriented Programming (OOP) learning not an individual process but a collective one where students play different roles to solve a software-based problem (from requirements specification to software development). Based on the results of the experts' review made in the previous study, a case study is now proposed to assess the feasibility of this approach. Eight students took part of this study following each of the stages proposed in the approach and the results show that even though this is still a good starting point, some changes need to be made to achieve better results.

Keywords: Computer-supported collaborative learning · Object-oriented programming

1 Introduction

Getting a group of people to work together, share understanding and achieve a common goal is a difficult task [2], especially for educators, since achieving true collaboration requires activities carefully designed for that purpose. Collaborative Learning (CL) is a strategy where a group of people learn together by interacting with each other and taking advantage of one another's skills and knowledge [3, 4]. Positive Interdependences are considered the 'heart' of collaboration [5] and they basically provide the elements to assure true collaboration among a group of learners. Some of these interdependences are: goals (group and individual), defining roles, sharing resources among team members, giving rewards for work done, creating identity for the team.

This paper presents a case study to validate a CSCL approach presented in [1] with eight students of the Systems Engineering program of the University Antonio José Camacho (UNIAJC) in a programming course, through interactive collaborative tools supported by computers. The paper is structured as follows: Sect. 2 shows related work on collaborative learning for programming courses. In Sect. 3, the CSCL proposal is presented. Section 4 presents the case study carried out, Sects. 5 and 6 show the results and discussion, finally Sect. 6 concludes the study.

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 55–64, 2022.
https://doi.org/10.1007/978-3-031-07018-1_5

2 Background and Related Work

Several studies discuss about how students in programming courses not always achieve expected results [6–8] and this may be the consequence of multiple reasons such as lack of motivation or not appropriate teaching/learning methods [9]. Collaborative Learning could fill this motivational gap by allowing students to learn from each other as a group. For this research, the following studies were taken as a starting point for the design and implementation of an approach presented in [1].

An Object-Oriented Programming (OOP) Course was redesigned in [10] were knowledge mediation was carried out through a system called ViLLE, a collaborative education tool that allow students to work on different type of programming problems. While students work, the systems automatically assess their work and give proper feedback when it is submitted.

The course was redesigned to promote collaboration, active learning and to facilitate communication between students and their teacher. This system also allowed integrating surveys in a different way that allowed learners to identify visual, auditory, and communicative variables related to the process of OOP learning. The software also provided tutorials as didactic material and the student has the opportunity to express concerns about the progress with the system.

The results obtained through this system show that the implementation of the evaluations through learning environments favors communication. Researchers were also able to integrate writing skills to be able to compile the code and test it to identify mistakes. The main goal was to promote collaboration among students by using learning environments that allow cognitive, communicative, and technological development in the learning process related to OOP. The main component of the study is that it supports the development of collaborative learning as a process of educational innovation. The number of students that passed the course increased by more than 20% in both instances of the redesigned course according to the authors of the study. This study shows one way to redesign a typical programming course, making good use of available technology to promote collaboration.

Beck and Chizhik [11], review the principles of cooperative learning, and describes how these principles were incorporated into a comprehensive set of cooperative learning activities for a CS1 course. In the activities carried out, roles were assigned to the members of the group for individual accountability.

The group processing is followed by a whole-class debriefing led by the instructor, which works in tandem with the group activity to help students improve their understanding of the material. The effectiveness of these cooperative learning activities was assessed in a series of educational research studies which spanned three academic years and included two different instructors. The results of these study showed statistically significant benefits from the cooperative learning approach, both overall and for a broad range of subgroups of students.

This study gives outstanding examples of how students can collaboratively help others understand the process of software development and this was considered for our proposal.

3 Computer-Supported Collaborative Learning Proposal for OOP Teaching

The CSCL proposal of this study is aimed at students from the Systems Engineering program at university Antonio José Camacho in Cali (Colombia). The course is Systems Seminar where students learn the basics of software engineering (algorithms, system requirements, class diagrams and object-oriented programming). In this course, the students must follow a series of steps to give possible solutions to common problems.

To make this work collaborative, Positive Interdependencies (PI) were considered to assure collaboration among students. The PIs that were chosen for this approach are: Roles, Resources, Identity, Goal, Tasks, and Reward (This is the grade for the activity). Some strategies proposed by Kaila et al. (2016) were also considered in the design of this approach.

3.1 Defining Roles

First, students are split into groups of 4 people and all of them must choose a name that identifies them as a team. Each team member is given a role and their correspondent responsibilities/resources. The roles are explained in detail in the following section.

Role 1: Requirements Specifier (RS). This student is in charge of defining the requirements of the system. The client (teacher) gives the information needed for this work. The student is allowed to ask as many questions as necessary to gather and specify the requirements of the system.

Role 2: Class Diagrammer (CD). This student receives the requirements and analyzes them with the rest of the group to make the necessary changes (add/remove/modify the requirements proposed by the RS). Then the CD designs the class diagram of the solution.

Role 3: Algorithm Designer (AD). This student analyzes the class diagram along with the rest of the group to make the necessary changes to it (add/remove/modify the classes proposed by the CD). Then, the AD designs the algorithms of the methods defined in the class diagram.

Role 4: Solution Developer (SD). This student analyzes the algorithms along with the rest of the group to make the necessary changes to the algorithms. Then, SD develops the solution in Java programming language.

The stages to be followed are shown in Fig. 1.

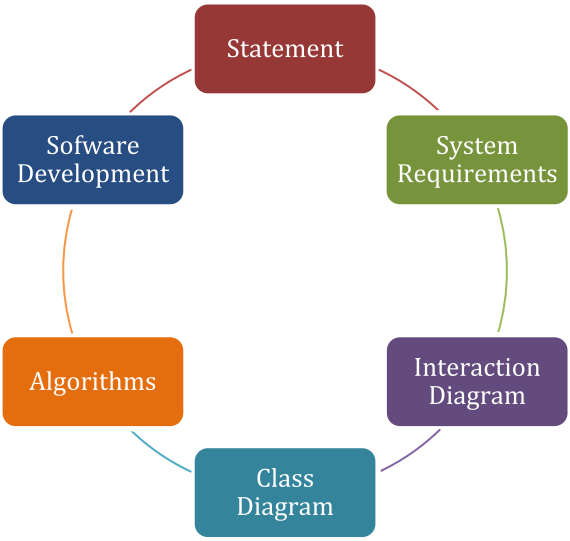

Fig. 1. Stages of the proposal

Each role has its purpose in each stage. Sometimes students will work on their own playing their roles in the corresponding stage with the opportunity to discuss the work done with the rest of the team. The Interaction Diagram stage is the only one with no specific role for it, instead, all team members will work together to define the interaction between objects. The idea behind this proposal is to let students build knowledge in the whole process of developing software, from requirements to the final product. It is important to highlight that changes proposed by the experts' in the review done in [1] will be considered for the case study.

4 Case Study

4.1 Methods

Participants. Eight students at University Antonio José Camacho (Cali, Colombia) were invited to be part of this case study. According to the proposal previously mentioned, each team should have 4 students, each one taking one of the roles proposed for the activity. One teacher was in charge of moderating the activity and his role was to explain what the students had to do, how much time was going to be invested and the tasks assigned to each role.

Students' Profile.

- Age: All students are between 20 and 23 years old.

- Gender: 3 Girls and 5 boys
- All students are in 3rd semester of the systems engineering program.

Environment. The activity was carried out in a virtual environment through the ZOOM platform due to the available features such as breakout rooms to separate students in isolated virtual spaces and thus ensure that they do their work individually. It also offers text, video, and voice interaction.

Programming Language. The software must be developed in Java language since this is the language they are learning in the current semester. The user interface (UI) is managed using the JOptionPane package through pop-up dialogs given that they have not yet learned how to create their own UIs.

Problem Statement. A small store is having problems with their inventory because all the information about products is being kept in a notebook (prices and available units), and this information must be updated every time a unit is sold or if the price changes. Sometimes, due to the amount of people buying in the store, the person in charge does not have enough time to write down the information about all the sells made, so the notebook remains out of date. A simple system is required so that information about prices, available units of each product and sells can be easily updated or viewed through a computer.

Setup and Execution. This process guarantees individual accountability and support from peers in every stage of the process. This process should be repeated interchanging roles to ensure that all students develop or strengthen different skills, unfortunately, it was not possible for the 8 students to be in this activity for 4 consecutive weeks to play all the roles due to their different commitments with the regular semester and their jobs.

This proposal is based on a 3-h class, and two teams of 4 students were created, each student with a role. Then, the requirement specifiers (1 per team) were isolated in a virtual classroom and only the teacher was allowed to talk to them and answer the questions they ask. This first stage (system requirements) lasts 12 min (Fig. 2).

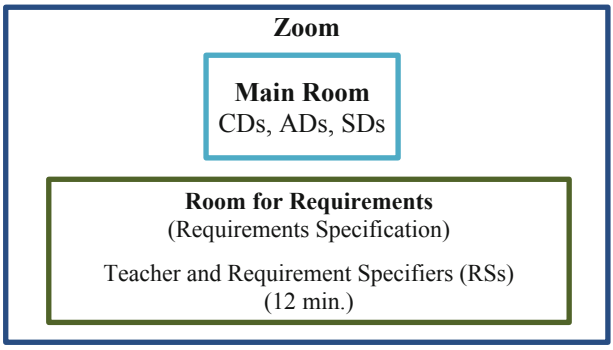

Fig. 2. Requirements specification stage

Once each RS defined the requirements for his/her team, they were called to the main virtual classroom. Virtual spaces were created (one for each team). The four members of each team were invited to join their virtual space to discuss the requirements for 8 min (Fig. 3).

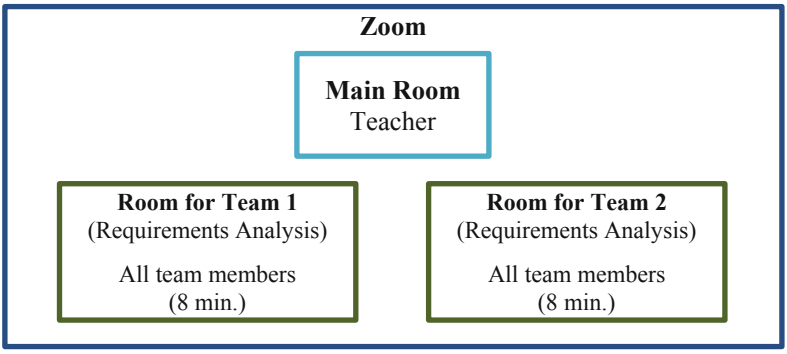

Fig. 3. Requirements analysis

With the requirements specified, all team members remained in their virtual room and defined the Interaction Diagram of the solution. 15 min were given for this stage.

After that, the RS, AD (algorithm designer) and SD (solution developer) left the room and only the CD had the task to design the class diagram of the solution (17 min). If the CD needed help (with conceptual elements of the diagram), only the teacher could provide it (Fig. 4).

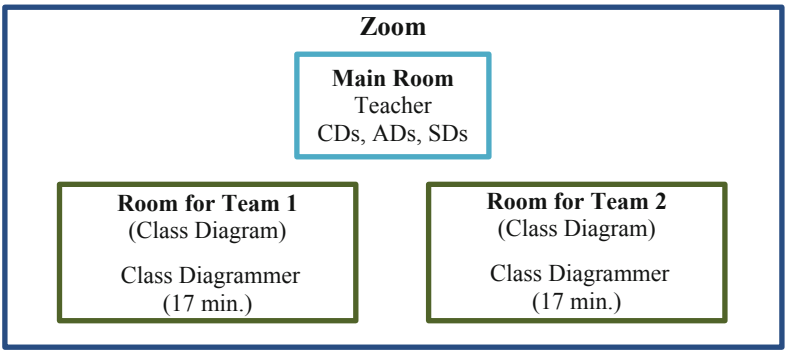

Fig. 4. Class diagram stage

When the CD's of each team finished their diagrams, the rest of the team members joined the separated virtual space to discuss the diagram for a period of 8 min. After that time, only the AD stayed in the room to design the algorithms (35 min) while the rest of the team members returned to the main classroom. If the AD needed help (with conceptual elements of the algorithm), only the teacher could provide it (Fig. 5).

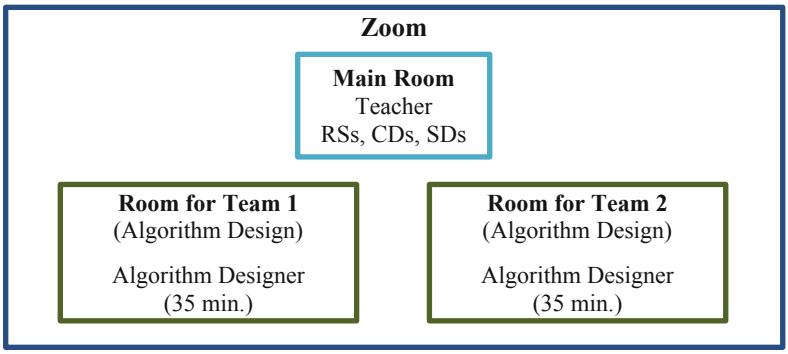

Fig. 5. Algorithm design stage

Finally, all team members joined the AD in the team's virtual space to discuss the algorithms for a period of 15 min. When the discussion ended, only the SD stayed in the team's virtual room to develop the software solution according to the class diagram and the algorithms designed in previous stages (Fig. 6).

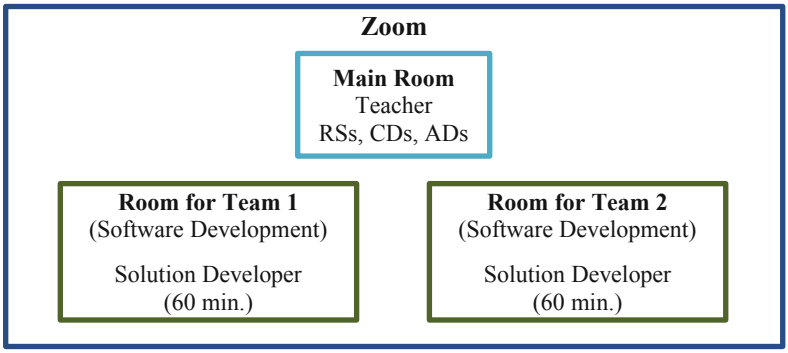

Fig. 6. Software development stage

In this stage, the SD had the possibility to ask for help. All members of the team could join the SD for a maximum of 3 min to solve issues with the software development, then, the RS, CD and AD had to leave the room. If the problem was not solved, the SD could ask for help from the teacher. Help from team members could be requested 3 times maximum (3 min per request). The development of the software could not last more than 1 h.

The remaining 25 min of the class were invested in analyzing the solutions of each team and discussing the problems faced in the design process.

5 Results

During the activity, the role of the teacher as moderator was very important to control the time during the activities and provide help when needed. Students from Team 1 were very agile during the activity, they even finished some stages before the estimated time, while students from Team 2 had some troubles not only at an academic level but also at a technological level because 2 of the team members were having serious problems with their internet connection, so they could not perform their role as expected, this led to change some of the rules for this team and provide more time to finish some stages.

At the end of the activity, during the analysis of both solutions, the students of Team 1 presented a well-designed solution with minor flaws. The solution presented by students from Team 2 had some major issues due to not all students were at the same academic level and some of them needed more time with their team mates to clear their doubts, but for the purpose of the activity, and with so limited time for it, it was not possible to give them more time.

Both teams presented:

- Enough and well written requirements
- Interaction diagram (Team 2 had minor problems with it)
- Class diagram (Team 2 had some conceptual doubts about it that were resolved during the analysis phase with all team members)
- Algorithms for some methods
- A software based on pop-up dialogs (Team 2 had an issue that could not be resolved within the given time and sometimes the application was unexpectedly closed).

Before ending the activity, students were asked the following open questions:

- What do you think about breaking down the activities, so each student is in charge of a particular task?
  - o All 8 students agreed that having different stages and roles for it strengthen their skills on a particular stage of the process, so they all think that this is something valuable for the learning process.
- What would you change about the overall activity?
  - o 4 out 8 students think that the time for algorithm design and software development is too long for those who are not in charge of these activities, they felt like they wanted to do more (requirement specifiers and class diagrammers) but all they could do was wait for the solution developer to request for help.

- Do you think this method could improve your understanding of the whole process of software development? Why?

  - All 8 students agreed this could improve their learning methods since they count on their team mates to support the work they are doing and not rely only on their knowledge but everyone's in the team. 5 students expressed their willing to be part of the whole process (4 weeks) in the future.

6 Discussion

Having the teacher moderate the activity is very important to control time, clear doubts and make students feel there is someone backing up the process.

While this proposal is promising to take advantage of virtual education, these activities mediated by technology may be interrupted by technical problems like those experienced by Team 2.

The results showed that dividing the work by stages and roles, help students master skills and share knowledge with their peers. Although, the time spent by those not working on algorithms or programming, must be rethought to take advantage of it. Before carrying out a new case study, it would be important to improve this approach with these results and opinions given by students.

7 Conclusions and Future Work

This case study was proposed to continue the approach presented in a previous study. Taking advantage of the current situation where some classes are still being held in virtual environments, a group of students were invited to take part of this study to validate a CSCL approach for OOP learning.

First, all recommendations given by experts in the previous study were taken and applied for this case study, such as decrease time for some stages and adding the Interaction Diagram stage.

The case study showed that working in the development of a simple software-based system as a team can be beneficial for learning OOP and strengthen individual and collective skills during the process, understanding that each team member has individual accountability, and the efforts of all members are necessary to achieve a common goal. The implementation of positive interdependences made it easier to guarantee true collaboration.

While the results of the case study are positive, there are still improvements to be made and more case studies must be carried out to evaluate the process of the learners performing different roles each time. Case studies with in-person classes are also necessary to guarantee that it can be beneficial also without virtual environments.

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HProgramming: a Helping Tool for Teach and Learn Programming

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Abstract. Programming is the process of creating and organizing a set of instructions to solve a problem using a computer. In a first phase, we can see programming learning as the acquisition of a set of basic elements of a language. At this stage, this set of elements can be easily memorized. However, for this learning process to be effective, it is necessary to closely monitor each student, focusing on students who begin to manifest difficulties in the first stage of learning. It is important to emphasize that a tutorial action can be performed by people or automated systems. In this work, we present a helping tool to teach and learn to program. Where the plan and activities created by the teacher are privileged. The student has at his disposal a set of exercises framed with the plane defined by the teacher, and practice at his own pace and as often as he deems necessary with the respective immediate feedback.

Keywords: Programming · CS1 · Teaching programming · Learning programming · Intelligent tutoring systems · ITS

1 Introduction

Today's society environments are extremely dynamic and surrounded by new technologies. Students must be able to follow and adapt to this society. Basic computer skills are not enough to remain competitive in today's demanding job market and for years to come [4]. It is essential for students to develop deeper knowledge in the field of computer science. Programming courses are generally considered effective in promoting and developing soft skills such as creativity, problem solving, persistence, collaboration, communication and critical thinking [12]. These skills are crucial for a student's future success, given the constant evolution of technology, regardless of their field of study. However, programming courses have a negative connotation, there is a widespread opinion among students that programming is difficult [12, 13].

There is a widespread concept that programming is difficult, in the work done by Derek Sleeman in [18], we can find some reasons for the difficulty of programming. The author states that the programmer's main role is, in the first place, to build a plan,

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 65–76, 2022.
https://doi.org/10.1007/978-3-031-07018-1_6

a strategy that will lead to the resolution of a problem. Second, it is necessary to know the syntax and semantics of a programming language. Then, it is necessary that the resolution strategy is in accordance with the resources available in the programming language. This coordination between tasks significantly increases the complexity of the programming activity.

In the report developed by the working group of the Conference on Innovation and Technology in Computer Science Education (ITiCSE) in [14], the main objective was to obtain an overview of the main topics covered in the area of introduction to programming. As a result, we found that many works address topics such as: identifying students' difficulties, designing tools to help students, encouraging students to change their behavior with a view to success, predicting success, and detecting undesirable behaviors, between others.

This article is structured as follows Sect. 2 describes related work. Section 3 details HTProgramming and the predictive model for the student's performance. Section 4 explains presents and discusses the results obtained and finally, in Sect. 5 conclusions and future work are addressed.

2 Related Work

The world is increasingly digital. New skills are required of each of us. Many countries are introducing computing skills teaching into their education systems. A computer education prepares students to use Computational Thinking and creativity to understand and change the world. With computer science students acquire fundamental knowledge to become digitally literate to be able to use, express themselves and develop their ideas through information and communication technologies at a level suitable for the future in a digital world. These are some of the ideas proposed by England [16]. Like England, other governments, educational authorities, and schools are introducing the teaching of computer science at different levels of education [17]. In countries such as Lithuania, Finland, Korea, Japan [11], and Singapore [17], initiatives and policies are made to introduce Computational Thinking skills and programming in the schools. With the widespread use of programming at pre-university education levels, soon the difficulties in teaching and learning programming, experienced by all, will be minimized.

Several works have been carried out where the focus is the use of automatic tools with the aid of learning programming. One such example is the work done by [2], where an investigation is carried out on the attitudes, behavior and performance of students using the C Tutor, a program visualization tool. According to its authors, C Tutor appears to be an effective tool that can be used directly, even by beginners in programming. C Tutor can help teachers reduce the need for manual drawing of program execution diagrams.

In study [1], an Intelligent Tutoring System, CPP-Tutor, based on pattern recognition techniques and error correction strategies is presented. The goal is to understand the student's "intent" by carefully analyzing the student code and communicating it to the Expert module to effectively tutor the student through C++ programming problems.

A wide variety of intelligent tutoring systems have been created for the purpose of teaching computer programming. In [3], a systematic review is made of important information about existing systems and the prevalence of different resources within

them. In general, the systems were developed with the aim of teaching introductory programming concepts; other systems guide more specific aspects of programming [3]. The literature reports that these systems address many of the difficulties associated with teaching programming to novices. Most smart programming tutors involve some form of interactive programming exercises. This systematic review reports important information about existing systems and the prevalence of different resources within them.

3 HTProgramming

To minimize high failure rates, students do not acquire basic skills in the area, demotivation, and student dropout. On the other hand, to monitor the knowledge and difficulties of each student, and to intervene quickly with the individual and necessary help of each student, a tool that helps students and professors in this process is needed. For this purpose, we developed an application, called HTProgramming (Help to Programming), which aims to improve our introductory programming teaching and learning process, integrating several techniques described as good practices and with good results in numerous published works. This application was developed in a context and with specific characteristics of computer science students at Polytechnic of Guarda.

In the following sections we describe our project, we start with an overview and general scheme of the HTProgramming application in Sect. 3.1. Then, in Sect. 3.2, we present in detail the administrator module and in Sect. 3.3 the student module. In Sect. 3.4, we describe the predictive neural network model of student failure. Section 4 presents and discusses the results obtained and finally, in Sect. 5 conclusions and future work are addressed.

3.1 General Scheme of Application

The application was developed with the aim of helping the entire process of teaching and initial learning of programming, for students in the first year of the Computer Science course at Polytechnic of Guarda (IPG), Portugal, which, in our opinion, reveal very special characteristics. The C language is used to teach basic programming concepts. The number of students per year is around 100 students, on average, including repeat students. The computer science course, IPG, is generally not the first choice of students; the average candidacy grade is between 10 and 12 points; and, in recent years, it has included students from Portuguese-speaking African countries (Portuguese: Portuguese Africanos de Língua Oficial Portuguesa; PALOP), with various problems in their general education.

The application HTProgramming was developed in Java language, with the Apache Netbeans IDE (Integrated Development Environment). The desktop application interacts with a remote MySQL database, in a Hosting Smart Linux service. The application consists of two modules: the administrator module and the student module, with access to a remote database. We present (see Fig. 1) the general scheme of the HTProgramming application.

The administrator module is used by the teacher to control the entire teaching and learning process. The teacher has access to individual student data and the activities

performed. The teacher also has the possibility of inserting new activities or changing existing ones.

The student module is used by students taking the course. After identifying the student before the application, the student has at their disposal a set of activities directly related to the contents covered during the introduction to programming. In each activity performed, the student receives immediate feedback, scores obtained, suggestions for reading or reviewing, or even suggestions for new activities, and their profile is updated.

The following subsections describe each of the modules that make up the application and describe each of its functionalities.

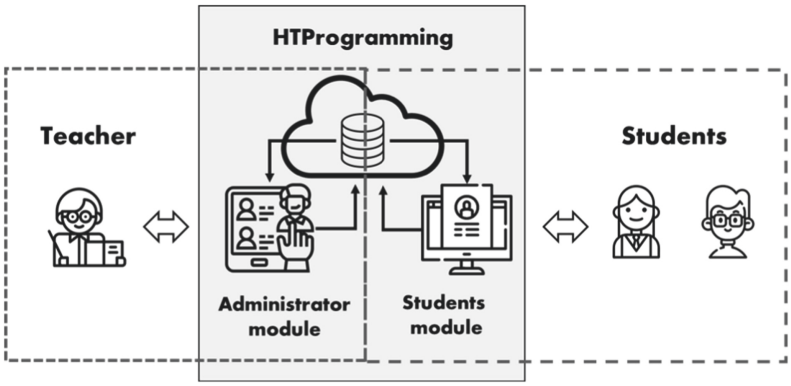

Fig. 1. General scheme of the application HTProgramming.

3.2 Administrator Module

This module of the HTProgramming application is intended for the teacher. The teacher can configure and add activities and follow in detail the activities performed by students. The first screen of the administrator module is a general listing of all students and their respective score, or the student's profile. The various roles assigned to the teacher are also shown. The teacher can filter students by course and sort by profile value. By selecting a student from the list, it is possible to view the results of all activities carried out and change some of the student's identifying data.

Definitions. This functionality is used to manage some of the operations such as: initializing and updating student data, checking for active students in the system and blocking or unlocking activities available to students.

Basic Concepts. In this option you can view and add MCQ (Multiple Choice Question) type activities. The activities are related to introductory programming concepts, in C language, such as data types, names and identifiers, and error identification. In Fig. 2 we can see an example of creating a new MCQ and the existing ones in the HTProgramming application.

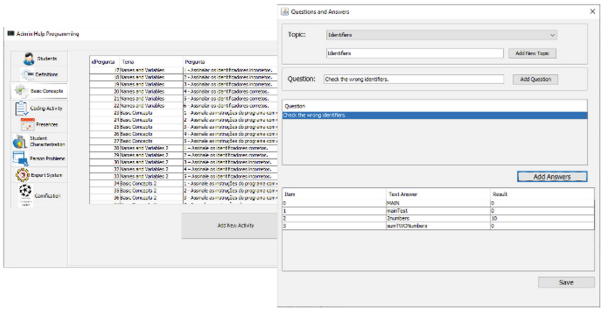

Fig. 2. Basic concepts allows you to view and configure multiple choice questions activities.

Coding Activity. In the Coding Activity functionality (see Fig. 3), the teacher creates questions related to coding in C. When creating each activity, the teacher must consider that he must add the respective test cases. It is also possible to add Test Code Keys, that is, add keywords that the program contains. For example, the teacher considers it important to use the for loop to solve the activity. With this option the teacher will check if the *'for'* keyword exists in the code. Or, as in the example in the figure, check for the existence of output formatting *'%.2f'*.

The code made by the student is compiled by the GNU GCC compiler for windows. If there are errors, the program gives the corresponding message, the student must submit a new program. If the program runs, it is tested with the defined test cases. The result is calculated according to the number of correct test cases plus the value defined for the test code keys.

Presences. This option of the HTProgramming application allows the teacher to register the presence of students in each class. The teacher selects students from an alphabetical list. Students are added to the list of students present on the date indicated. It is also possible to see the different classes and the respective total number of students.

Student Characterization. In the first classes, we collected data that characterize the students. With this dataset, we intend to characterize and better understand our group of students. The items collected are the date of birth, the number of times enrolled in the course, which pre-university course, in which order you chose the IPG computer science course, the candidacy grade, if you have a personal computer and internet connection, how they assess their knowledge in computing in general and in programming and, finally, which programming languages they have already used.

Parson Problems. One way to learn and practice an introduction to programming is to use Parson's Problems [5, 6, 15]. Parson's problems are programming instructions in which the student must select, order, and indent code fragments. These tasks are great for the early stage of learning programming because students don't make syntax errors. In Fig. 4, we can see the functionality that allows the teacher to manage Parson Problems activities.

The teacher introduces the code of the program he wants to use, in the program solution area. To create the Parson Problem activity just select the "shuffle" button, see

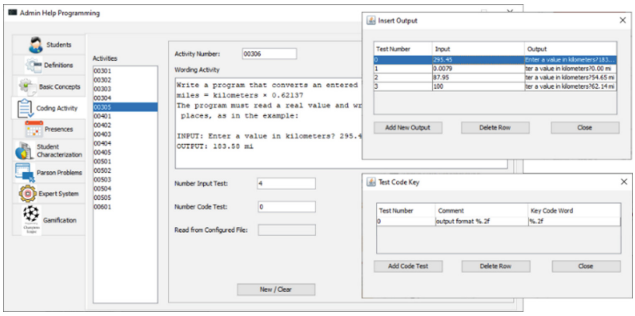

Fig. 3. Coding activity functionality with test cases and test code keys.

Fig. 4. Immediately, the program code entered with its lines swapped is displayed. Once saved, the shuffled program is used as a student activity.

Expert System. Based on the results of student activities, we use a predictive neural network (NN) student failure model, to predict student outcomes. Work developed in [7]. For that, we have used the obtained results to train our predictive neural network model. This area allows the teacher to view and select the data to be used. In future work, the process can be done automatically, and as the various activities are carried out by the students, the model indicates a prediction of the possible failure of the student.

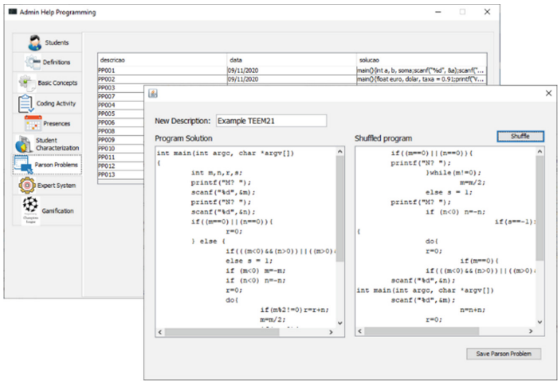

Fig. 4. The parson problems activity management.

Gamification. Games have important motivational power. They take advantage of a set of tools to encourage people to engage with them just for the joy of playing and the possibility to win. As discussed, the teaching and learning of programming is a topic widely studied due to students' difficulties in acquiring basic skills. Therefore, one factor prevails, the lack of student motivation or how to motivate students to learn programming. One way to combat this problem is to use gamification. Using game design elements in non-game contexts is one of the good ways to motivate and encourage students to learn

programming [8]. To assess how gamification can motivate students, we have included the use of one of the elimination tournament gamification techniques, represented in the functionality in Fig. 5.

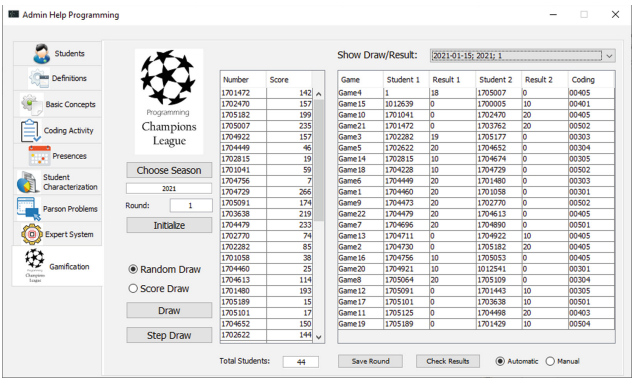

Fig. 5. Gamification technique - Elimination tournament.

To make it more appealing and interesting, we call it the Programming Champions League. The idea of this activity is to draw lots among students and assign a coding exercise to solve in a pre-established time. Students who solve correctly and faster advance to the next stage, and so on until they find the champion. Scores are established by the teacher according to the stages reached. In previous experiences [8], some students reported that they were not motivated to play because they were confronted with students with a much higher level of knowledge than their own. To minimize this factor, in addition to the random drawing, a form of drawing by score was also added. Where students are drawn according to their score value.

3.3 Student Module

The student module is used by students taking the course. After a login process, the student has at his disposal a set of activities directly related to the contents covered during the introduction to programming and defined by the teacher in the administrator module. For each activity performed, the student receives immediate feedback, score obtained, suggestions for reading or reviewing, or even suggestions for new activities, and their profile is built.

The first screen presented to the student is their personal data. Data such as student number and name, subject and course, date of birth, nationality, gender, and email. The student is also allowed to change their password.

Messages. This functionality of the HTProgramming application provides the student with comments and suggestions for improving the activities performed. The student can check when the activity was performed, the score obtained, and suggestions for reading or exercises to address the detected problems.

Work Done. Once this tab is chosen, the student can view all activities and. scores, see Fig. 6. The different activities are organized by groups. The pre-activities group includes the presence of students, the value obtained in the characterization of the student, the value obtained in the paper folding test, the results of the introductory concepts activities, and Parson Problems. The remaining groups are related to coding activities in C:

- Basic activities concepts: activities related to building simple programs in c, data input/output, formatted output, sequential instructions.
- if-switch concepts: construction of programs with conditional structures.
- Loop concepts: building programs using for, while, and do-while loops.
- Arrays concepts: activities related to building programs with matrix manipulation.
- Advanced concepts: problem solving using knowledge acquired in language

Note that students can perform the proposed exercises several times. However, the result considers the number of times the student performs each exercise, to prevent each student from increasing their score with a maximum score exercise.

Basic Concepts. In this option, the student performs introductory programming concepts activities in C language. The questions are of the MCQ (Multiple Choice Question) type, and asks to mark the correct/incorrect identifiers, or to mark the incorrect instructions of a program.

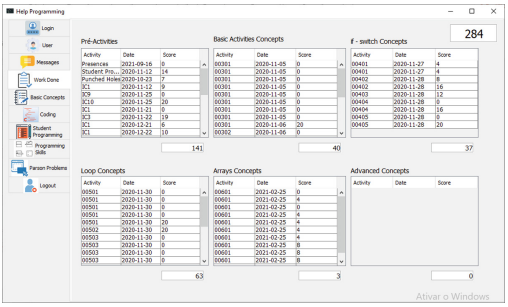

Fig. 6. Work done, presentation of results by activity of each student.

Coding. In coding activities, students write code in C language, responding to activities proposed and defined by the teacher (see Fig. 7). Using the IDE they want, they submit their resolution proposal in the application. The application runs the program with a set of verification tests calculating the final score.

Parson Problems. In this set of activities, the student must build a program starting from a set of disordered instructions. The student drags and drops the instructions from the area with the disordered instructions to the area where he must build the solution. At the end, the student must validate their answer.

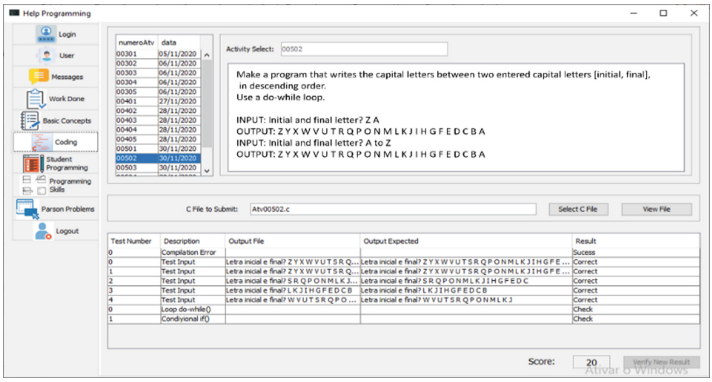

Fig. 7. Coding functionality of the student module.

3.4 Predictive Neural Network Model of Student Failure

As described earlier, in the Expert System functionality of the administrator module, we included in this project a predictive Neural Network (NN) model of student failure based on student profiles collected during classes. The resulting model allows teachers to early identify the students most likely to fail and take corrective action.

To build a NN predictive model for student failure, Multiple Back-Propagation software, available at http://mbp.sourceforge.net/ was used. Several networks were trained with the aim of testing the dataset for the best results [7]. From the set of student results, we divided randomly into a train dataset and a test dataset, see Fig. 8. With the train dataset we build a neural network, that will be applied to the test dataset, which will result in a prediction of student failure, information that will be used by the teacher to help the student, to correct the detected trend.

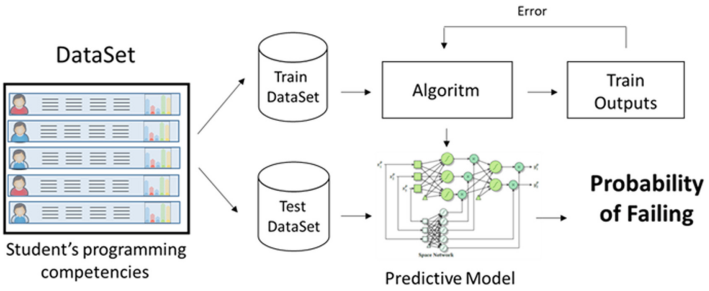

Fig. 8. General scheme of predictive neural network model of student failure.

4 Results and Discussion

The HTProgramming application is the result of the experience and needs felt over the years of teaching introductory programming at IPG. With this application, we are close to achieving a very useful tool for the initial teaching and learning process of programming.

So far, the results obtained are encouraging. Students express that they like to use the application, and teacher has at his disposal a set of data that help him to monitor all student activity. First-year students, often lost and disoriented of how to organize their study, have many activities with the contents and objectives organized and defined by the teacher, with immediate feedback.

After analyzing the results of the percentage of approval of students in the last year, using the HTProgramming application, we verified that it was 54.4%, in the 2020–2021 school year. In the two previous years, without using the application, it was 35.3% in 2018–2019, 16.8% in 2019–2020. We found that there was a significant improvement, however, it should be noted that the last academic year was not normal. The COVID-19 pandemic had a devastating effect on all educational activities [9, 10]. In this last year, there were many students who did not attend classes and did not participate in the various activities of the introductory programming class, repeating students, who ended up taking the final exam successfully. On the other hand, our evaluation system was not adapted to the situation. We think that some of the students resorted to the most diverse help, or cheating, which affected the result of the entire assessment system.

Relatively to the NN model, it presents high accuracy (95%), and only one student was incorrectly classified. Although the metrics provide a good general estimate of the performance of our predictive model, it can be misleading, as there is a considerable discrepancy between the number of samples in each class and the total number of students, which should be improved.

5 Conclusion

We present an application, HTProgramming, as an aid to teaching and learning introductory programming. Application built considering the very particular characteristics of our study group.

With the results obtained and the opinion expressed by the students, we consider the HTProgramming application to be a good tool to help teachers and students. The student has at his disposal a set of exercises, with immediate feedback, planned and organized according to the contents introduced by the teacher. On the other hand, the teacher has a private and immediate view of the difficulties of each student and, also, given the profile of each student, he has a prediction of student failure.

With current technologies and tools, any student can easily find examples of the same activities or similar activities solved. The teacher needs a lot of work in typifying and controlling the set of activities suggested, so that the results obtained are not false. Therefore, it is very important that the classes are in person so that the teacher has a knowledge of the activity developed by the student. The application must assist the teacher in this task, and not function as a tool for grading and certifying the student's knowledge. On the other hand, to combat fraud, it is important to do a lot of awareness and understanding work with students. It is important to convey the message that introductory programming is important to course success. A student with difficulties in the initial programming course, especially in a computer science course, will always be unmotivated, worried and with great difficulties to complete the course.

There are many tools with the same activities and functionalities, however a single tool with a set of diversified exercises and with well-defined objectives aiming to complement training in an introductory programming course does not exist.

An application with this type of functionality needs constant updating and evolution. It is important that it is visually attractive and easy to access, use and install. A set of technical improvements must be carried out, such as: improvements in access time, automatic correction of coding activities, and in the predictive model of student failure.

We hope that the HTProgramming application will soon be a tool that significantly minimizes the problems of teaching and learning introductory programming. We also hope that it will be a good contribution to demystifying the problem of teaching and learning programming to the entire science community of interest in the area.

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Assessment Methods Determining the Higher Education Students' Academic Success

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Abstract. It is well known that academic success of undergraduate students depends on a variety of factors; several of them are external to their higher education institution. However, it is crucial to reflect on the impact of the factors controlled by the higher education institution (e.g., faculty or college) that can influence their success and achievement, including the assessment methods. To this end, this study analyzes the extent to which the assessment methods have a substantial impact on approval rates of students. In doing so, 797 averages of course grades from a Portuguese higher education institution were collected in different academic years between 2013/2014 and 2017/2018. The significance effect of the course field, laboratories, projects, mini-tests, group work, individual work, frequencies, exercises, and presentations on the final averages of the courses was evaluated based on the modeling of structural equations. The results showed that the use of laboratories, presentations, individual and group-based works/tasks are the most explanatory elements (25%) for positive averages. The remainder is justified by other factors associated with students, such as socio-economic, previous education, and motivational factors that explain academic success. In future work, the proposed model, with different teaching strategies, could be studied and evaluated within different educational contexts.

Keywords: Assessment methods · Higher education · Structural equations · Academic success

1 Introduction

Assessment is a process of checking objectives, in which what students produce at the school/college level, is compared to a model [1]. Trotter [2] states that assessment or evaluation is a generic term used for a set of processes that measure the students' learning outcomes. This process contributes to the effectiveness of teaching since it consists of the observation and interpretation of its results. It is in the teaching-learning process that the assessment arises, functioning as a mechanism that verifies whether the intended objectives were effectively achieved [1].

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 77–87, 2022.
https://doi.org/10.1007/978-3-031-07018-1_7

Assessment methods are considered an essential component of any course materials and curriculum provided to concerned students enrolled on academic programs within different higher education institutions all over the world. Such assessments provide a better understanding and solid evidence on the effectiveness of the teaching and learning process [3] and help in assessing and improving the academic performance and achievement of the concerned internal stakeholders, including the students, instructors, and the higher education institution itself. However, many flaws in the process still require further investigation in both theory and practice. In addition, although there are several prior studies that have been conducted to assess the major factors impacting the academic performance, achievement, and success of students (e.g., [4–9]), within higher education institutions in various nations around the world. However, it could be noted that there are few studies have been carried out concerning the good assessment practices in higher education, the relationship between summative and formative assessment, self-assessment and peer assessment, and the role of technology in assessment [10], especially within the context of higher education institutions in Portugal. This represents clear arguments and evidence on the existing gaps and indicates that there are several points and issues related to assessment methods in terms of effectiveness and outcomes that still require great attention by scholars mainly in the current global context.

To address the aforementioned gaps, the current paper seeks to analyze the extent to which the assessment methods could impact approval rates of undergraduate students in higher education institutions in Portugal. To be more specific, this study examines how the assessment methods, namely the course field, laboratories, projects, mini-tests, group work, individual work, frequencies, exercises, and presentations work, could affect the academic success of students in a higher education institution in Portugal. By doing so, the present study provides several theoretical and practical implications that could be beneficial for higher education institutions and their associated internal stakeholder. More specifically, this paper contributes to the existing body of knowledge concerning the educational process in higher education institutions by concentrating on the connections between certain assessment methods and students' final grades. It also provides practical guidelines and managerial implications for the concerned bodies in higher education regarding the impact of elements and methods of assessment on students' success in higher education.

2 Assessment Methods in Higher Education Institutions

It is evident that one of the top priorities for educators or higher education is students' performance-related quality, which leads to making a difference between institutions at local, regional, national, and global levels. Academic success and/or achievement is regarded as a metric reflecting the quality and efficiency of the educational management process and its associated activities [4]. As a result, it is crucial to identify the most crucial factors impacting students' academic performances. In this vein, there are several factors that have significant influences on the academic performance of students, such as status and school background, admission points, and socio-economic factors [11]. Moreover, assessment methods are also considered a substantial predictor of students' academic success [2].

In their study, Pereira and Flores [12] highlighted that the most assessment methods used by teachers, according to the students' opinion, are: oral presentations in group classes, written tests or exams, reports made in a group, the resolution of practical group work, the project work carried out in the team and the individual reports. To do so, the authors carried out a study with 254 respondents, of which 165 were integrated master students and 89 were undergraduate students. It should be noted that all students attended the 3rd year of a Portuguese university. In the same study, the authors indicated that many students believe that the assessment would be fairer if at least two different assessment methods were used.

Acceding to several prior studies (e.g., [13, 14]), the student work assessment is divided into two main aspects or categories: formative assessment and summative assessment.

Formative assessment mainly focuses on activities and aims to facilitate learning [15]. In short, students must respond to what is asked without assigning a rating because of their response, to reduce the high levels of stress and anxiety [1], usually detected in summative assessment situations. Fernandes, Rodrigues, and Nunes [14] refer to a literature review article by Black and Wiliam, on formative assessment practices where they show that: a) the systematic practice of formative assessment improves students' learning; b) the students who benefit most from the formative assessment are those who have the greatest difficulties; and c) the students who attend classes in which the formative assessment predominates, obtain better results in external assessment exams than those who attend classes in which the assessment model predominant is of a summative nature.

The summative assessment has the function of verifying and quantifying what the students have retained. It is therefore a terminal and retrospective assessment. It is applied at the end of the learning process. Besides, it places students at different levels according to the result obtained and is therefore grading [16]. It is in this context that this investigation is centred.

In the last few years, some research has been focused on students' and teachers' perceptions about distinct models of assessment and their impact on grades. For example, the study of Seggers and Dochy [16] analyzed students' perceptions of two types of assessment in a problem-based learning environment: a written exam and collaborative work. The authors report in their results that both types are highly correlated with the final assessment of the course. However, the exam grades were lower than expected by supervisors. Although the students had two weeks completely free to work on the exam, they only used half the expected time, even though, according to Seggers and Dochy [16], they had been supported and motivated to do it, but there were no significant changes. Interestingly, the students' perception was that the results did not match.

Meijer, Hoekstra, Brouwer and Strijbos [17] analyzed several models of collaborative learning assessment, namely: group assessment, individual assessment and group assessment combined with intra-group peer assessment. The authors emphasize the need for large-scale studies that can analyze and validate the most efficient assessment tools for collaborative work. Day, van Blankensteina, Westenbergb and Admiraal [18] also analyzed the perceptions of students and teachers but they focused on the middle assessment. The authors found that both teachers and students have a positive opinion on the middle assessment. However, although teachers refer to the potential of intermediate

assessment as an opportunity to evaluate different knowledge, students prefer that the intermediate assessment measures the same knowledge as the final exam.

2.1 Data Collection

At this stage, it was necessary to proceed to the collection, filtering, and processing of the data. The collection of data related to the averages of the courses between the academic years 2013/2014 and 2017/2018 was obtained through the tool developed in the work described by Miguel, Ramos, Martins and Costa [19] that contained the information regarding the averages of each course in the institution where the investigation took place, among other options. Figure 1 shows the layout of the tool by Miguel et al. [19] that allowed the selection of the respective information.

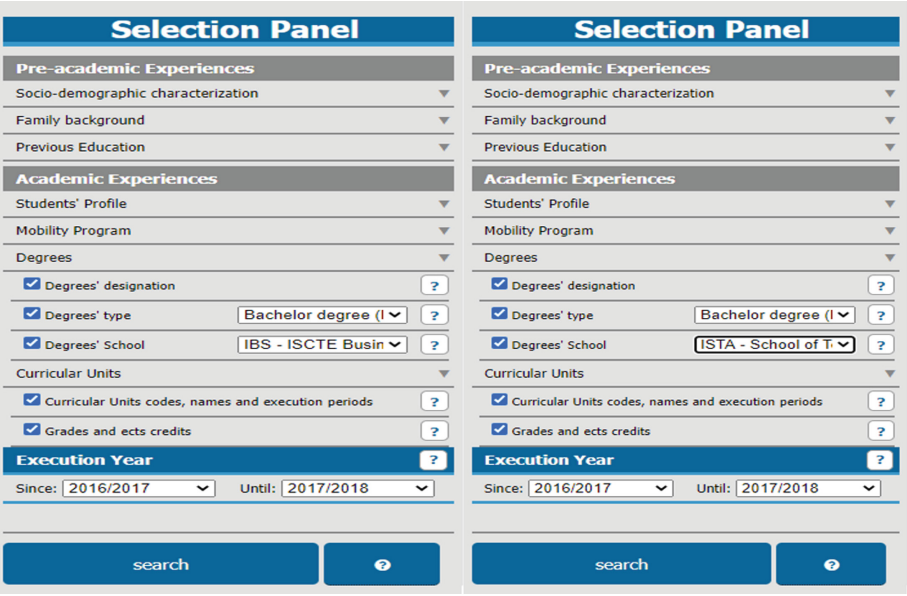

Fig. 1. Layout of Miguel et al.'s [19] tool.

Then we began the process of manual collection of information on the assessment methods present in all annual course plans. Next, the data were interconnected, joining the evaluation methods present in the course plans and the respective average classifications of all years available in the sample. The variables considered for this study were as follows: Course Name, Academic year, Average Grade, Assessment instruments (Project, mini-tests, single test throughout the semester, two or more tests throughout the semester, group work, individual work, frequency, exercises, participation, labs, and presentations).

The data were processed using the SPSS Statistics software (v.26) where it was possible to verify if the data were well treated, that is, if they had no wrong values or missing values (Table 1).

Table 1. Missing values.

Variables	Valid	Missing
Course	792	0
Academic year		
Project		
Mini-test		
Individual work		
Frequency		
Exercises		
2nd test		
Group work		
Lab		
Participation		
Presentation		
Single test		

2.2 Statistical Analysis

The study was based on the procedures of Marôco [20] for the modeling of structural equations. The following variables were considered:

- Lab – Weight of laboratories
- Proj – Weight of project
- MT – Weight of mini-tests
- 1T – Weight of one single test
- 2T – Weight of 2 or more tests
- GW – Weight of Group Work
- Pres – Weight of oral presentation
- F – Weight of frequency
- IW – Weight of individual work
- Part – Weight of participation in classes
- Ex – Weight of exercises

The significance of the effect of the variables described above on the average grades was assessed using multiple linear regression with the estimation of the parameters by the maximum likelihood method implemented in the AMOS software (v. 25, SPSS, An IBM Company, Chicago, IL). The existence of outliers was assessed by the Mahalanobis square distance (D2) and the normality of the variables was assessed by the univariate and multivariate coefficients of asymmetry (Sk) and kurtosis (Ks). No variable showed Sk and Ku values indicating severe violations of the Normal distribution (see Appendix 1).

Multicollinearity was assessed using the VIF statistic as described by Marôco [20]. The existence of strong multicollinearity between the variables recommends the removal of two of these three variables 1T (VIF = 24.8), GW (VIF = 22.5), and F (VIF = 17) (see Table 2).

Table 2. Multicollinearity check.

	B	Std. error	Beta	t	P-value	Tolerance	VIF
(Constant)	11,065	1,260		8,785	0,000		
Proj	0,046	0,013	0,344	3,511	0,000	0,095	10,476
MT	0,021	0,013	0,138	1,598	0,110	0,124	8,088
1T	0,011	0,013	0,133	0,886	0,376	0,040	24,756
2T	0,034	0,017	0,092	2,032	0,043	0,446	2,245
GW	0,043	0,013	0,484	3,369	0,001	0,044	22,506
IW	0,034	0,013	0,233	2,578	0,010	0,112	8,933
F	0,010	0,013	0,096	0,766	0,444	0,059	16,967
Ex	0,020	0,014	0,101	1,453	0,147	0,189	5,301
Part	0,032	0,015	0,124	2,160	0,031	0,280	3,576
Lab	−0,020	0,014	−0,107	−1,444	0,149	0,168	5,965
Pres	0,050	0,014	0,224	3,499	0,000	0,223	4,483

3 Results

The final model for positive grades was evaluated only with the predictors Lab, Proj, GW, Pres, and IW as it was the only combination whose estimates were statistically significant (Table 3). Effects with $p < 0.05$ were considered statistically significant. The model adjusted to positive averages according to the use of laboratories, projects, group and individual works, and presentations explain 25% of the variability of the averages observed in the 792 observations analyzed. All trajectories analyzed between the variables are statistically significant (Table 3).

Figure 2 presents the model with standardized estimates of the model's regression coefficients and the explained average variability. It is also observed that the use of laboratories as an evaluation element is the only variable that has a negative effect on the average value. Group work and the project are the most significant elements in explaining the positive grades.

To check if the model results would be related in any way to the scientific area of the course, we started by grouping the sample courses by scientific area (Social Sciences, Mathematics, and Technology). The data indicated that about 57.8% of the records belong to the group of social sciences with 458 averages. Mathematics has 92 records and Technologies has 242.

Table 3. Missing values.

Variables	Estimate	Std. Er	C.R	p
Avg.  Lab	−,020	,006	−3,535	***
Avg.  Proj	,030	,004	8,013	***
Avg.  Group Work	,027	,003	10,525	***
Avg.  Presentation	,035	,006	5,874	***
Avg.  Individual Work	,019	,004	4,853	***

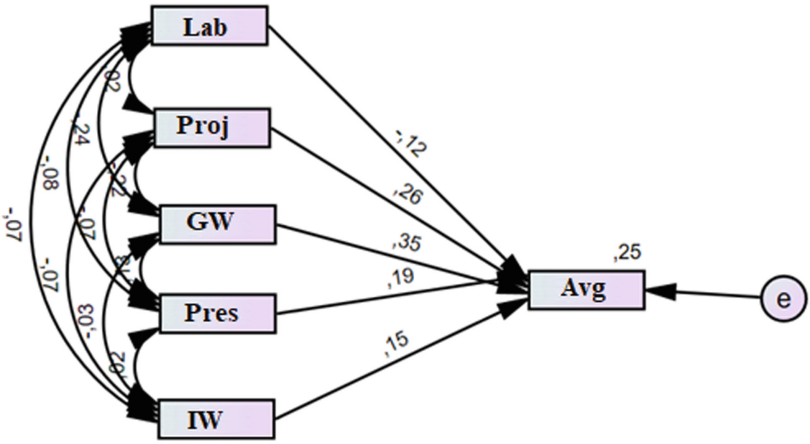

Fig. 2. Model for positive grades.

As for the sample distribution (Table 4), it was found that only the data in the Mathematics group follow the normal distribution ($p > 0.05$).

Table 4. Shapiro-Wilk test.

Scientific area	Statistics	Df	P-value
Social sciences	0,993	458	0,028
Mathematics	0,984	92	0,335
Technologies	0,977	242	0,001

Figure 3 shows the graph of averages by the scientific area. The Social Sciences group has the highest average and the Mathematics group has the lowest average. To assess the existence of a relationship between the scientific area and the average, the Kruskal-Wallis test was applied. The results ($p < 0.05$) confirm that there is no significant relationship between the scientific area and the course average (Table 5).

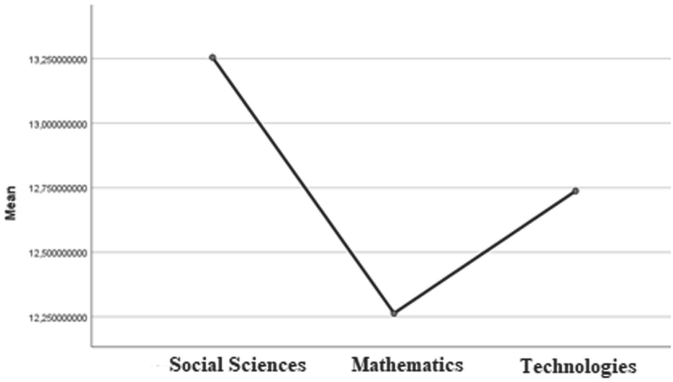

Fig. 3. Average by scientific area (n = 792).

Table 5. Kruskall-wallis test.

	Average
Kruskal-Wallis H	22,902
df	2
Asymp. Sig	0,000

4 Conclusions

This study aimed to analyze the relationship between assessment methods and instruments and the final classification of courses. It was possible to conclude that there is no strong relationship but that there is an associated explanatory percentage that differs in the cases in which positive averages are analyzed.

After developing the analysis from SEM, it was possible to find models that have an explanation variation of the average of 25% for mean values equal to or greater than 10 on a scale of 0 to 20. This means that this model does not explain much of school success, but it affects a percentage, and therefore, other external factors can explain the remaining 75%. We also found that there are no significant differences in the averages between scientific areas and therefore it is not one of the factors that affect the results.

According to Afonso [21], factors such as parents' education, household income, socio-professional category of household class, gender, self-regulation, self-efficacy of learning, motivation for study, relationship with colleagues, and the relationship with teachers are also explanatory factors for school success. Afonso [21] concludes that the socio-psychological model with the factors: classification of the relationship with teachers, motivation for study, female gender, and household income are the important parent factors for academic success, concluding that these variables have an explained variation of 52%. Completing the two studies together, that is, the correct assessment method in line with all socio-psychological factors can explain academic success by 77%. Also, Gil, Martins, Moro and Costa [22] analyzed the academic success of 1st-year students

with a 10-year assessment dataset (n = 9652) and concluded that there are 68 predictors of successful academic that is not related to the assessment instruments, including socio-demographic characteristics, social origin, previous academic path, special statutes and educational path.

In Portugal, students have at least two phases to complete a course in the same semester. When they complete the first phase, they do not have to make assessments in the second phase, usually an exam. As a limitation during the development of this dissertation, it was observed that one of the problems detected when data collection started was the impossibility of knowing whether the grids present in the tool by Miguel et al. [19] belonged to one of these phases or the set of both. For this reason, we started from the assumption that all grids were the first phase and it was from this assumption that the averages of each UC were calculated.

The current research provides various implications for both academics and practitioners. To begin with, this paper adds to the extant literature regarding the educational process in higher education institutions by underlining the role of assessment methods in determining the academic success of students. This also produces a better understanding on the extent to which the assessment methods (i.e., laboratories; project; group work; oral presentation, and individual work) could impact students' academic success in a Portuguese higher education institution. This paper also adds to the limited studies conducted within the higher education context in Portugal (e.g., [23–25]). Another prominent contribution of the present paper is related to theory, as it develops a theoretical model which helps allow identifying the multiple dependency relationships between the studied variables. Furthermore, this paper provides valuable practical implications and solid practical guidelines for the concerned managers and other stakeholders of higher education institutions, in Portugal in particular, by highlighting and providing evidence in relation to the impact of assessment methods and tools on the final grades of students in higher education. This could help in evaluating the effectiveness of such methods used in higher education and increasing the call for deploying innovative and unique assessment methods to substantially improve the educational process.

It is hoped that this study will contribute to the choice of assessment instruments in courses that have difficulties with approval. As future work, we suggest the extension of this dissertation based on the analysis of more external factors that may influence the average of students in higher education.

Ramsden, Bennett and Fuller [26] warns that it is difficult to combine learning results from different assessment methods, giving us an example that the classification of practical work or project will be different from the classification achieved by the same student in a test or exam. For this reason, the evaluation systems must become creative concerning the adopted evaluation practices, and it must be possible to use diversified and innovative methods.

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Human Computer Interfaces for Education, Study cases for Accessibility and Wellbeing

HCI 2020 Master's Degree Study: A Review

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Abstract. This paper presents an exhaustive review of the state of the university masters or graduate programs in the discipline of Human-Computer Interaction (HCI) and related areas up to 2020. This work has been done as part of the design and development process of a new interuniversity and international Master's program graduate developed between the Universidad Nacional Abierta y a Distancia (UNAD) of Colombia and the Universidad de Lleida (UdL) in Spain. The review was necessary to know what other institutions did, the needs of the market and organizations, contrast with our own experiences and ideas to propose a graduate program. It was done by searching for information using educational databases, listings that group masters or graduate programs at the level of master in these areas, search engines for master's degrees, articles, documents of organizations that work on HCI. The objective of achieving the state of the masters in HCI is to know what universities are teaching worldwide compared to the needs of companies or organizations and if there is a congruence between what is being taught at the level world in the academy and the requirements of organizations .

Keywords: Human interaction computer · User experience · Graduate education · Higher education

1 Introduction

The paper presents the review of the state of the art of university graduate programs offered in the topics related to the Human-Computer Interaction discipline (and

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 91–103, 2022.
https://doi.org/10.1007/978-3-031-07018-1_8

related areas) up to 2020. The study does not include non-official programs or other denominations with HCI topics.

This work has been done with the purpose to build an inter-university and international Master's between Universidad Nacional Abierta y a Distancia, UNAD, (Colombia), and Universidad de Lleida, UdL, (Spain). The review was done by searching information using educational databases, websites that group together graduate programs in these areas, search engines, articles, documents from organizations that work in the HCI field (including general topics such as usability or UX), university websites, and interviews with experts in the area.

Contextualized in the HCI field, the study objective is to acquire deep knowledge about what is taught in academia around the world and the industry needs, in terms of which are the professional skills and competencies of the professionals be contracted [1]. Our primary interest rises in knowing the concordance between what is currently being taught in the universities at the graduate level and the real needs of organizations [2]. This review is one of the initial steps to build the curriculum, the educational processes, the themes, and the required competencies in the academy [3].

The paper is structured as follows: the first part presents the need for review; second, the process of finding information and the tools used; third part presents the needs of the organizations; fourth, the comparison between what is taught in academia and the needs of the organizations; and finally, the conclusions and future work are presented.

2 Need for Review

The development of technology generated a critical space to study and research in the Human-Computer Interaction (HCI) discipline. In the design, development, testing, and use of hardware and software products that are related to the needs and successful experiences of users with the use and interaction of technology, and thus generate new aspects, such as forms, methods, media to provide comfortable and exciting user interactive experiences with new technologies applied in different areas. These experiences will also be as accessible and usable as possible [4].

Moreover, the evolution of the needs of information and communication technologies, users, organizations, contexts, and education generated the need to review and verify if what is taught in the academic programs of universities at different levels of academic degrees corresponds with the needs and abilities of related companies [5]. It is necessary to review the consistency between organizational requirements and academic offerings and review research trends at universities and whether they are applied in the industry [6].

The following is the information search process used to obtain the data of the HCI related master's degrees worldwide. The starting point was proposing a question to drive the search and posterior results validation. This searching process was supported by Kitchenham's systematic review methodology and a market study [7].

3 Search Process

A search for information was proposed based on Kitchenham's systematic review methodology [7]. The processes of searching the primary data sources were defined, and the review of each of the pages of the master's programs found was developed. With the information obtained, a classification was made according to geographical location, analysing the curricula programs to define areas and topics work is in the programs. In addition, some studies about state of the art in HCI in different regions were taken into accounts, such as What is Being Taught on Computing Courses in the UK [8], HCI Education in Brazil: Challenges and Opportunities [9], Human-Computer Interaction in Ibero-America: Academic, Research, and Professional Issues [10], Analysis of formal and informal degrees in Ibero-America of UX: challenges for online training [11], Human-Computer Interaction in the Curriculum of Higher Education Institutions in Colombia [12] and The State of HCI in Ibero-American countries [13].

3.1 Review Process

The review process was developed considering the themes of global master searches in HCI related areas. A review question was used to guide the search; different means were used to search data and information.

An information search process was carried out, considering the review question, the inclusion and exclusion criteria, the search means, the definitions set out in the document, and the Kitchenham methodology [7] as a reference for information searches to have an order in the development of the review process. The process used in the review is presented below with the following steps: 1) Research question, 2) Definitions of the concepts, 3) Information media consulted, 4) Inclusion and exclusion criteria, 5) Search chain, 6) Review process, 7) Search results.

First, we developed the search in databases of the different countries European Union, United Kingdom, Spain, United States, Asia, Oceania, and Latin America México, Colombia, Chile, Brazil, Argentina, among others, in these searches, were applied the criteria of inclusion and exclusion.

Second, we searched databases with information for HCI; these searches were performed in IEEE, ACM, Science Direct, and SCOPUS.

Third, information was searched in meta-searches and search engines where the previously defined inclusion and exclusion criteria were applied. In these searches, lists of undergraduate and master programs in HCI were found.

Fourth, interviews were conducted with different experts in human-computer interaction, user experience design, and related areas. Through various means, the interview was applied with short questions about the knowledge of master's programs in the search areas.

Data arrays were used to organize and analyze the information once the search results for master's programs were obtained. A code was registered for each program in the collections, including name, URL, country to which it belongs, the number of credits, emphases, and the master's program work areas. Then, with the registered data, a process of revision and debugging was initiated to generate helpful information in developing the classification and analysis process of the information. The master's programs found

were classified in the following regions: Latin America, North America, Europe, and Asia and Oceania, according to each of the regions. Finally, the location of the master's programs is presented on a global map.

Following the previously mentioned criteria and procedure, the lists of undergraduate and master programs in the HCI area were found. After that, the interviews (consisting of a set of short questions about the knowledge of master's programs related to the study) with different experts in HCI, UX design, and related areas enabled us with the data to analyse. It was registered in data arrays with a code for each program, including the name, URL, country, the number of credits, the emphases, and work areas. Once cleared and classified, the revision process emerges valuable information with the master's programs found organised in the following regions: Latin America, North America, Europe, Asia and Oceania. The following sections will present specific information about the main activities of the review process.

3.2 Research Question

Bearing in mind that our primary goal is to know the state of HCI's graduate programs, the objective of the search is to know the state of the masters of the HCI areas and related areas such as user eXperience, Usability, Accessibility, and so on, up to the year 2020. From above, the following question emerged: **What are the worldwide graduate programs in the Human-Computer Interaction discipline**?

3.3 Information Media Consulted

Different concepts were defined to carry out the information search process. The initial reviews were carried out in educational databases, lists of graduate programs websites, scientific articles, organization documents, and interviews with experts in the area, among others:

- **Interviews:** different media conducted interviews with experts in HCI and UX.
- **Databases:** information systems from different countries were searched for masters in different countries such as the European Union, Spain, United Kingdom, United States, Mexico, Colombia, Chile, Argentina, Brazil, Australia.
- **Search engines and meta-searchers:** Google was the search engine with more information available for the work.
- **Scientific Papers**: scientific databases with bodies of knowledge related to our areas of study: ACM, IEEE, Science Direct, and SCOPUS.

3.4 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria included in the information search were focused on the postgraduate level HCI masters, UX user experience and related areas worldwide.

Inclusion criteria were the following: 1) Articles published between 2010 and 2018, 2) Articles published in conferences, congresses, journals and book chapters, 3) Articles written in Spanish, English and Portuguese, 4) Articles related to HCI, UX and areas to end, 5) Searches in educational databases, 6) Listings of postgraduate programs in HCI, UX and areas to end, 7) Interviews with experts, 8) Masters at the postgraduate level and official and 9) the search for postgraduate was conducted until 2020.

The exclusion criteria were the following: 1) Articles not available for download, 2) Articles written in languages other than Spanish, English and Portuguese, 3) Articles not found in the indicated databases, 4) Information on undergraduate programs, specialization programs, free courses, diplomas, non-official or unrecognized masters, 5) Own master's degrees and 6) Inactive master's degrees.

These criteria were applied in the search results for information on master's degrees and in the acceptance of programs that were included in the results of the search for master's degrees in HCI, UX and related areas. The exclusion criteria were: 1) Articles not available to be downloaded, 2) Articles written in other languages than Spanish, English, and Portuguese, 3) Articles not found in the indicated databases, 4) Information on undergraduate programs, specialization programs, free courses, diplomas, non-official or unrecognized graduate programs, 5) Non-official degrees and 6) Inactive graduate programs.

3.5 Search Chain

A general search string was defined in each language to search the databases and search engines used; according to these search strings, the following results were obtained, which are presented in the article. Three search strings were defined in English, Spanish and Portuguese; the search chain used was the following:

- **Spanish: (("Maestría" OR "Master") OR ("Interacción Humano Computador" OR "Interacción Persona-Ordenador" OR "HCI") OR ("Experiencia de Usuario" OR "UX"))**
- **English: (("Master" OR "Magister") OR ("Human-Computer Interaction" OR "HCI") OR ("User Experience" OR "UX")).**
- **Portuguese: (("Mestre" OR "Mestrados") OR ("Interação Humano-Computador" OR "HCI") OR ("Experiência do usuário" OR "UX")).**

Following the previously mentioned criteria and procedure, the lists of HCI-related graduate programs were found. After that, the interviews (consisting of a set of short questions about the knowledge of master's programs related to the study) with different experts in HCI, UX design, and related areas enabled us with the data to analyse. It was registered in data arrays with a code for each program, including the name and URL, the country, the number of credits, the emphases, and work areas. Once cleared and classified, the revision process raised the information we needed to continue.

3.6 Search Results

We found 34 master programs worldwide with the information of each of the masters could be established the name of the program, the geographical location, the emphasis of training, curricula, and whether they have access to do a doctorate.

The masters found they were classified according to the geographical location in which they are located; the classification was made as follows: Europe, Asia and Oceania, North America, and Latin America (see Table 1).

Table 1. Master's programs in HCI and related programs worldwide with the topics, educational methodology, and average time to complete the programs.

Heading level	Countr (# programs)	Topics master's programs	Modality (#Presence – Virtual)	Average time (months)
Europe	Spain (6), Netherlands (3), Sweden (2), Portugal (1), France (1), Finland (1), United Kingdom (1), Germany (1), Norway (1)	HCI User-Centred Design UX Interaction	15–2	12
Asia and Oceania	Hong Kong (1), India (1), Singapore (1), Australia (2)	HCI User-Cantered Design UX	4–1	16
North America	United States (12)	HCI, UCD, UX	8–4	12
Latin America	0			

In Europe, there are 17 master programs in Spain, the Netherlands, Sweden, Germany, Finland, Norway, France, the United Kingdom, and Portugal.

There are five master programs in Asia and Oceania located in India, Singapore, Australia, and Hong Kong.

In North America, there are 12 Master's programs located in the United States.

In Latin America, there are no master programs in HCI or related areas. For this reason, we conducted a search for masters in different areas, and that within its curriculum or academic program include courses or research with related areas, so we found master programs in Mexico, Colombia, and Chile.

Latin America does not have master's degrees in the field of study but finds the offerings of the online master's programs available. For this reason, a search was done for master's programs in other areas that will have courses in Latin America within the curriculum or research in this topic area. The countries that have some courses included in other masters are Chile (3 courses), Mexico (3 courses), and Colombia (2 courses) (Fig. 1).

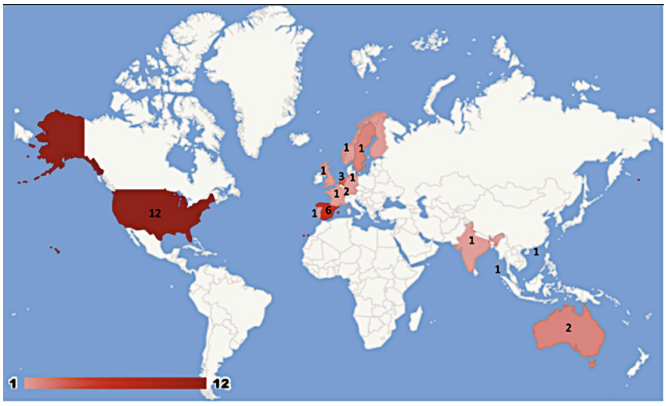

Fig. 1. World map of HCI master's programs located in each country

While it is true that the master's programs are working on some of the topics that companies currently need, it should be noted that a majority of topics are not observed in the needs of companies. On the other hand, some topics are required in companies and that the master's programs are not working on these topics.

In addition, companies' work topics according to their needs are studied and worked on by a low percentage of the master's programs. From the 34 master's programs, very few universities work on information architecture, ubiquitous computing, machine learning, pervasive computing, social computing, and interaction. Most of the master's programs work on User-Centered Design, user experience, Human-Computer Interaction, and Interaction Design.

3.7 Market Study

In 2018 a market study was undertaken to investigate the feasibility of implementing a master's degree program related to Human-Computer Interaction and national and international coverage. This study focused on potential applicants to the master's program. It was used a survey (383 surveys were conducted using convenience sampling) using two profiles: 1) students or graduates, and 2) professionals or students interested in HCI (Human-Computer Interaction) from other universities in Spanish-speaking countries. Among the most important results of the study are: 84.1% of respondents would be willing to study a master's program in HCI in virtual mode; the training topics of most significant interest are usability (69.4%), information architecture (69.2%), universal design (67.6%), user experience design (67.1%), and interaction paradigms (65%);

89.7% of the respondents who expressed interest in the master's program had previous training in Engineering; 48.1% of respondents who expressed interest in the master's program are between 31 and 40 years old, 31.1% are over 41 years old, and 19.5% are between 21 and 30 years old.

These results show the excellent perception of acceptance by potential applicants for the proposed master's program in HCI and the need for specialized HCI professionals to work in the organizations.

4 The Need for HCI Knowledge in Companies and Organizations

We found different articles specifically focused on education in HCI during the review, showing us a broad and general teaching overview [17]. When analysing, we observe an essential consensus about what should be taught in academia, which is the same as the skills and knowledge that future graduates need to acquire and demonstrate to work for private companies [18].

According to gathered information, interaction design is an essential issue in the development of the educational processes of HCI related topics, to know: user experience, experience design, accessibility, information architecture, social computing, ubiquitous computing, universal design, usability, prototyping, usability testing, interactivity, mobile technology development, social media, pervasive computing, data mining, machine learning, social network analysis, and product and service development [19].

In the competitive context of the global IT industry, one of the essential premises is the agile and practical application of the knowledge, technical abilities, and creativity in the development of technological products because "time is money" [20, 21]. In addition, for industry experts, users' experiences with different technologies are more important than the products and services themselves. Companies started to change how they create, deliver, and measure the value of their products and services [22], although they still have a long way to go.

Organizations and companies that provide valuable and friendly content, methods and products (e.g., mediation between humans and electronic devices) need human talent trained in the area of HCI (currently in UX) to generate satisfactory results and user experiences which become positive product and service recommendations to increase revenue and profits [23].

5 Academy-Organizations Comparison

The analysis led to the emergence of a list of common topics to be addressed. To better understand, we organized in three categories (see Table 2): first, topics found in masters, needs of the companies, and third, the collection of common topics [23, 24, 25, 26].

Table 2. Academy-organization comparison common topics.

Topics graduate programs		Organizational needs	Common topics
User-Centred Design, User Experience, UX Evaluation, Human-Computer Interaction, HCI Evaluation, Usability, Accessibility, Prototype Design, Evaluation, Testing, Interactive Environments, Sensors, Interaction Design, Human-Robot Interaction, Human Media Interaction, User Interfaces, Interface Design, Product, and Service Design, Innovation, Development and Creativity, Multimedia, Digital Media, Visual Communication Design,	Immersive Environments, Virtual and Augmented Reality, Mobile Applications, Web Design, Mobile Design, Information, Tangible Interaction Design, Human-Human Interaction Design, Video Game Design, Animation, Simulation, Machine Learning, Artificial Intelligence, Ubiquitous Computing, Affective Computing, Real World Computing, Social Computing, Mobile Computing, Thought Design, Context, Collaboration, Information Architecture	Experience design, Accessibility, Information architecture, Social computing, Ubiquitous computing, Universal design, Usability, Prototyping, Usability testing, Interactivity, Mobile technology development, Social media, Pervasive computing, Data mining, Machine learning, Social network analysis, Probability computing, Product and service Development	Experience design, Accessibility, Information Architecture, Social computing, Ubiquitous Computing, Usability, Usability testing, Prototypes, Accessibility, Machine Learning, Product and service design, Social Media

While it is true that graduate education is working with some of the topics that companies currently need, it should also be noted that a majority of topics are not observed in the company's needs. At the same time, there are uncovered topics that are needed in companies and other demanded by companies that are not enough studied/worked in the current programs. Most of the programs intensely work on topics related to User-Cantered Design (UCD), User eXperience (UX), Human-Computer Interaction (HCI), and Interaction Design (ID).

Once the analysis has been carried out according to the data obtained and the comparisons made, a more in-depth analysis should be proposed within the master's programs to verify and validate whether the curricula are up to date to define some correspondence with current needs. Based on the comparison, we can conclude that a new graduate program should include new topics adapted to current needs.

6 The Need for HCI in Organizations

According to the review, we found different articles that work specifically on the issue of education in HCI, the articles are the teaching and learning of Human-Computer Interaction past, present, and future, and the article the future of education in HCI, in these articles, are presented a consensus of what should be taught in the academy so that graduates acquire the skills and knowledge that allows them to enter the companies and apply their knowledge [12, 13].

According to the articles, the teaching and learning of interaction design are essential issues in the development of the educational processes of HCI and related: user experience, experience design, accessibility, information architecture, social computing, ubiquitous computing, universal design, usability, prototyping, usability testing, interactivity, mobile technology development, social media, pervasive computing, data mining, machine learning, social network analysis, probabilistic computing, and product and service development. These are the topics of knowledge and the development of academic processes that allow students and graduates to acquire the skills [15, 16].

One of the essential industry premises is the agile and practical development of the topics in applying the knowledge and abilities in the development of the products because time is money. It is crucial to make the products and services fast to arrive at the users in little time [17, 18].

7 Conclusions and Future Work

We have conducted a profound analysis that validated or refuted our suspicions and provided us with some significant new findings such as:

- 34 HCI-related graduate programs were found worldwide, according to the inclusion and exclusion criteria defined for the search. These programs are geographically divided as follows: 17 programs are in the European context, 5 in Asia and Oceania, meanwhile, North America owns 12 programs.
- From these, only 7 are completely virtual (2 in Europe, 1 in Asia and Oceania and 4 in North America), that is, 20.5% of the total, while the remaining 79.5% are face-to-face.
- Although some programs include HCI topics in their curricula (or in some of its courses), there is no HCI-related graduate program in Latin America.

These insights confirm our suspicion that a real opportunity/need exists to contribute to Latin America with HCI-related graduate programs. Another essential finding is that UCD and UX are crucial topics worldwide; meanwhile, ID is also critical in Asia, Oceania, and North America but lower in Europe [30, 31]. However, it is also necessary to strengthen the programs to include themes related to interaction paradigms since organizations need current needs.

In this sense, and due to the importance of this type of study, we believe that shortly HCI graduate programs in other languages such as Chinese, Japanese, Arabic or Russian will be needed.

The analysis and the experiences of some HCI authors discovered two knowledge problems to design a new curriculum: a) Discovery of the needs, characteristics, and

contexts of people, from the experiences mediated by technology; 2) Development of technological solutions focused on the design of user experience and interaction through appropriate paradigms and methods.

Another important insight is a gap between existing graduate programs and some of the topics that companies currently need. We identified some but, more research must be done. In this sense, one important future work is too deep for a better understanding of what the company's needs and teaching them the advantages and richness of what HCI can bring to them.

Following the high-level training proposals for graduates in the field of HCI, we consider it essential to incorporate, in new programs, features such as: i) Virtual mode to take advantage of the benefits of information and communication technologies to provide access to education for professionals anywhere in the world and eliminate mobility restrictions for multiple reasons; ii) Articulate academic networks to leverage capacities of researchers from multiple universities; iii) Spanish language to enable inclusion of the Spanish-speaking population of all Latin America.

Considering the results of this study, both universities, UNAD and UdL, begin the challenge to design and to offer the first online interuniversity and international Master's program in the field of HCI in Latin America.

New Master must include all the findings and considerations discovered to have courses that support the discovery of the user needs, characteristics, and contexts of people from experiences mediated by technology and the development of technological solutions focused on the design of UX and the interaction through appropriate paradigms and methods, we proposed the following competencies by support the Master: establish requirements that can be expressed in functionalities of the technological solution by applying techniques and procedures of User-Centered Design; integrate the human aspects of interaction in the generation of technical solutions; build user-centered solutions based on the use of Information and Communications Technology development methodologies and propose improvements to the user experience by evaluating interactive systems in the context of User-Centered Design and generating solutions for people with disabilities that guarantee fair use through the use of technical standards and tools.

The Master will be supported on three main lines of emphasis: related courses that meet the needs of organizations and that result from disciplinary reflection. The lines are user experience design, interaction design, and inclusive design. The syllabus has been organized to enable students to fulfil the Master in one and a half years, completing 72 ECTS (equivalent to 36 Colombian credits). The first semester involves four compulsory courses (IT-centred product design, User Requirements, Information Architecture & Prototyping and Accessibility Design) to establish the main foundations. Then, they will combine some remaining compulsory courses (UX Evaluation and Interaction Paradigms) with a set of optional subjects (they must choose four topics out of a total offer of nine), and ending with the Final Masters Project (that, to adapt to Colombian regulations, has been divided into two subjects).

Finally, we plan to extend this collaboration to joint research programs and, if we have success, we plan to extend this collaboration model to other disciplines.

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Are the Mobile Applications of Portuguese Higher Education Institutions Accessible?

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Abstract. The number of smartphone users has increased significantly, and the development of mobile applications has brought convenience to daily life. However, large numbers of users who have various barriers, such as visual or hearing impairments, and physical disorders, are not able to fully access and use the referred applications, which is unfair to them, especially when considering its use by students in a university campus where all users should be able to enjoy equal opportunities and experiences. The main goal of this study is to assess accessibility in mobile applications of the education sector. Thus, an evaluation model is also proposed to assess the accessibility of the applications from two perspectives, which are the inherent properties of the applications and the user experience of different disability categories. 46 official mobile applications were tested which related to 23 universities and institutes of Portugal, using automatic and manual testing methods. Several frequently occurring accessibility issues in the apps were identified and summarized, such as color contrast, touch target, missing focus. The results of the accessibility testing showed that the status of web accessibility of mobile applications in the higher education sector in Portugal is unsatisfactory. Most apps have multiple accessibility issues, and they are extremely unfriendly to the users with visual impairments. In addition, the study also proposed a series of accessibility recommendations for mobile application designers and developers, with the purpose of improving the accessibility of apps and providing an equitable user experience for all users.

Keywords: Accessibility · Web accessibility guidelines · Mobile applications · Education

1 Introduction

In the last decade, with the popularity of smart phones, people accessing Web services through a mobile terminal and applications has been an increasingly prevalent

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 104–121, 2022.
https://doi.org/10.1007/978-3-031-07018-1_9

phenomenon [1]. The growth in the use of mobile devices has been very significant and nowadays this type of system has become one of the most used means by people to access services and information online [2]. The education sector has also benefited greatly from this. People in universities, polytechnic institutes, and other organizations in the higher education sector, including students and professors, are enjoying the convenience provided by mobile application development, such as consulting the daily schedule of a course, the academic calendar, the events to be held, and they can also register online to their favorite subjects via mobile phones.

However, for the user groups with a disability, the Internet has brought new opportunities to them, but it also presents unprecedented challenges [3]. According to the World Health Organization (2020), it is estimated that about one billion people in the world (approximately 15% of the world population) have a disability, being this either visual, auditory, motor, or mental [4]. Therefore, improving the Web accessibility of mobile applications is one of the main factors that motivated this article.

Meanwhile, another important factor is the lack in the literature and of research on accessibility in mobile applications for the education sector. In order to improve web accessibility and make it better for the disabled population, some guidelines and standards were established in the industry, but most guidelines and standards aimed to improve the web accessibility on fixed terminals, such as computers, and not for mobile devices, being rarer for mobile applications [5].

With the elaboration of this paper, we propose to analyze the official mobile applications of Portuguese higher education sectors, regarding their level of compliance with accessibility, finding the common accessibility issue in apps. In the final section, the results of the analysis were discussed, and a set of guidelines and recommendations based on the study was developed, which are provided to application designers and developers with the aim of improving applications' accessibility.

2 Conceptual Framework

2.1 An Overview on the Web Accessibility Paradigm

Web accessibility indicates that all people (whether a healthy person or a disabled person, young or old) should have the ability to access and use the Web resource and information equally and conveniently under different types of circumstances [6, 7]. Accessible Web content needs to be able to support differentiated people using alternatives or tools to complete the input and output of information, as well as accessibility services that require accessibility tools and language features [6, 8].

The overall accessibility concept involves the inclusive design area, thus offering a wide range of products and services that cover the needs of different populations, the adaptation of artifacts and the implementation of alternative means of information, communication, and mobility [9–11].

The societal awareness of accessibility in laws has also been increasing in recent years and many governments around the world have also actively carried out Web accessibility construction and formulated relevant laws and regulations to guarantee equal access to information [5]. In Portugal, for example, the Decree-Law No. 83/2018 emerged, which has determined a series of accessibility demands for websites and mobile applications

in the sector of public organizations [12]. It means that improving Web accessibility is not only a public service, but also a requirement according to the laws and regulations.

With the continuous improvement of data processing and storage technologies of mobile terminals, the interaction between people and mobile terminals has also changed from a single physical button to touch screen operation and voice-assisted operation [13, 14]. Various mobile application requirements have been gradually stimulated, from entertainment, to basic services such as communication and information inquiry that have been extended to auxiliary office services such as business office and network finance, and then to public services such as education, medical care, and transportation [15]. Mobile application accessibility is the basic requirement to ensure an equal experience for all users, especially those with disabilities.

2.2 Standards and Guidelines

In 1997, the organization World Wide Web Consortium (W3C) announced the launch of the Web Accessibility Initiative (WAI) to promote and achieve Web functionality for people with disabilities [16]. Since then, W3C has proposed a series of accessibility guidelines and standards. WCAG is the Web Content Accessibility Guidelines which was developed by W3C, which provided suggestions for easier access to Web content [6]. The first version WCAG 1.0 was launched in May 1999, and WCAG 2.1 is the latest version of the standard at present [16]. The document of WCAG indicated the method to make Web content more accessible to people with disabilities. Web content generally means the information in the Web page or application, including natural information such as text, images, sounds and code or markup that defines structure and presentation [10]. The WCAG 2.1 guidelines and Success Criteria are organized around the following four principles:

- Perceivable: Information and user interface components must be presentable to users in ways they can perceive.
- Operable: User interface components and navigation must be operable.
- Understandable: Information and the operation of user interface must be understandable.
- Robust: Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies.

Moreover, according to WCAG 2.1, the specific guidelines under each principle also include different eligibility criteria, which are generally divided into the following three levels, A, AA, AAA, which means the basic level, enhanced levels, and optional level eligibility criteria [8]. This criterion is also applied to the assessment of accessibility.

Google and Apple also provided their own guidelines for mobile application accessibility besides W3C. Google has created guidelines for mobile accessibility to make it easier for developers to develop apps, which aimed at improving the app accessibility to enhance the usability for all users, including those people with visual impairments, hearing impairments, cognitive impairments, motor impairments or situational disabilities. The guidelines of Google have several aspects, which are Assistive Technologies, Hierarchy, Color and Contrast, Layout and Typography, Writing, Imagery, Sound and Motion, and

finally Implementing Accessibility [17]. Apple has also established a set of mobile accessibility guidelines for making applications more accessible. The guidelines of Apple have several aspects including Inclusive Design, User Interaction, Navigation, Text Size and Styles, Color and Contrast, Appearance Effects and Motion, and Content [18].

2.3 The Design of Mobile Web Interfaces

The mobile user interface (mobile UI) is the graphical and usually touch-sensitive display on a mobile device, such as a smartphone or tablet, that allows the user to interact with the device's apps, features, content, and functions [19, 20]. Mobile applications usually consist of several parts: Start page, Guide page, Dialog, Home page and menu bar interface, Login and personalized settings interface, as well as the List page. The control in a graphical user interface is an element of interaction, such as the Textview, EditText, Radio Button, and Checkbox [21].

In mobile applications, the focus is the location of the current event being processed, which is crucial to screen reader [21]. Screen reader is the tool to deliver the visual information to users by sound. It will not recognize the content on the position of the screen where users touched or clicked if there is no focus.

In general, users mainly interact through the UI to achieve access to the content or services of the application, which means that the elements and the design of the UI will affect accessibility, and these are the main targets in accessibility testing.

3 Methodological Approach

3.1 Global Overview

This study researched the official mobile applications of higher education sectors in Portugal, including 134 universities and institutes [22]. In order to assess the current state of accessibility of the educational mobile applications, an accessibility testing model was proposed in this study, which was derived by analyzing and summarizing the rules applicable to the mobile application part of numerous standards and guidelines including WCAG 2.1, best practices published by Google and Apple, and additions made by the researchers of the present study during the tests.

Moreover, the analysis of user type was conducted based on the common types of disabilities and the best solution for each type of disabled user was proposed. After the accessibility testing was implemented, the most common accessibility issues in the tests were summarized, and the accessibility of each App was evaluated, as well as the assessment of suitability for different kinds of disabled users according to the best solutions. Finally, this study also proposed specific recommendations for App designers and developers, aiming to improve the accessibility of mobile applications and increase accessibility awareness among the general public.

3.2 Methodological Approach

i. User Type Vs. Best Solution Analysis

In daily life with smartphones, there are certain barriers for users with disabilities to

use a mobile application [23]. It is important to note that a disability is not only a permanent physical impairment, such as being blind and deaf, but a barrier that everyone may encounter, including temporary and situational disabilities. A temporary disability means an injury to the body that occurs over a period of time which is reversible, such as impaired vision due to cataracts, impaired mobility due to an injured arm, or impaired hearing due to an ear infection [24]. Situational disability means that the impairment is due to environmental factors, such as the inability to stare at the mobile phone while driving, that hearing is affected in a noisy environment, or cognitive decline in stressful situations [24].

Considering those situations, the types of users with disabilities were divided into four categories including Visual impairment, Hearing impairment, Physical disorders, and Mental disorders (Table 1). For the four types of disabled users above, the following best solutions were proposed (Table 1).

Table 1. Best solution for disability

User types	Best solutions
Visual Impairment	
Color-blindness	Color inversion
Low vision	Zoom in & out
Blind	Screen reader Speech Recognition
Hearing Impairment	
Deaf Weak hearing	Vibration or visual reminder
	Subtitle
	Mono audio
	Adjustable volume
Physical Disorders	
Finger-related mobility problems Users suffering from arthritis	External devices
	EasyTouch (Android)
	Assistive Touch (iOS)
	Speech Recognition
Mental Disorders	
Input prompt Unlimited time for operation	

ii. Accessibility Testing

In the accessibility testing, two different mobile phones were selected as the testing platforms, which have different systems with remarkably similar features (Table 2). Both have a screen size of approximately 6 inches, multi-touch, and fingerprint and

16M colors. Although the iPhone 10 has a higher screen resolution than the XiaoMi 8 and both phones have different screen types, these differences are not significant for the tests performed. All tests were performed in the same environment and conditions.

Table 2. Platform of testing

Features	XiaoMi 8	iPhone 10
Operating System	Android 10.0	iOS 13.3
Release Date	2018, May	2017, November
Display (Type)	Super AMOLED, Capacitive touchscreen, 16M colors	Super Retina OLED, Capacitive touchscreen, 16M colors
Display (Size)	6.21 in., 97.1 cm^2	5.8 in., 84.4 cm^2
Display (Resolution)	1080 × 2248 pixels, 16:9 ratio (402 ppi density)	1125 × 2436 pixels, 19.5:9 ratio (458 ppi density)
Sensor	Fingerprint (front-mounted)	Fingerprint (front-mounted)
Screen reader	TalkBack	VoiceOver

Screen reader is an important accessibility tool, helping users perceive information through sound. Every iOS device comes with a screen reader which is VoiceOver, and most Android devices come with a screen reader called TalkBack. Both iOS and Android feature a similar base set of gestures when it comes to navigation; finding and activating a control on the screen [18, 25].

In this study, there are 46 Apps of the Portuguese higher education sector that were searched from Google Play and the Apple Store, related to 23 universities and institutes (Table 3). In the target group, 25 mobile apps have both android and iOS versions, one App "Exames Nacionais" is only available for iOS, and others are only for android.

Table 3. University & Institute and related Apps

University/Institute	Related applications
Universidade de Aveiro	UAmobile, actUA
Universidade do Algarve	MILAGE Learn+
Universidade Autónoma de Lisboa	my Autónoma
Universidade Beira Interior	UBI
Universidade de Coimbra	UCoimbra
Universidade Católica Portuguesa	MyCatólica
Universidade de Évora	My.UE
Universidade Europeia	UE|IADE|IPAM, Univ. Europea

(*continued*)

Table 3. (*continued*)

University/Institute	Related applications
Universidade Lusófona	Ensino Lusófona, Lusófona Docentes, Lusófona Acesso
Universidade Lusíada	eLusiada, eLusiada Mobile
Universidade de Lisboa	Técnico Lisboa, myFenix, ISEG, ISCTE-IUL, ENE3@LISBOA
Universidade da Madeira	Académica
Universidade do Minho	App UMinho, DEI - Universidade do Minho,where@UM
Universidade Nova de Lisboa	SAS Nova, netPApp, @NOVA IMS, myISG
Universidade de Trás-os-Montes e Alto Douro	alunosUTAD, estudarUTAD, InnGage - UTAD, alumniUTAD, juniorUTAD, Active Gym/UTAD, UTAD Innovation
Universidade do Porto	Acontece na U.Porto, uni - A FEUP no teu bolso, FEUP for Students, UPorto
Instituto Politécnico de Leiria	MyInfo@IPLeiria, Exames Nacionais
Instituto Politécnico de Tomar	IPT Mobile
Instituto Politécnico de Bragança Instituto Politécnico de Cávado e do Ave Instituto Politécnico de Viana de Castelo	SAS MOBILE, SASocial
Instituto Politécnico de Viseu	PVStudent
Instituto Politécnico de Beja	MyIPBeja
Instituto Politécnico de Coimbra	MyIPCoimbra

In the sector of mobile applications, no tools were found which could fully and thoroughly assess accessibility at the present time [5]. However, there are certain valuable tools that were uncovered in this study. The Accessibility Scanner is the tool for suggesting accessibility improvements for Android apps without requiring technical skills [26]. The AXE for Android Accessibility Service is an automated accessibility analysis toolkit available for analyzing the accessibility of android applications [27].

WCAG 2.0 guidelines are categorized into three levels of conformance in order to meet the needs of different groups and different situations: A (lowest), AA (mid-range), and AAA (highest) [8]. Therefore, in this study, a qualitative assessment was performed using four levels, where level A, B, and C, correspond to the high, medium, and low degrees, and level D is indicative of being non-accessible. It was implemented to assess the degree to which the application complied with the rules of the accessibility guidelines.

iii. Preliminary Assessment of Apps

In the preliminary assessment of these 46 Apps, 11 Apps were inaccessible which cannot be running normally, including “UBI”, “ISCTE-IUL”, “UPorto”, “MyIPBeja”,

"MyIPCoimbra", "DEI-Universidade do Minho", "Active Gym/UTAD", "myFenix", "InnGage-UTAD", "MyInfo@IPLeiria", "SAS Nova".

On the other hand, since the mobile applications of the education sector only serve the students, professors, and administrators who are the members of their university or institute, there are 20 Apps with a certain degree of privacy which led to researchers only getting limited access and we hence could only access the login pages and the public areas.

Table 4. Issue of home page in 20 Apps ("VA" Version Android, "VI" Version IOS, "-" skip)

20 apps-with limited access	VA	VI	Issues
where@UM	A	-	
my Autónoma	A	A	
UCoimbra	B	A	Unlabeled button, small focus
MyCatólica	B	A	Unlabeled button, small focus
My.UE	B	A	Unlabeled button, small focus
UE|IADE|IPAM	B	A	Unlabeled button, small focus
Univ. Europea	A	A	
eLusiada	B	B	Unlabeled button, Image no description
eLusiada Mobile	B	-	Low text contrast
App UMinho	B	B	Small focus, Buttons unpronounceable
uni - A FEUP no teu bolso	A	-	
FEUP for Students	A	-	
SASocial	C	-	No access in screen reader
SAS MOBILE	B	-	Unlabeled button, small focus
PVStudent	B	B	Low text contrast
Ensino Lusófona	B	B	Login button no label
Lusófona Docentes	A	A	
netPApp	B	B	Low text contrast
@NOVA IMS	A	B	Low text contrast
myISG	A	B	Low text contrast

The accessibility testing was conducted in normal mode and screen reader mode respectively. As the results of the evaluation of these apps with limited access make evident, as shown in Table 4, there are 6 apps which have good accessibility, 5 Apps which have issues of text color contrast, and others which have low accessibility in screen reader mode, particularly "SASocial" did not work in this mode.

Finally, the rest of the Apps which can be fully accessed, were tested in the main process of accessibility testing, including 16 Apps. There are 8 Apps with both android

and iOS version, 7 Apps with only android version, and “Exames Nacionais” has only an iOS version.

4 Testing Mobile Applications Accessibility

4.1 Accessibility Testing

Although both Google and Apple offer fully automated accessibility evaluation tools, such as Espresso and Robolectric for android and Accessibility inspector for iOS [28, 29], all these tools require the source code of the Apps for testing as well as the developer mode, which are not suitable in this study.

The accessibility scanner and AXE for Android were utilized in the automated testing, which analyzed the App and summarized the result automatically, providing suggestions of accessibility, focusing on four properties: content labels, clickable items, contrast, and touch area size. However, they are not available in iOS, so that the automated test was skipped in iOS applications. In addition, due to the complexity and the number of pages in different Apps, the repeatability of accessibility issues will also be affected, so the App with more suggestions given by Accessibility Scanner does not mean its accessibility is lower than an App with fewer suggestions.

The manual testing was also an essential part in the testing. Manual accessibility testing of mobile apps largely involves exploring and inspecting the apps and checking each encountered UI component. It was implemented by two methods, comprising accessibility testing by visual review and under screen reader mode. In the testing by visual review, global settings and user interfaces of Apps were tested, and also evaluated for users with different barriers, using and testing the mobile accessibility under real situations, for example, a near-sighted user needs to resize the text of the App. In the testing under screen reader mode, the composition of Apps was tested, such as the button, edit box, image, and dialog.

4.2 Test of Accessibility Issues

Firstly, the most common issues found by accessibility scanner include that the text/image contrast ratio is lower than the guideline recommended, that the item label is missing, that multiple items have the same description on one page, that a multiple long clickable item should not share its location on the screen, as well as unsupported item types and small touch targets.

Secondly, the most common issues found by visual review, include that the content is unable to resize or generates errors when resized, unchangeable screen orientation, UI dependent on color, and a lack of multi-language supporting. To test the influence of color of user interface, the tool Coblis - color blindness simulator [30] was used in the test, which works by uploading screenshots of the UI to the platform, simulating the UI under the vision of color-blind users, to determine whether the viewing of the UI depends on color.

Thirdly, we registered frequent occurring issues under screen reader mode, which is also the part of the testing where the most problems were found. The issues about

focus include one focus covers multiple elements, the focus sequence is not logical, the controls have no focus, the focus is so small that it is hard to click on, error focus, and transparent transmission of focus between two pages. The issues about Dialog box, when the screen reader is running and after the dialog box pops up, are linked to the fact that there is no way provided to close the dialog box. The issues about controls include control with no access, prompt text, status notification of control, and control type cannot be read properly.

4.3 Performed Results

In Fig. 1, we show a stacked bar chart graph, with every column indicating the number of suggestions provided by accessibility scanner, including 7 colors which means 7 accessibility issues in applications. All applications tested have issues of accessibility and the problems with the high frequency issue which happened are text contrast, touch target and item label.

The Apps "MILAGE Learn+", "estudarUTAD" and "juniorUTAD" have the best performance in analysis by accessibility scanner, but they still have some issues of item label. The Apps "IPT Mobile", "alunosUTAD", "ISEG" and "Lusófona Acesso" have the most suggestions provided by accessibility scanner, especially in touch target and text contrast. It is necessary to mention that "Acontece na U.porto" was scanned with a lot of meaningless focus in this test, making it impossible to be evaluated, which was also confirmed later in the test in screen reader mode.

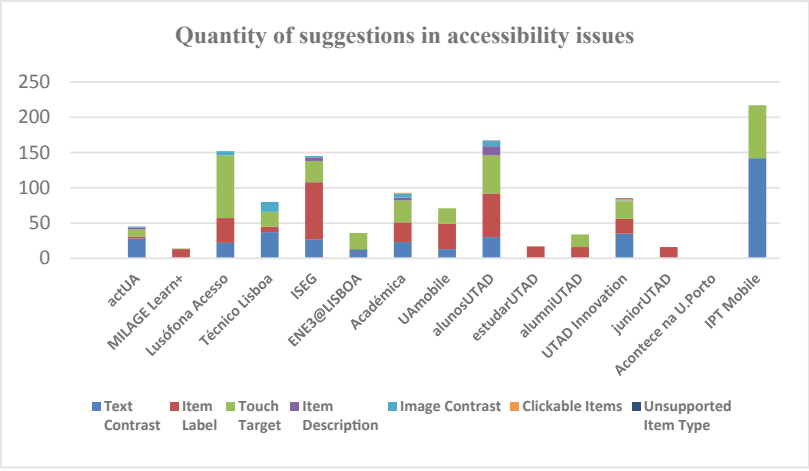

Fig. 1. Quantity of suggestions in accessibility issues

In the test by visual review, the results are shown in Table 5, with REQ 1–4 representing Resize text, Screen orientation, UI not dependent on color, and Multi language support.

Table 5. Issues of control in Apps ("VA" Android, "VI" IOS, "N" Not applicable, "-" skip)

Apps	REQ 1		REQ 2		REQ 3		REQ 4	
	VA	VI	VA	VI	VA	VI	VA	VI
actUA	B	-	D	-	B	-	D	-
MILAGE Learn+	D	D	C	C	B	B	A	A
Lusófona Acesso	B	B	D	D	B	B	D	D
Técnico Lisboa	C	C	B	B	B	B	C	C
ISEG	D	-	D	-	B	-	C	-
ENE3@LISBOA	B	-	D	-	B	-	D	-
Académica	B	-	D	-	B	-	D	-
UAmobile	D	D	D	D	B	B	D	D
alunosUTAD	B	-	D	-	B	-	D	-
estudarUTAD	B	-	B	-	B	-	D	-
alumniUTAD	B	-	B	-	B	-	D	-
UTAD Innovation	B	D	D	D	B	B	C	C
juniorUTAD	B	-	B	-	B	-	D	-
Acontece na UP	D	D	D	D	B	B	C	C
IPT Mobile	B	B	D	D	C	C	B	B
Exames Nacionais	-	B	-	D	-	A	-	D

Most apps have good user interfaces not dependent on color, which means different types of color-blind users have no barriers to accessing those apps. At the same time, the resize text testing had good performance in android, which is better than in iOS. Only three iOS apps could change the text size when the setting of the system changed, but in android, there are 11 apps resizing the text. On the other hand, most apps have no changeable screen orientation, only 5 android apps and 2 iOS apps could change the screen orientation. Those 15 apps have no multiple language supports and will not change the language when the device global setting has changed, but 6 android apps and 5 iOS apps can change language inside of apps.

Tables 6 and 7 show the result of accessibility testing under screen reader mode, the issues of focus, with FCS 1–6 representing Multiple elements, Sequence not logical, No focus, Small focus, Error focus, Transparent transmission; the issues of control, with CTL 1–4 representing No access, Prompt Text, Status notification, and Control type.

Table 6. Issues of Focus in Apps ("VA" Android, "VI" IOS, "N" Not applicable, "-" skip)

Apps	FCS 1		FCS 2		FCS 3		FCS 4		FCS 5		FCS 6	
	VA	VI	VA	VI	VA	VI	VA	VI	VA	VI	VA	VI
actUA	A	-	A	-	B	-	D	-	A	-	A	-
MILAGE Learn+	N	N	N	N	N	N	N	N	N	N	N	N
Lusófona Acesso	B	B	A	A	B	A	B	B	A	A	A	A
Técnico Lisboa	A	A	A	A	A	A	B	B	A	A	A	A
ISEG	A	-	A	-	D	-	C	-	B	-	D	-
ENE3@LISBOA	A	-	A	-	C	-	A	-	A	-	A	-
Académica	A	-	B	-	B	-	A	-	A	-	A	-
UAmobile	A	A	A	A	C	A	B	B	A	A	A	A
alunosUTAD	A	-	A	-	C	-	B	-	A	-	A	-
estudarUTAD	N	-	N	-	N	-	N	-	N	-	N	-
alumniUTAD	N	-	N	-	N	-	N	-	N	-	N	-
UTAD Innovation	A	A	A	A	B	C	B	B	B	A	A	C
juniorUTAD	N	-	N	-	N	-	N	-	N	-	N	-
Acontece na UP	A	C	A	A	B	B	C	C	D	A	A	D
IPT Mobile	A	B	A	A	B	C	B	B	A	A	A	C
EBamesNacionais	-	-	-	A	-	A	-	B	-	A	-	A

"MILAGE Learn+", "estudarUTAD", "alumniUTAD", "juniorUTAD" cannot work with screen reader, and users cannot access the apps when screen reader is running. The most common issues are lacking focus and small focus, only "Técnico Lisboa", "lusófona Acesso" and "UAmobile" of the iOS version have no issues in missing focus, and "ENE3@LISBOA" and "Académica" have no problem regarding small focus.

As concerns the issues of control illustrated in Table 7, the iOS applications have no issue of control with no access, but the android applications have worse performance, and "ENE3@LISBOA" got the lowest level due to many controls with no access. The most frequently occurring issue in both android and iOS applications is the CTL 2 -Prompt text, no Apps got A level and 6 Apps got C - low level. The controls get the focus, but screen reader does not read any information, due to lack of description, operating method, which led to users not knowing what the control is, what it does, and how it operates, which is the biggest barrier for blind users. Most Apps have good performance regarding status notification, control type, except for "Lusófona Acesso" and "Acontece na UP".

Table 7. Issues of control, "N" Not applicable, "-" Skip

Apps	CTL 1		CTL 2		CTL 3		CTL 4	
	VA	VI	VA	VI	VA	VI	VA	VI
actUA	A	-	B	-	A	-	A	-
MILAGE Learn+	N	N	N	N	N	N	N	N
Lusófona Acesso	A	A	C	D	B	B	B	B
Técnico Lisboa	A	A	B	B	A	A	A	A
ISEG	B	-	D	-	A	-	A	-
ENE3@LISBOA	C	-	C	-	A	-	A	-
Académica	A	-	B	-	A	-	A	-
UAmobile	A	A	C	C	A	A	A	A
alunosUTAD	A	-	C	-	A	-	A	-
estudarUTAD	N	-	N	-	N	-	N	-
alumniUTAD	N	-	N	-	N	-	N	-
UTAD Innovation	A	A	C	C	A	A	A	A
juniorUTAD	N	-	N	-	N	-	N	-
Acontece na UP	A	A	C	C	B	A	B	A
IPT Mobile	A	A	B	B	A	A	A	A
EBames Nacionais	-	A	-	B	-	A	-	A

Furthermore, "actUA", "Académica", and "IPT Mobile" have issues concerning dialog boxes. While the screen reader is running, there is no way provided to close the dialog box after it has popped up, and there is no response after clicking the blank space in the screen.

5 Recommendations to Training Courses for Mobile App Developers

5.1 Incorporating the Mobile Accessibility Topic

Through the accessibility testing and analysis above, it can be seen that there are too many accessibility issues of mobile Apps in the education sector, which bring great inconvenience to disabled users and it is unfair to them. The reason for this is the lack of awareness of accessibility construction and the lack of appropriate training for the designers and developers of mobile applications. Therefore, mobile accessibility topics should be incorporated in relevant training courses to establish a human-centered accessibility awareness for every designer and developer from the very beginning.

5.2 Mobile App Accessibility - Functional and Technical Requirements

Based on the WCAG 2.1 guidelines and the best practices published in the market, this study proposed recommendations for mobile apps after mobile application accessibility testing, including the requirements of property of application, the UI design of applications, and advanced requirements. This proposal aims to increase accessibility awareness among designers and developers and can also be adapted to improve the accessibility of mobile applications already released (Table 8).

Table 8. Functional & Technical Requirements

Content	Requirements
Guidelines - Global Settings (Basic Requirements)	
Resize text	Legible and without loss of content at 200 percent zoom;
Small screen size	App user interface is adaptive to mobile phones with different sizes of screens;
Color inversion	Supports color inversion tool of mobile phone;
Screen orientation	Supports orientations (portrait or landscape);
Magnification/Zoom in&out	Supports magnification tool of mobile phone;
Multiple language support	App adaptive language following mobile phone system language setting;
Guidelines - User Interface Design	
UI not depend on color	Color palette of application is appropriate for all users;
Multiple language setting inside app	Provide language switching function inside App;
Consistent Layout	Ensuring that repeated components occur in the same order on each page;
Text alternatives for non-text content	Subtitles for content audio or video with audio; Provide sign language for audio-only content;
Text/image size adjustable inside app	The internal text or image could zoom in&out in Apps
Contrast of text/image	Contrast ratio of at least 4.5:1 for small text, Contrast ratio of at least 3.0:1 for large text;
Touch Target Size and Spacing	Target size bigger than 48 × 48dp, or 32 × 32dp for Views within input method windows or against the display edge; Space length between elements at least 2 mm;
Touchscreen Gestures	All functionalities should be used by simple gestures;

(*continued*)

Table 8. (*continued*)

Content	Requirements
Easy button in proper position	Placing buttons where they are easy to access;
Accessibility label (for screen reader)	Ensure all text, image, controls are usable from VoiceOver/TalkBack;
Provide clear indication that elements are actionable	Avoid users ignoring elements that can be interacted with;
All functionality has unlimited time to be actionable	Provide user enough time for operation
Contextual help	Contextual help is available when a label lacks of explaining of the fill of an area;
Notification for error	Input error automatically detected should have suggestions for correction;
Instructions for gestures	Provide instructions for custom touchscreen and device manipulation gestures
Guidelines - Advanced Requirements	
Positioning important page elements before the page scroll	
Grouping operable elements that perform the same action	
Set the virtual keyboard to the type of data entry required	
Provide easy methods for data entry	
Support the characteristic properties of the platform Provide tips and contact details to collect feedback of accessibility issues encountered by users	

5.3 Mobile App Developers' Ethical Requirements

Privacy and confidentiality are primary concerns when developing mobile applications, especially in the current situation where the technologies of fingerprint and face ID have become popular.

It is also significant to recognize that there are no specific laws which require that mobile applications must become more accessible to all users, even for users with different types of disabilities, which means that the most important factor is the overall smooth operation rather than accessibility in application development [2].

6 Conclusions

Theoretical and Practical Implications

With this study, we can conclude that, in general, most mobile applications tested in the higher education sector in Portugal have an unsatisfactory level of accessibility and have various accessibility issues. The most common issues include text/image contrast, resize text, touch target, accessibility label, controls, and dialog, etc., generated barriers for the users, especially the user with visual impairments.

The App "Exames Nacionais" in iOS, "IPT mobile" in both Android and iOS have better accessibility for users with visual impairments. Since only two Apps provided video content and they have subtitles, all hearing impaired users can access these apps without barriers. All Apps have unlimited time for operating, which is friendly to the users with cognitive disabilities, but the input prompt part only achieved medium level which means certain barriers for those users.

The main reason for this state-of-affairs is that most developers do not pay much attention to accessibility development and testing during the development, and there is no accessibility standard for this process. This study summarized the common accessibility issues and proposed the accessibility recommendations that can help designers and developers to improve the accessibility of apps.

Limitations and Future Work

In this study, there are still several limitations regarding the assessment of mobile application accessibility. The lack of literature and guidelines is the first limitation encountered. Only two studies were found, which focused on the public administration and the tourism sector in Portugal [3, 5]. Another limitation encountered in this study is that the accessibility analysis tools are limited. The automated testing tools Espresso, Robolectric and Accessibility Inspector can only work in the developer mode and require the source code. Furthermore, manual testing requires to test all buttons and pages of a mobile application, which means a lot of work and spending much time, especially under the screen reader mode. Thus, this method is not suitable for a particularly complex application accessibility evaluation.

Concerning future work, the user testing will be supplemented, cooperating with the actual users who have impairments or disorders. This is because they are the related beneficiaries, and their user experience constitutes real feedback, and as a result more issues may be exposed regarding real use. In addition, a battery of tests will be created for applying and validating public service mobile applications, such as the applications for ordering delivery&food, to assess their current accessibility status and promote the recommendations for improvement that will meet all the needs of disabled users, so that they do not feel more excluded from society in this aspect.

Final Considerations

In this study, forty-six mobile applications relative to the Portuguese higher education sector were analyzed, and this analysis revealed that most mobile applications have low accessibility and a significant number of accessibility issues in this area exists. The main reason for this status quo is that most developers have not paid more attention to accessibility development and testing regarding the process of development and have not formed a standard. The mobile application designers and developers should have a greater awareness of accessibility before designing and developing applications, so as to understand the standards, understand the user needs, design rationally, and implement them properly. Hence, users with a disability may also enjoy the convenience provided by modern technology.

In the end, despite the limitations encountered in this study, all the initially identified goals have been achieved, and we hope that this study could lead to a better comprehension of the current status of accessibility for mobile applications in the education sector, thus serving as a case for future research on this topic.

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An Educational Digital Game for the Development of Phonological Awareness

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Abstract. Phonological awareness is the ability to perceive the sounds contained in words. This capacity begins to be developed before the literacy period. Some children work their phonological awareness in speech therapy sessions, in which educational games can be used. This work presents the Educational Quiz - Phonological Awareness, a game developed and tested with nine professionals in the Speech Therapy field and with eight children in speech therapy sessions. The game was well rated by experts, who fully agreed that it can be used in speech therapy sessions with children (aged between 4 and incomplete 6 years) with the disorder. The results of these tests are presented in this paper.

Keywords: Phonological awareness · Serious game · Educational digital game · Language acquisition

1 Introduction

Phonological awareness is the ability to manipulate the sounds of our language (Adams 2018). It is, for example, the ability to perceive that a word can start or end with the same sound or when we know that there are also short words and long words; and that there are phrases (and a segmentation in those sentences).

From 3 or 4 years old, the child can already have this awareness. However, it is significant to understand that the evolution of phonological awareness has steps that must be understood to begin the person's learning, namely: the ability to understand the language fractionation levels and the understanding that the same syllables can be seen in different words, however with divergent sound (Antony and Francis 2005). There are some factors that the subject must have to establish and develop language, and they are interdependent. For example, perceiving and reflecting sounds is necessary to understand, organize responses, and then articulate correctly (Adams 2018; Scherer 2007).

Phonological awareness that impairs speech affects more than 6% of children worldwide and is also considered a functional developmental disorder. Generally, these problems are accompanied by disabilities such as hearing, phonological disorder, apraxia,

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 122–133, 2022.
https://doi.org/10.1007/978-3-031-07018-1_10

among others. In these cases, it is necessary to constantly practice exercises that stimulate speech (Inacio and Nunes 2019).

Thus, it is necessary to seek help in the treatment of these children, which is usually done through follow-up with speech therapists and professionals specialized in the child's development. It is necessary for the patient to practice exercises necessary for their progress in learning to speak. One of the alternatives for this is the use of technologies as learning tools, including digital games (Inacio and Nunes 2019).

On the other hand, the educational game allows you to work with categories of toys, colors, human body, among others, stimulating the learning of children, young people and typical adults or with some disability; thus, they can be used for phonological awareness. Furthermore, digital games have been used as an additional resource to the learning process, as they can reinforce individual interpretation and build a meaningful experience. They simply present the gameplay rules and allow the user to engage himself freely (Noemi and Maximo 2014).

Taking this into account, the project aimed to implement a computational instrument with gameplay that can involve individuals who need to learn phonological awareness so that the instrument can be used as an aid object in speech therapy sessions.

After its implementation, the digital game went through tests with speech therapists and children in speech therapy sessions. The results of these tests are presented in this article.

This paper is structured in the following sections: The "Phonological awareness" section concerns phonological awareness concepts and the use of minimal pairs. The "Related works" section presents studies and games that seek to help develop phonological awareness and includes works with themes in the field that is closer to the instrument developed in this project. On the other hand, the "Methodology" section contains how the project was developed. The "Development" section contains a brief description, the functional and non-functional requirements, the design stage, persona samples and the game elaboration stage. In the "Results and discussions" section, the results of the application of questionnaires answered both by speech therapists, who evaluated the game and by the children who participated in the project are presented. Finally, the "Conclusions" section presents the main points of interest for this project.

2 Phonological Awareness

Phonological awareness is a skill divided into linguistic levels that comprise the segmentation of the language spoken in sentences, sentences in words, words in syllables and syllables in phonemes (Scherer 2007).

Studies focused on phonological awareness argue that children who have difficulties in phonological awareness tasks may be delayed in their acquisition of writing and reading. Therefore, stimulating children's learning through activities that stimulate their phonological awareness is essential, as the mechanism of learning to read and write depends on the subject's understanding of the alphabetical writing system, that is, the letter and phoneme relationship (Ferreiro and Teberosky 1991).

One of the objects of study in this work was to develop, within phonological awareness, the minimal pair's concept. To ascertain the distinct value of a segment, switching is used, representing the comparison between minimum pairs, that is, two words of the language that differ in their concepts only by one segment (Donicht Miranda and Miranda 2019).

According to (Kahl et al. 2007), it can be concluded that there is a minimum pair at the moment when two phonic sequences differ by a single phoneme, such as the Portuguese words "tom" (tone) and "dom" (gift), here there is a minimum divergence defined by the sonority when whereas / t / is cataloged as an occlusive, alveolar, voiceless consonant segment; the / d / segment is classified as occlusive, alveolar, voiced […]. The difference is seen in an identical space since it is found in the course of a single sound, in the same place, in the two sound sequences.

Certain pairs of phonemes demonstrate as an attribute the fact that they are distinguished by their loudness, that is, some of them are deaf and others are sonorous. The phonemes / p /, / t /, / k /, / f /, / s /, are considered deaf since they do not present vibration of the vocal folds when produced. In turn, the phonemes / b /, / d /, / v /, / z /, are performed with vocal fold vibration, being considered, therefore, as sonorous phonemes. The tone of sound leads to an important differentiation between the pairs of these sets of phonemes: / p / x / b /; / t / x / d /; / f / x / v /; / s / x / z / (Zorzi 2019).

Minimum pairs were carefully analyzed, and a quantity was selected for the assembly of the game, and they were observed throughout the game.

3 Related Works

The use of digital games is widely referred to in the study of literacy, as in a way, it involves the person in a comfortable environment, ensuring their attention more efficiently compared to other methods.

As mentioned in (Kahl et al. 2007), the world of games enables students to interpret and dictate rules, thus carrying out a social and human activity. Therefore, for the tool to be placed in an educational and study space, it is essential to authenticate the computational tool by professionals in the same field to guarantee the maximum use of it.

Amorin et al. (2020) examines the effectiveness of Escribo Play, a game-enhanced educational program, on preschool students' phonological awareness, word reading, and writing skills in 17 schools with 749 students.

Guindeira y Gil (2017), using the Microsoft PowerPoint programme, aimed at the development of phonological awareness in pre-school children with special educational needs. The study was qualitative and exploratory, constituting a multiple case study.

Studies have been discovered with a similar objective: phonological awareness development, such as Domlexia - Dom e Letras – Afabetização game. It is available for Android and IOS platforms, has a map of Letters AZ, and each map has words and voices corresponding to the chosen Letter, so the child validates whether it is true or false.

The game known as “Kera Puzzle”, available for desktop platforms, was developed to treat phonological disorders. This game is a puzzle that in one of the game modes, every time a piece fits into the other voices is reproduced referring to the minimum pairs, and the user has to interact and validate the voices (Figueiredo et al. 2021).

Another identified study that aims to make users understand how to express proper words is “Tellfunny” (Inacio and Nunes 2019). This game was made available for Android and IOS platforms and divided the gameplay into two parts. Firstly, focusing on word speech and the second with speech exercises based on the understood phonemes.

The main difference of this work in relation to almost all related works is in its use within speech therapy sessions, as an auxiliary instrument for specialists and not a use within schools, in the literacy period.

4 Methodology

Regarding the methodology used in this work, the project initially had a literature review on related topics. The purpose of the review was to understand the phonological awareness concept and information about the necessary components for the game’s development and investigate how methodologies based on educational games are used.

The methodology of this project had a collection of information obtained through the speech therapist specialist, for the elaboration of the educational game that works, in a playful way, the phonological awareness, more specifically, the minimal pair’s concept. Participatory methodology was not used because we are in a period of the Covid-19 pandemic when the game was developed and the children were in social isolation.

The theoretical foundation of the research was obtained through scientific research, websites, articles, publications, descriptive documentation, and theses. The reading and analysis of theoretical material focus on understanding phonological awareness, the treatment techniques used by speech therapists and the creation process as an object capable of assisting in learning.

Soon after the completion of the development stage, a stage of exhibition and execution of the game developed was carried out and then verified by the specialist to validate the game. Therefore, it was sought if the developed game could reach the expected levels to make it viable for users who need to learn phonological awareness in speech therapy sessions.

To achieve the objectives presented in this project, the following steps were performed: a. Study of the content involved (phonological awareness, minimum pairs, educational games, Unity; b. Meetings with a professional in the field of Speech Therapy; c. Research on phonological awareness for individuals who need to develop it; d. Submission and approval of the project to the Research Ethics Committee, number CAAE 38448720.5.0000.0084; e. Implementation of the computational tool through Unity; f. Availability of the game to professionals in the speech therapy field for validation and feedback. Analysis of results/feedback; g. Availability of the game to be tested by children in Speech Therapy sessions; h. Evaluation of results.

5 Development of the Digital Game

This section aims to present the requirements analysis, the project phase and the tool implementation.

5.1 Requirements Analysis

The following sections have the purpose of displaying tool description, personas description, functional and non-functional requirements.

- **Tool description**. The game's purpose is to be applied as an instrument to help professionals in the speech therapy field in the treatment of people who are in the process of literacy and who need stimuli for the development of phonological awareness, ensuring the focus and interaction of children throughout the tasks.
- **Personas description.** Two personas were created and described below to understand the children profiles sought to achieve with the educational game.

  Roberto is 3 years and 7 months old. During the last two months, he attends the speech therapist once a week, preferring to stay at home rather than appearing because he finds it repetitive and not very encouraging. One way for Roberto to continue in the treatment process while having fun will be using the tool, as it will be effective for learning and fun.

  Gabriele is 4 years and 2 months old and has been attending the speech therapist for three months. However, her parents notice that she still finds it exceedingly difficult to perform activities that need to describe the initial Letter of the images.
- **Functional requirements**. For the game, the following functional requirements were found through frequent meetings with a specialist in Speech Therapy:

  - Function to decrease and increase the volume of the Music/Effects.
  - Choose the Theme you want to play.
  - By clicking on the Theme, load the game screen and display the respective questions.
  - Game mode 1: show a Picture and by clicking on the sound icon, play the sound.
  - Game mode 2: show an Image and the user click on the initial Letter of it.
  - Game mode 3: show a Letter and the user click on the Picture that starts with that it.
  - Save game progress automatically.
  - Reset game progress functionality (found in Options).
  - Back to the menu functionality, where it will exhibit all available themes.
  - Redo the game mode functionality, after finishing it.
  - Exit functionality by clicking the X button found in the upper right corner, in the respective scenes.

- **Non-functional requirements**. The educational game was developed to be easily installed and used, to be intuitive, fun, educational. For installation, the computer/notebook or device must meet the following requirements:

- Operational system - Windows 7 or higher, or macOS 10.12 or higher (if computer/notebook),
- The device must have audio/sound output.
- If it is a mobile device, it must be Android 4.1 or higher.
- The device should have 27.4 MB of available storage.

5.2 Design Phase

The educational game was developed to be compatible with desktop/notebook devices, Windows and macOS operating systems, Android 4.1 or higher mobile devices.

For the application development, the C# programming language was manipulated, and the element packages provided by Unity Engine were used.

1. Creation of scenarios and figures: Most of the figures were taken from Assets available on the Unity website, and some of them modified as necessary.
2. Audio creation: The "TextAloud" software was used to create the audios responsible for interacting with the user in each game mode.
3. Creation of gameplay: When it comes to gameplay, it was thought about how the user can interact with minimal pairs playfully. Different game modes were created that could fulfill the requirements.

For example, there is a game mode focusing on listening to phonemes and puts the user in a situation that dictates whether he/she can distinguish words with similar phonemes. Another game mode aims to display an image to the user and to validate the initial Letter of the image presented. Finally, a game mode in which a Letter is displayed, and the user needs to decide which figure corresponds to the Letter presented.

5.3 Game Implementation

UnityEngine, known as Unity 3D or simply Unity, was used for the construction of the game. It is a 3D and 2D game engine created by Unity Technologies, which supports the use of several assets found on the Internet on the Unity website itself. In the case of game development, 2D technology was used, as it is a simple game.

Regarding the interaction with the application, the user needs to use the mouse if it is a desktop or the touchscreen if it is an Android device because it was developed to have easy-to-use controls. Next, the game process, along with the images, will be presented.

An important point to mention is that a large part of the game screens has linked audio, explaining the instructions for each screen. These details will be presented below.

When opening the game, the user is presented with the welcome screen (Fig. 1a). Next, an audio is played that portrays the information the image is going through, in this case, "Welcome to the game!!:) Is it your first time playing? If you have any difficulty, ask an adult for help". After a few seconds, Fig. 1b, The Play and Options screen is displayed.

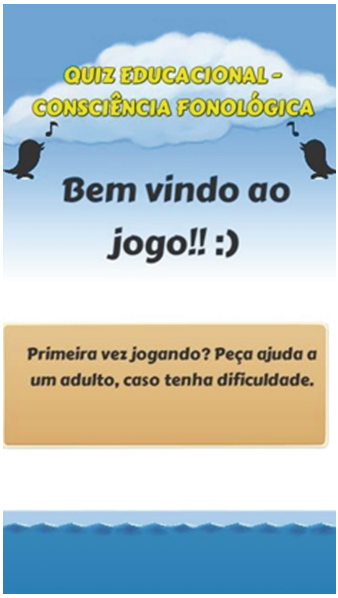

Fig. 1a. Welcome screen

Fig. 1b. Play/Option screen

By clicking on the Options button, a screen is loaded (Fig. 2a) with the player's preferences regarding the Effects/Music volume and the option "Reset Game Progress". By clicking the button with the Play icon (Fig. 1b), the Themes screen (Fig. 2b) is displayed, with the 3 available Themes in the game. In addition, there is an audio on this Themes screen, which says "Select a theme".

Fig. 2a. Option screen

Fig. 2b. Theme selection screen

If the user selects Theme 1, Fig. 3a is loaded. The user identifies the drawing, clicking on the Soundbox, and validating (true or false) whether the audio matches the displayed image. When loading Game Mode 1, automatic audio is played that says, “Does the picture correspond to the audio? True or false?”. If the user selects Theme 2 (Fig. 2b), Fig. 3b is displayed. Now, the user discovers the initial Letter of the image presented. When the user selects Game Mode 2, automatic audio is played that says, “Discover the initial letter of the figure shown below”. If the user selects Theme 3 (Fig. 2b), Fig. 3c is displayed, presenting a letter on the screen and four alternatives with images. The user must validate which image corresponds to the Letter presented. When loading Game Mode 3, automatic audio is played that says, “Which figure corresponds to the letter shown below?”.

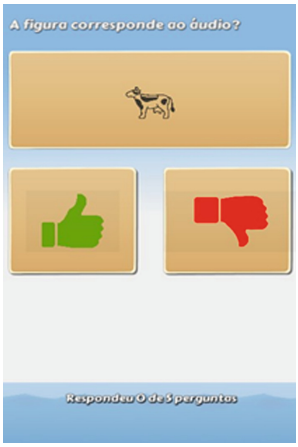

Fig. 3a. Game mode 1

Fig. 3b. Game mode 2

Fig. 3c. Game mode 3

The feedback screen is displayed by the user finishing any of the Themes, whether they are 1, 2 or 3. If the user’s score is negative feedback, the user scored was 4. Figure 4a is displayed. Then the audio says, “Ops! You didn’t do very well this theme”. If the feedback of the user’s score is positive, in the following example, the user scored 10. Figure 4b is displayed. Then, the audio says, “Congratulations!! Wow, you got all the correct questions!”.

Fig. 4a. Negative feedback

Fig. 4b. Positive feedback

6 Results and Discussions

The structure for carrying out the tests comprised two questionnaires developed and applied by the speech therapist.

Speech therapy professionals answered the first questionnaire after evaluating the tool. The second questionnaire was answered by the child audience, under the supervision of their parents. The results of these questionnaires can be checked in the section below.

The executable format of the game was made available so that professionals in speech therapy and children could play and evaluate the game.

The questionnaires mentioned above were made to collect information related to the game and its evaluations for improvements in the game. Recruitment of the 8 children it was for convenience and their age was 4 to 6 years old. All children were already attending speech therapy sessions. The questionnaire made for the child audience was evaluated by the children during the days 17 to 18 of November 2020. Recruitment of the 9 professionals of speech therapy it was for convenience. They had at least 10 years of experience in the field. The questionnaire made for the professionals of speech therapy was evaluated during the days 16 to 18 of November 2020.

6.1 Test with Experts

The experts' questionnaire addressed themes related to motivation, design, audio, being intuitive, suitable for the treatment or diagnosis of children. The results were:

- "The game is motivating for children between the age of 4 and 6 years old": the majority (2/3) of the professionals considered that the game is motivating to be used by children of the stipulated age group. This may mean that, concerning motivation,

the tool was evaluated positively; however, 11.1% disagreed. Therefore, there may be future work to improve this issue.
- "The design is adequate (colors, figures, texts, buttons and messages": the majority (2/3) of the professionals considered that the design of the tool is adequate and pleasant; however, 22.2% remained neutral. So, it is possible to think about a future work to improve the design of the tool.
- "The audio of choice of pictures is adequate for the treatment": 100% of the professionals considered that the audio of the figures is adequate for the treatment. This may mean that in future changes to the tool, the audio will not be affected.
- "The game is intuitive": 100% of the professionals considered that the audio of the figures is adequate for the treatment. This may mean that in future changes to the tool, the audio will not be affected.
- "The game is adequate for aid in the treatment of diagnosis of children children (aged between 4 and incomplete 6 years)": 100% of the professionals considered (strongly agree or agree) that the game could aid in the treatment or diagnosis of children (aged between 4 and incomplete 6 years) with the disorder. This may mean that the game is a potential tool to be used by professionals in their sessions.

6.2 Test with Children

The children's questionnaire addresses themes related to pictures and sounds. The results were:

- "Did you like the figures in the game?': the great majority of the child audience liked the figures in the game; however, 25% remained neutral. This may mean that, in future work, there may be an improvement in the tool's figures.
- "Did you like the sound of congratulations": the great majority of the child audience liked the tool's voices; however, 12.5% remained neutral. This may mean that there may be an improvement in the game's voices in future work, but it will not be the focus.
- "Did you like the sound "try again"": 75% of the child audience liked the sound of try again; however, 12.5% remained neutral, and 12.5% disagreed. This may mean that, in future works, there may be an improvement in the sound of the try again, which is reproduced when the user scores less than 5.

When the children were asked about what they liked the most, they answered: "To listen often", "To try again", "Guessing", "To play alone", "To choose right". When the children were asked about what they liked least, they answered: "From the end", "From the cell phone", "It's very easy", "It's very fast".

7 Conclusions

The project aimed to show the stages of building a computational tool able to help speech therapists in sessions for training phonological awareness.

Investigations were made to understand why an educational game becomes effective in learning, such as what type of design would be ideal for users and how the gameplay would need to be developed aiming to be intuitive and easy to understand.

Through the information collected in the questionnaires, it can be seen that the game can be used in speech therapy sessions to train phonological awareness, also taking into account its playful character.

The game will be standardized in future works since some points need to be modified and corrected as the game design issue. For example, there are black and white figures, and there are also color images. That means that the color pattern is required.

It is also thought to add new themes. Currently, there are only three. The goal is to study and validate which theme can be added to make the game more and more complete. There may be an improvement to make the game more motivating since 11.1% of the professionals disagree that it is motivating.

Another future work, totally considerable, is about the sound effects and audios of the figures. As seen in the graphics of evaluations about the game, one of the points mentioned and needs attention is these. It is reflected in adding more appropriate voices to be heard to make the game more fun and interactive.

All tests were carried out online due to the social isolation period because of the Covid-19 pandemic. The speech therapist who effectively participated in this project was responsible for making the contacts so that the tests could be carried out.

Acknowledgment. The work was supported by the Coordenação de Aperfeiçoamento de Pessoal de nível superior - Brazil (CAPES) - Programa de Excelência - Proex 1133/2019.

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Using Exergames to Promote Healthy Habits in Schools

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Abstract. Educating children in healthy lifestyle habits is one of the most effective ways to prevent future diseases such as obesity and improve their health. This chapter presents an educational intervention project to promote healthy lifestyle habits using active video games and gamified activities as a motivational tool towards healthier habits. In particular, we describe the workshops carried out in different primary schools using an active video game called TANGO:H and other gamified tools. The results of these workshops have shown a very high satisfaction with the intervention itself and the active video game .

Keywords: Exergames · Healthy habits · Gamification · Childhood obesity

1 Introduction

Childhood is the stage of life where habits that will be consolidated throughout our lives begin to develop. Educating children in healthy lifestyle habits from an early age is the most effective preventive measure to improve their health and quality of life [1].

In 2004, the WHO declared obesity as the epidemic of the 21st century after reaching global proportions, although as early as 1998 in its World Health Report, it spoke of obesity as an emerging health problem [2].

This epidemic mainly affects developed and developing countries. However, it is no longer exclusive to high-income countries and is beginning to be present in developing countries, affecting the entire population from childhood to adulthood.

Overweight and obesity are the fifth leading risk factors for death globally and are attributed to nearly three million deaths per year. Health problems from being overweight

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, pp. 134–146, 2022.
https://doi.org/10.1007/978-3-031-07018-1_11

or obese are estimated at 58% of the burden of diabetes, 21% of ischemic heart disease, and between 8% and 42% of some cancers, and these risks grow in proportion to the increase in body weight [3]. Obesity has been increasing progressively in recent decades. It has become one of the most severe public health problems in the pediatric population, estimating that about 41 million children under five years of age were overweight or obese in 2016. If current trends continue, the number will increase to 70 million by 2025.

The Spanish Society for the Study of Obesity (SEEDO) confirms that 44.5% of Spanish children suffer from excess weight; this means that practically one out of every two children are overweight, concerning the growth patterns established by the WHO. These results are added to those given by the ALADINO study [4]. It specifies that the child population aged between 6 and 9 years has a prevalence of 26.2% overweight and 18.3% of obesity. In the Canary Islands, the results were 21.2% and 28.4%, respectively, being the Spanish autonomous community with the highest rate of childhood obesity, together with Andalusia. In its latest update in 2019, there is a downward trend in overweight since 2011 and stabilization for 2015. However, the prevalence of overweight and obesity in schoolchildren aged 6 to 9 years in Spain remains high (the prevalence of overweight is 23.3%, and obesity is 17.3%).

The association between childhood obesity and risk factors for chronic diseases, its persistence in adulthood, and the scarce success in its treatment makes the efforts of governments and health organizations focus on prevention at this stage of life, knowing that most behaviors and habits are acquired at an early age, it becomes crucial to promote healthy lifestyles from all spheres. For some years now, social policies, research, and educational programs have appeared for their prevention and treatment from different areas (school, society, families) [5].

Therefore, the project we have developed seeks to:

Promote the acquisition and permanence of healthy lifestyle habits in children with overweight and/or obesity through health education.

Promote social awareness about the importance of childhood obesity prevention in our society.

This intervention program was designed, conducted, supervised, and analyzed by professional researchers in the areas of health (medicine, physiotherapy, nursing, psychology, physical education, and sports), education, and computer science [6]. Each area of this study focused on analyzing different characteristics of the intervention.

This paper will present background about gamification and healthy lifestyle habits, the reference project, the experience developed in different educational centers that participated in the project, and the main results. Likewise, the tool used as an active video game in the project will be described.

2 Gamification, Exergames and Healthy Lifestyle Habits

Non-pharmacological interventions should be the basis of obesity treatments, especially in children, where they are considered the first-line treatment [7]. The goals to be achieved include long-term changes in lifestyles, especially in eating and physical exercise habits. Generally, only when these are profound, long-term weight changes are observed [8].

According to the review of controlled trials of lifestyle interventions, despite multiple methodological limitations, family-based behavioral lifestyle interventions targeting dietary change, physical activity, and thought patterns could lead to a significant and clinical decrease in overweight in children and adolescents [9]. Although this review includes 6- and 12-month follow-ups, follow-up studies with longer time frames are desirable. From a review of trials carried out with overweight and obese adults, with follow-up of changes in weight over a minimum period of two years, it is concluded that modern interventions aimed at changing lifestyles cause a modest but sustained decrease in weight over time, with clinical significance, as it has a positive impact on complications such as diabetes and hypertension [10]. The interventions reviewed combine specific dietary changes, calorie restriction, exercise, and counseling using behavioral techniques. Some of these techniques include self-monitoring, modeling, environmental restructuring, and group and individual support. In addition to being effective, these interventions generate participant acceptance, low dropout rates, and compliance in attending sessions. There are some factors that, according to the authors, favor the long-term maintenance of the changes achieved. Firstly, suppose the goals set are simple and involve small weight changes. In that case, this facilitates their achievement and maintenance, and this small success can favor the feeling of self-efficacy and promote both the maintenance of weight change and the acceptance of new changes. On the other hand, the long-term efficacy of the interventions was related to the maintenance of contact with the participants during the entire follow-up period, rendering obsolete the idea that a lifestyle modification intervention can take place in a limited time and maintain its benefits for life. One of the complications of maintaining professional care is its cost; in that sense, minimal monthly or bi-monthly telephone or group contacts seemed effective in maintaining weight reduction [10].

Feelings of autonomy linked to healthy eating and physical exercise are positively related to short- and long-term weight loss. This implies the establishment of an internal locus of control and self-regulation for weight control. Weight control is also predicted by considering physical exercise as intrinsically reinforcing, exciting, and a source of enjoyment and feelings of confidence in its performance [11, 12].

According to a review of papers on mediating variables of the effectiveness of interventions to promote physical activity in children and adolescents, self-efficacy is a target to be established in interventions to increase physical activity. Although the generalization of the results should be considered caution because most of the works reviewed were implemented in a female population, self-efficacy was the only cognitive variable that acted as a mediator in the relationship between change in physical activity and weight. Outcome expectancy behaved as a mediator in only one paper. However, it was related to changes in physical activity, as were attitudes, changes in perceived barriers, and changes in the enjoyment of the physical activity. Among the behavioral variables, only commitment to planning acted as a mediator and, among the interpersonal variables, none played this role [13].

Another critical factor in the success of intervention with children with obesity is the inclusion of parents in the programs. It has been found, for example, that parental motivation, especially their confidence in achieving changes in lifestyle behaviors in

the early phases of treatment, can reduce treatment dropouts and improve treatment outcomes [14].

Interventions have even been designed to work only with parents. For example, West et al. (2010) [15] intervene with parents to improve their skills and confidence in managing their children's weight-related behaviors. Compared to a non-intervention group, improvements in children;s weight, weight-related problem behaviors, parental self-efficacy, and decreased ineffective parenting practices are evidenced immediately and at 12-month follow-up.

In addition to including self-esteem, eating habits, and physical activity, it has been shown that group exercise programs can be a helpful tool, and parental involvement is required for the effectiveness of obesity treatments [16]. Likewise, intervention should pursue behavioral changes because knowledge does not guarantee them [16]. This is consistent with the self-determination theory, from which it is proposed that the feeling of autonomy and self-defined will during changes, the feeling of effective and optimal challenge and feeling connected in a meaningful way with other people, have an intrinsic value for the self and are essential for well-being and behavioral persistence [11].

The promotion of change can be approached and promoted from two approaches, not necessarily mutually exclusive. On the one hand, the implementation of desirable behaviors and reducing the frequency of undesirable behaviors can be promoted from classical behaviorist paradigms, administering reinforcers contingently to behaviors. From this approach, behaviors are managed according to extrinsic motivations. On the other hand, as we have just seen, intrinsic motivation can help the change to last. The achievement of feelings of autonomy and competence, social recognition, and evidence of the positive impact of behavioral change become intervention objectives. Both types of approaches are easily combined in the design of intervention programs. Furthermore, both are addressed when designing programs that use play to promote healthy lifestyles.

Research reports positive results in video games that promote healthy lifestyle habits [1, 16]. In the studies reviewed by Baranowski et al. (2008) [16], the objectives varied between changes in diet, increased physical activity, the combination of both, and other health-related habit changes (i.e., in the management of asthma or diabetes). The designs and methodology used are very varied. Video games differ, for example, in aspects such as whether they are contextualized in a narrative, interactivity, and whether the player assumes roles. They also vary in the behavioral theories guiding the approach (i.e., trial-and-error learning with reinforcers, goal direction, social cognitive theory, action through practice, self-regulation theory) and the methods used to promote change (i.e., increasing knowledge, increasing preference by associating positive stimuli, practice, modeling, goal setting, problem-solving, rewards, persuasive communication, social support). Despite this variability, in general, video games increased knowledge and changed attitudes and behaviors. The authors suggest that video games could influence behavior by

two mechanisms: by including the behavior change procedure in the game, for example, by establishing goals, or employing a story that includes change concepts. The story's usefulness that can contextualize a video game is highlighted since the narrative can help capture and maintain the interest of the student/player and allows the modeling of desirable behaviors through the characters. Thus, the characters guided by the player face the challenges through habit change, favoring the player's actual habit change. When the story is presented in an episodic structure, it favors attention and strengthens behavior change messages, interrelating them by appearing in different stories. The immersion, which favors intrinsic motivation, and the interactivity characteristics of video games, allow the story to be experienced in the first person and encourage learning through planning skills, decision making, and cause-effect relationships. Added to this is the powerful tool of feedback that can be offered in different formats and immediately. One difficulty of this type of tool is that its design is costly in terms of time and varies significantly in economic terms [16].

Gamification is a growing trend nowadays, which is proving its usefulness in educational and health promotion contexts. It is understood as the design of non-game activities using elements of game design to achieve behaviors that can be considered "playable" in contexts where they are generally not considered "playable" [17–21]. It has been applied to achieve results in designing tools to improve physical skills and increase physical activity [22]. In this way, some applications and websites allow sharing and reinforcing behaviors linked to physical activity, making it more fun. These applications involve earning points, overcoming levels and achievements, and earning badges for social and physical activities [21, 22].

Likewise, some applications and communities include a broader ratio of healthy habits, making it possible to set individual weekly or biweekly goals and rewarding (reinforcing) healthy behaviors and for example, not giving in to temptations generated by stress, taking hypercaloric food, but carrying out a healthy behavior, such as drinking a glass of water or going for a walk [22].

Intervention programs based on gamification have been designed to promote healthy habits from the school context [23, 24]. This is the case, for example, of the FIT Game, a program aimed at increasing vegetable and fruit consumption in the school cafeteria [25]. In it, each day, a fruit, or vegetable was set as a goal for consumption. The days when none was chosen constituted the experimental control situation (does consumption increase differently when promoted?). The program had a narrative context, with heroes (FIT) who had to capture the villains (VAT, vegetable annihilation team). Moreover, a format was proposed with three phases of competition against other schools, although these were fictitious. The winning school would help the heroes. The fictitious competition phase lasted seven days.

Each day a teacher read a very short script (less than 1 min) in which he communicated the progress. Phases were won by eating more of the selected fruits or vegetables compared to the other schools. When they met or exceeded the consumption criteria established by the researchers, they were informed that they had won, and the school was rewarded with a badge placed on the project screen. Once the competitive phase

was over and the school had won, the hero support phase began. Before lunch, teachers would read a 3-min story to their students, highlighting their role in achieving the goals (eating fruit or vegetables). When the goal was met or exceeded, teachers would read an episode the following day. Each episode began by congratulating the school on its success, progressed through the narrative, and usually ended in a moment of suspense. When the goal was not reached, the reading encouraged students to eat more of the selected food than usual because the heroes needed it. Each gram that exceeded the consumption criterion was bonused with a game currency unit placed on the game screen. Every four days, students voted on spending that "money" or the direction of the narrative. An increase in vegetable and fruit consumption was observed, linked to the intervention (restricted to target days). However, the starting point of group vegetable and fruit consumption at school was not low. One relevant limitation is that it does not capture individual improvements because this study was conducted in a group setting; also, we lack follow-up information [25].

As we can observe above, gamification and exergames can help in the promotion of healthy habits. Thus, in the following section, we will describe the structure of the PROVITAO "Educational Intervention Program using Active Video Games and Motor Games to Support the Outpatient Treatment of Obesity" project, which includes effective interventions for treating obesity and promotion of healthy habits in children.

3 PROVITAO Project

The research project entitled PROVITAO is a project of a research group called Interaction, Technology, and Education (ITED) of the University of La Laguna formed by computer scientists, education professionals, health professionals, designers, pedagogues, and psychologists are working on the design of active video games and motor games with an educational and health approach.

The project aims to improve children's physical, emotional, affective, and cognitive states through active video games and other ICT-based educational activities. To this end, in this project, we carry out an educational intervention focused on the acquisition of healthy lifestyle habits in primary school children with childhood obesity and other interventions to raise awareness in society about this health problem. The study consists of different phases: the initial evaluation phase, the intervention phase, differentiated for parents and children, the final evaluation phase, and the follow-up evaluation phase. Figure 1 shows an outline of the intervention carried out.

In addition, the PROVITAO team carried out theoretical and practical workshops with the students and teachers at the schools participating in the study to promote healthy lifestyle habits, prevent and raise awareness of childhood obesity. The following is a description of the experience carried out in the different schools participating in the project.

Fig. 1. Diagram of the intervention carried out in the PROVITAO project.

4 Experience

The schools that participated in the project were the following: CEIP Las Mercedes, CEIP Aguere, CEIP Aneja, CEIP San Rosa de Lima, CEIP Samoga, and CEIP La Verdellada belonging to San Cristobal de La Laguna, Tenerife, Spain. Activities were carried out for grades 3 to 6 of primary school (boys and girls between the ages of 8–12 years). A total of 581 students and the teachers responsible for each class (16 teachers) from the four schools involved participated for three months. The age range of the teachers was 38 to 59 years, although 75% were older than 50 years (mean age = 51.62). Most of the teachers participating in the study were women (81.25%).

The activities carried out in the schools, aimed at students from third to sixth grade of primary school and the teachers responsible, were structured as follows:

– School hours and 45 min.
– Theoretical-practical gamified activities: included a brief presentation on the subject focused on healthy eating and games to improve healthy lifestyle habits in a gamified

way using the Kahoot tool in group form (4–5 students per tablet) (Fig. 2) and continued with the realization of motor games and active video games using TANGO:H individually (Fig. 3) [26].

Overall satisfaction with the workshops was measured using a Likert scale (1 = Very insufficient/inadequate; 5 = Very good/Very adequate), and we can say that in the case of the overall intervention, it was very high (4.69), as well as with the use of the active video game TANGO:H (4.75). Other variables measured concerning the satisfaction with the intervention were: time (4,69), duration of the session (4,44), use of Kahoot (4,67), educational contents (4,63), goals of the program (4,63). Also, we measured variables related to the dynamization, such as the knowledge of facilitators (4,88), the skills of

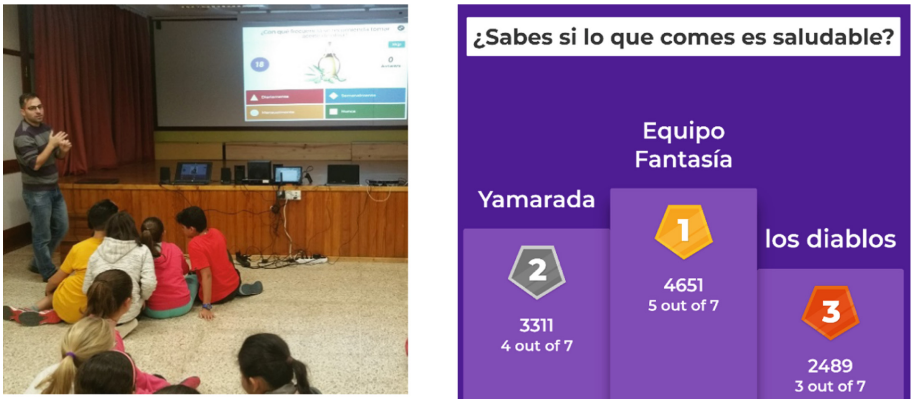

Fig. 2. Use of the Kahoot gamification tool as a group activity in schools.

Fig. 3. Use of the active video game TANGO:H in schools.

communication (4,63), their capacity to answer questions (4,67), and their capacity to create interest (4,75).

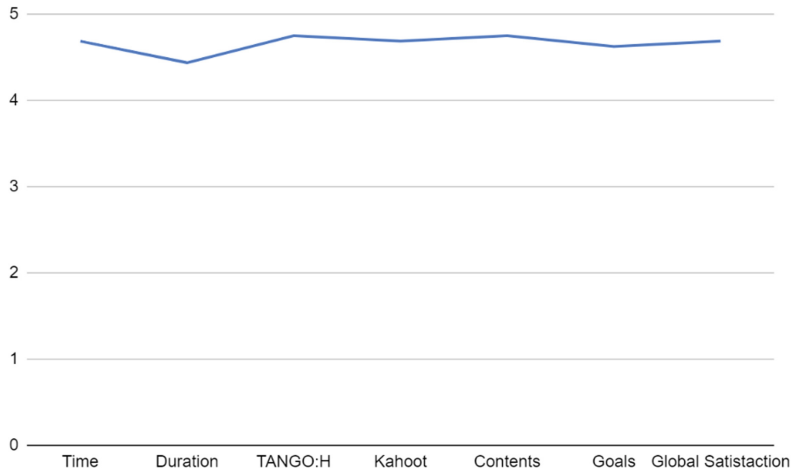

Fig. 4. Use of the active video game TANGO:H in schools.

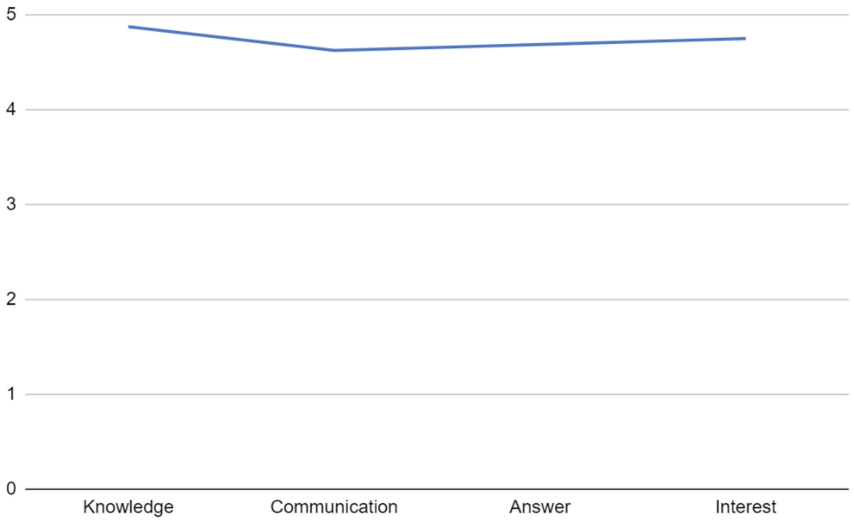

Fig. 5. U Use of the active video game TANGO:H in schools.

Next, the active video game TANGO:H used as a tool in these workshops will be described (Fig. 5).

5 TANGO:H

As we have previously described, PROVITAO is an educational intervention program that uses gamified physical exercises, stimulating body movement and more active participation through active digital games or exergames, which allow capturing, virtualize, and reproduction the physical movements of the player to carry out the challenges presented in the game.

Therefore, all the sessions carried out were designed from a ludic point of view; this means that after each theoretical content, an active game was carried out to reinforce it, using an active video game or exergame called TANGO:H [26].

TANGO:H is a platform created through a collaboration agreement between the Instituto Tecnológico y de Energías Renovables (ITER) and the Interaction, Technology and Education (i- TED) Research group of the Department of Systems and Automation Engineering and Computer Architecture and Technology of the University of La Laguna. TANGO:H allows the user to interact with the application without a physical intermediate medium through gestures using his own body.

The system allows the user to play both individually and in a multiplayer mode in a sequential, collaborative, or competitive way. There is also an intelligent game mode, using the recommender system, which recommends exercises based on the user's skills.

Likewise, TANGO:H provides the user with a gamified system, which stimulates the user to improve his evolution in the game using a reward system, which he will obtain by redeeming points. This system is used to increase motivation in the physical exercises' performance through challenges in the game.

The exercises and the reward system (prizes) can be created and modified through an application called TANGO:H Designer (Fig. 4). This allows teachers or specialists to design customized exercises that meet their specific needs and objectives (Fig. 6).

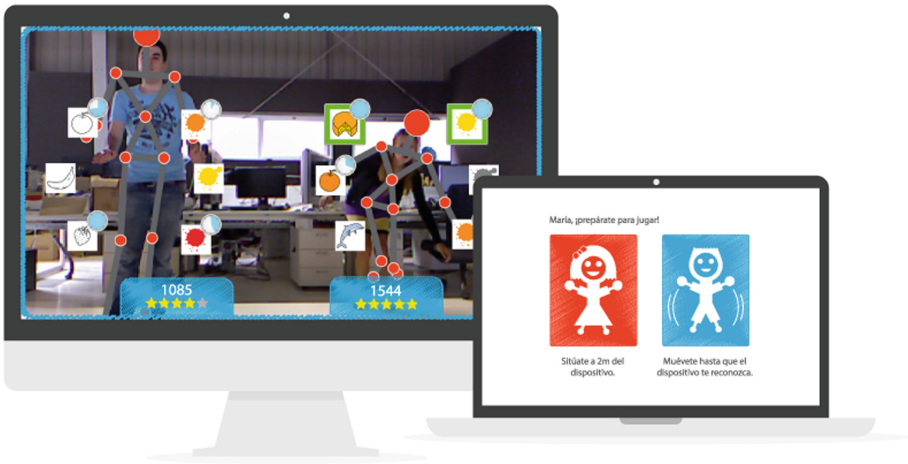

Fig. 6. TANGO:H application. Source [27].

6 Conclusions

As conclusions, we believe that there is a need for greater awareness and mobilization of society about problems derived from sedentary lifestyles, overweight, and child obsessiveness. The interest of the educational intervention program presented does not aim to promote interaction with active video games or exergames for their purposes. However, with the motivation, they can awaken students' awareness of the health problem in question. We see that interaction with exergames can generate a motivating environment that can translate into effective changes in people's lifestyles who interact with it.

Nevertheless, we believe that it is necessary to perform an intervention only on active video games. However, different strategies are needed to achieve a real change in the lifestyle habits of minors. In schools, it is possible to replicate this type of intervention by combining different gamification tools and active video games that motivate students to acquire knowledge and practice healthy physical activities. We believe that it would be interesting to integrate this type of program into the educational model of the centers, as it is a program that educates and motivates behavioral change from an early age using the dynamics of games, which are so close to children.

We also consider that it is necessary to introduce in the short-term space for education in healthy lifestyle habits in the educational curriculum of minors. This type of education should not be left to chance and to the teacher's interest in training his or her students in this subject. The fact that education in healthy lifestyle habits is part of the curriculum would ensure the long-term acquisition of healthy behaviors and the prevention of non-communicable diseases related to bad habits, resulting in improved health for society.

Finally, we conclude that active video games and gamification can increase motivation towards physical activity, learning, and healthier lifestyle behaviors in children.

Acknowledgments. The authors would like to thank researchers and participants involved in the project PROVITAO, from different areas: Health (Raquel Martín González, Carmela Quirce González, Norberto Marrero Gordillo, Honorio Armas Ramos, Mariana E. Cairós González, Josué Monzón Díaz, Mercedes Murray), Technology (Alberto Mora Carreño, Belén Armas Torres, Vanesa Muñoz Cruz, Lorenzo Moreno Ruiz, Jesús Rodríguez Álamo, Miguel A. Padrón, Niobe Jerez, Pablo V. Torres Carrión) and Education (Vicente Navarro Adelantado, Luis Navarro Campillo, Elisenda Espino Espino, Silvia Vera González, Isa Neves). We would also like to thank the Department of Education of the Government of the Canary Islands and the schools and teachers who collaborated with the project. This work has been funded by the Fundación CajaCanarias, Project PROVITAO OBE05.

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Correction to: Is the Gender Pay Gap an Outcome of Other Gender Gap?

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Correction to:
Chapter "Is the Gender Pay Gap an Outcome of Other Gender Gap?" in: T. T. Primo et al. (Eds.): *Advanced Virtual Environments and Education*, CCIS 1425, https://doi.org/10.1007/978-3-031-07018-1_3

In the originally published version of chapter 3 the first-last name order of the author's name was incorrect. Further, figs 1, 2 and 3. contained typesetting errors. The author's name has been changed as "Danilo Santos Piñeros Perea" and typesetting errors have been corrected.

The updated version of this chapter can be found at https://doi.org/10.1007/978-3-031-07018-1_3

T. T. Primo et al. (Eds.): WAVE 2021, CCIS 1425, p. C1, 2022.
https://doi.org/10.1007/978-3-031-07018-1_12

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