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# **Gamification and game-based learning for education in healthy lifestyle habits in children**

**Doctoral thesis  
Extended abstract in English**

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# INTRODUCTION

## Childhood obesity and current status of the problem

In 2004, the WHO declared obesity to be the epidemic of the 21st century after it reached global proportions, although as early as 1998 in its World Health Report it spoke of obesity as an emerging health problem. Progress in the fight against childhood obesity has been slow and irregular, and in 2014 the Commission on Ending Childhood Obesity was established with the aim of reviewing existing strategies, developing a set of recommendations aimed at combating obesity adapted to different global contexts [1, 2].

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

Obesity has been increasing progressively in recent decades, and in the pediatric population it has become one of the most serious public health problems, estimating that about 41 million children under five years of age were overweight or obese in 2016, and if current trends continue, the number will increase to 70 million by 2025 [1, 3].

Those responsible for the growth of childhood obesity figures in the world are the changes in lifestyles, and the social and occupational development that most populations have undergone traditional foods have been replaced by foods richer in calories, fats, and sugars, in addition to favoring a poor diet based on pastries (food industry) snacks, salt and poor in fruit, vegetables, legumes and fish. Little or no physical activity is performed due, among other reasons, to the higher level of urbanization and mechanization, the evolution of transport systems, changes in social and health policies, the urban approach that leaves little space for green areas, and the long time spent by schoolchildren in sedentary leisure activities in front of the computer or television are some of them [4].

In addition, childhood obesity has a complex and multifactorial etiology, in which genetic and environmental factors are involved [5]. Although there is some genetic predisposition, unhealthy eating habits and sedentary lifestyle are the main factors in its appearance [6]. This is confirmed by the low proportion of patients diagnosed with obesity due to genetic disease or hormonal disorders, as well as the association between the physical activity of fathers and mothers and their children and their weight, thus demonstrating that weight is determined by modifiable factors, not only by genes [7]. Nor can we underestimate the influence of other risk factors such as parental obesity, low educational and socioeconomic status of the family, having few hours of sleep, high birth weight, or exclusive breastfeeding, which have been shown to play an important role in the development and maintenance of obesity in adulthood in different populations studied [8-13]. For example, in countries with a high per capita income, children from families with a lower socioeconomic status are more likely to be overweight or obese compared to those children from families with a higher socioeconomic status [14].

Spain has a high prevalence of obesity, with the Canary Islands and the south of the peninsula at the top of the list. The association between childhood obesity and risk factors for chronic diseases, its persistence into adulthood and the poor success in its treatment makes the efforts of governments and health agencies 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 areas. In recent years, social policies, research and educational programs for prevention and treatment from different areas (school, society, families) have been appearing.

In view of the above, we proposed the development of a study to assess the effectiveness of a gamified educational intervention model using active video games and motor games in changing attitudes and healthy habits in children with obesity compared to the current model of treatment carried out in doctors' offices, as well as to serve as a tool for the prevention and promotion of health in healthy lifestyles from the family environment. This research project was entitled PROVITAO, acronym for "Active Video Game Program for the Outpatient Treatment of Obesity", Ref OBE05. The intervention described and studied in this doctoral thesis is framed within this research project.

## Hypothesis and objectives

The hypothesis we set out in this research is the following:

"The proposed intervention is an effective tool to favor the acquisition of healthy habits in children and their families, and that it has an impact on the improvement of the quality of life, current and future, of minors suffering from childhood obesity."

The main research objectives of this doctoral thesis are organized into general and specific objectives, as cited below.

*-General objectives:*

1. to promote the acquisition and permanence of healthy life habits in overweight/obese children through health education.
2. To evaluate the influence of the educational intervention program in children with overweight/obesity.
3. overweight/obese children.
2. To promote social awareness of the importance of childhood obesity prevention (short and long term complications, health and social costs).

*3. -Specific objectives:*

1. diagnose the situation of overweight/obese children in relation to their physical condition and needs.
2. To assess the previous habits and lifestyles (habits, customs and beliefs) of overweight children and their families.
3. To give truthful information about healthy behavioral habits, and to eliminate myths.
4. Create a family environment that reinforces the educational program on healthy eating habits and frequent physical activity.

5. Analyze the effectiveness of the intervention for the promotion of healthy habits, through periodic evaluations.
6. Communicate and disseminate the activities and results obtained to the entire scientific, medical and social community.
7. To measure the motivation of the child to the physical activity developed with motor games and active video games.

This doctoral thesis is presented in the form of a compendium of articles whose original works are published in scientific journals indexed in the Journal Citation Reports (JCR), as detailed below:

1. González-González, C.S.; Gómez del Río, N.; Toledo-Delgado, P.A.; García-Peñalvo, F. (2021). Active game-based solutions for the treatment of childhood obesity. *Sensors* 2021, 21, 1266 **(JCR, Q1)**.  
DOI: <https://doi.org/10.3390/s21041266>.  
Available at: <https://www.mdpi.com/1424-8220/21/4/1266>
2. Gómez del Río, N.; González-González, C.S.; Toledo-Delgado, P.A.; Muñoz-Cruz, V.; García-Peñalvo, F. (2020). Health Promotion for Childhood Obesity: An Approach Based on Self-Tracking of Data. *Sensors* 2020, 20, 3778. **(JCR, Q1)**  
DOI: <https://doi.org/10.3390/s20133778>.  
Available at: <https://www.mdpi.com/1424-8220/20/13/3778>
3. Gómez del Río, N.; González-González, C.S.; Martín-González, R.; Navarro-Adelantado, V.; Toledo-Delgado, P.A.; García-Peñalvo, F. (2019). Effects of a gamified educational program in the nutrition of children with obesity. *Journal of medical systems*, 43(7), 198. **(JCR, Q1)**  
DOI: 10.1007/s10916-019-1293-6  
Available at: <https://link.springer.com/article/10.1007/s10916-019-1293-6>

In addition to the articles, which support the thesis modality by compendium of publications, other scientific contributions have been made, which are cited in the corresponding section, in addition to being included in the bibliographical references of the document. Therefore, we proceed to present a list of the publications related to the different objectives of the thesis, considering that, in responding to these, some objectives are closely linked and are answered (Table 0):

Table 0. Relation of the objectives of the doctoral thesis with published results.

General objective	Specific objectives	Published results
1. To promote the acquisition and permanence of healthy lifestyle habits in overweight/obese	1. Diagnose the situation of overweight/obese children in relation to their physical condition and needs.	Presentation of the design and gamified training program on healthy lifestyle habits [23,24].

<p>children through health education.</p>	<p>2. To assess the previous habits and lifestyles of overweight children and their families.  3. To give truthful information about healthy behavioral habits, and to eliminate myths.  4. Create a family environment that reinforces the educational program on healthy eating habits and frequent physical activity.</p>	<p>Exposure of active video games and technological tools that complement the gamification of the program [25,26].</p>
<p>2. To evaluate the influence of the educational intervention program in children with overweight/obesity.</p>	<p>5. Analyze the effectiveness of the intervention for the promotion of healthy habits, through periodic evaluations.</p>	<p>Partial results of all study areas within the project. [25,27]  Results focused on learning food-related habits [27,28].  Results focused on the use of sensors and ICT tools [24,29].  Exposure of the single case study to give a global view of the program [30].</p>
<p>3. Promote social awareness of the importance of childhood obesity prevention (short- and long-term complications, health, and social costs).</p>	<p>7. To measure the child's motivation for the physical activity developed with motor games and active video games.</p> <p>6. Communicate and disseminate the activities and results obtained to the entire scientific, medical, and social community.</p>	<p>Results on satisfaction with the games of program participants [32].</p> <p>Workshops conducted with minors in different schools on healthy lifestyle habits [33].</p>

To achieve the objectives proposed in the doctoral thesis, a methodology divided into different phases was proposed.

The methodological approach applied in the research was a mixed quasi-experimental approach for intervention in educational centers, hospitals, and case analysis, combining qualitative and quantitative techniques.

## **EXPERIMENTAL RESEARCH**

The research design was quasi-experimental, longitudinal, and prospective for 3 years (2014-2017). There were no problems or risks derived from the study for the participants. The legal guardians of all participants have been informed and have signed a consent to use their data for the study and to share them with the scientific community. The processing, communication and transfer of personal data of all participating subjects complied with the provisions of Organic Law 15/1999, of 13 December, on the protection of personal data. The protocols used in the study were approved by the Ethics Committee of the Hospital Universitario de Canarias and the Ethics Committee of the University of La Laguna, Reference CEIBA2020-0410.

The study was divided into two annual phases, in each of which the same intervention was repeated in different groups of subjects.

Each annual intervention phase was designed to be carried out with an experimental group and a control group of 10 to 15 boys and girls aged 6 to 12 years, all of them from the northern area of the island of Tenerife.

The inclusion criteria were age (6-12 years); body mass index (BMI) in the 97th percentile or higher; permission from the parents or legal guardians to participate in the study; no pathologies that would prevent them from participating in the study; and not having participated in another clinical trial in the last 12 months.

The exclusion criteria were participation in a clinical trial during the last 12 months; that the children did not present cognitive impairment that would prevent them from participating in the project; and that they did not have basic network technologies at home (computer and internet) and television (only for the experimental group). The project will provide the rest of the technological tools required for the intervention at home (Kinect sensor, Wii console and Wii balance board) and in the group sessions.

In Phase 1, the sample consisted of children selected from the Pediatric Outpatient Clinic of the University Hospital of the Canary Islands (HUC) who were undergoing outpatient treatment for childhood obesity. The Experimental Group (G1) consisted of 13 children with obesity/overweight (5 boys and 8 girls) who participated in the intervention program. The Control Group (G2) consisted of 10 obese/overweight children (7 boys and 3 girls) who did NOT participate in the intervention program.

In Phase 2, because not enough participants were found to meet the inclusion criteria of the study at the HUC, participants were selected from different public education schools in the district of La Laguna. The Experimental Group (G3) consisted of 12 obese/overweight minors (5 boys and 7 girls) who participated in the intervention

program. The Control Group (G4) consisted of 11 obese/overweight children (4 boys and 7 girls) who did NOT participate in the intervention program.

The assignment of the participants to the experimental and control groups in both phases was made according to the commitment and availability of the families to attend all the face-to-face sessions (experimental group) or only the evaluations (control group).

## Participants

A total of 46 children between 6 and 12 years of age participated in this study, divided into an experimental group (25 children) and a control group (21 children). The educational level of the families was considered as a socioeconomic indicator, considering three categories: high (university studies); medium (secondary education) and low (no education or only primary education).

## Instruments

The study involved the use of different instruments to analyze different data in each study area.

The following variables were collected: name, sex, date of birth and age, place of residence, grade, educational center, anthropometric measurements (weight, height, skinfolds, and body perimeters to assess not only body mass index, but also the amount of fat, muscle and bone mass), and analytical parameters. The following instruments were used to measure body composition and biomedical measurements: digital weight with measuring rod, lipocaliper and caliper, inextensible tape measure, growth curve to determine percentiles, and blood tests were used to determine biochemical values (cholesterol, triglycerides, insulin, hormones). Also recorded at the time anthropometric measurements were taken date and time of measurement, clothing worn at the time of measurement. The scale and measuring rod were checked and calibrated frequently, and at least at the beginning of each day the measurements were taken.

To analyze emotions during the intervention we used the Emodiana [15], an instrument that allows us to measure 10 basic emotions, represented with different expressions of a character associated with their corresponding labels, adjusted to the language used by the children. This instrument is represented as a target allowing the intensity of each emotion to be measured, on a Likert-type scale, with a 5 being the most intense emotion in the center and a 1 the weakest outside the target. It was used during the group intervention sessions at the beginning and end of each session.

To assess the effort perceived by the participants when exercising, the Children's Perceived Effort Rating Table (CERT) [16] was used, this scale presents a range of intuitive numerical categories (1-10) and verbal expressions of effort widely understood by children and adolescents. It was used at the end of the group intervention sessions.

To study the behavior and personality of the children we selected the BASC (Behavioral Assessment System for Children and Adolescents) Spanish adaptation of the Reynolds and Kamphaus questionnaire [17], it is a multidimensional questionnaire that measures

numerous aspects of behavior and personality. In the self-report the child or adolescent describes his or her emotions and perceptions and provides information on clinical scales (negative attitude towards school, negative attitude towards teachers, sensation seeking, atypicality, locus of control, somatization, social stress, anxiety, depression and sense of inadequacy) and adaptive scales (interpersonal relationships, relationships with parents, self-esteem and self-confidence). Four global dimensions were obtained: school maladjustment, clinical maladjustment, personal adjustment and a general index, the emotional symptoms index.

To find out about physical activity habits and the perception of well-being, we have opted for an adaptation of the questionnaire designed by Manuel Delgado and Pablo Tercedor in 2002 in the "Strategy for intervention in health education from education" [18]. The Adaptation of the Questionnaire on physical activity-sport and health-wellbeing is a 22-item questionnaire that assesses: physical activity status (physical activity or sport practiced, days and hours per week, hours of inactivity, etc.), enjoyment of physical activity, self-perception of motor competence and usefulness of physical activity and sport, diet, health and personal well-being.

On the other hand, to determine adherence to and the quality index of the Mediterranean diet, considered to be heart-healthy, the KIDMED questionnaire was used [19]. This test has 16 dichotomous items with affirmative or negative answers that include the main dietary indicators. The affirmative answers in the questions that represent a negative connotation in relation to the Mediterranean Diet (items 6, 12, 14 and 16) are worth -1 point, and the affirmative answers in the questions that represent a positive aspect in relation to the Mediterranean Diet are worth +1 point. If the answer is don't know/no answer, no points are given. Therefore, this index can range from -4 to 12.



Finally, to evaluate the children's video game player profile, we chose the Gamer Profile Test, an adaptation of the Questionnaire on use and attitudes towards video games by Alfageme, B., & Sánchez, P. [20], which is a questionnaire with a total of 12 questions that focus on the type of video games played by the child, the hours per week dedicated to them, and the values and beliefs regarding video games. As an exception, in phase 2 we designed a questionnaire entitled Child Health Report, in which we asked parents for their children's demographic data and medical information regarding health history (past illnesses), health problems (current illnesses) and medical treatment they were receiving in order to make an initial assessment, since these children were not selected from the hospital as was the case in the previous year. This report was under the data protection law and was only treated by the health personnel of the project for scientific purposes. This document was filled out only at the beginning of the study.

For the collection and recording of the variables: heart rate, distance covered, time, speed and caloric expenditure, the biometric sensors used in the intervention and the movement sensors for the TANGO:H exercises were selected and studied as instruments [21]. In the group intervention sessions, the wearable wristwatch + belt type heart rate monitors and accelerometers of the Decathlon brand (Geonaute Onmiles 600) were used; these commercial sensors have their own analysis software. On the other hand, the use of the TANGO:H platform is highlighted in the different sessions carried out in the project.

## Procedure

The procedure for this study was as follows:

First, the corresponding permissions and informed consent forms were requested. In Phase 1, approval for the research was requested from the Ethics Committee of the Hospital Universitario de Canarias, and in Phase 2, authorizations were also requested from the Territorial Directorate of Education of the Canary Islands Government and, subsequently, from the Administration in each participating center.

Next, the study's medical professionals conducted the search for potential participants. Once the sample was selected, an informative letter was sent to the parents or legal guardians detailing the main characteristics of the study to be carried out, ensuring the anonymity of the data and the scientific purposes of the study. During a face-to-face meeting with the families, their doubts were clarified, and they were asked to participate in the study, either in the experimental or control group. The study sample was confirmed once the fathers, mothers or guardians who decided to participate signed the informed consent form.

Finally, the study was conducted to coincide with the corresponding academic school year (September to June) for each annual phase. The work sessions were divided into three quarterly stages: intervention, creation of the vocational project and development of the vocational project (Figure 1). Evaluations using the instruments described in the

previous section were carried out before, during and at the end of each of the annual phases.

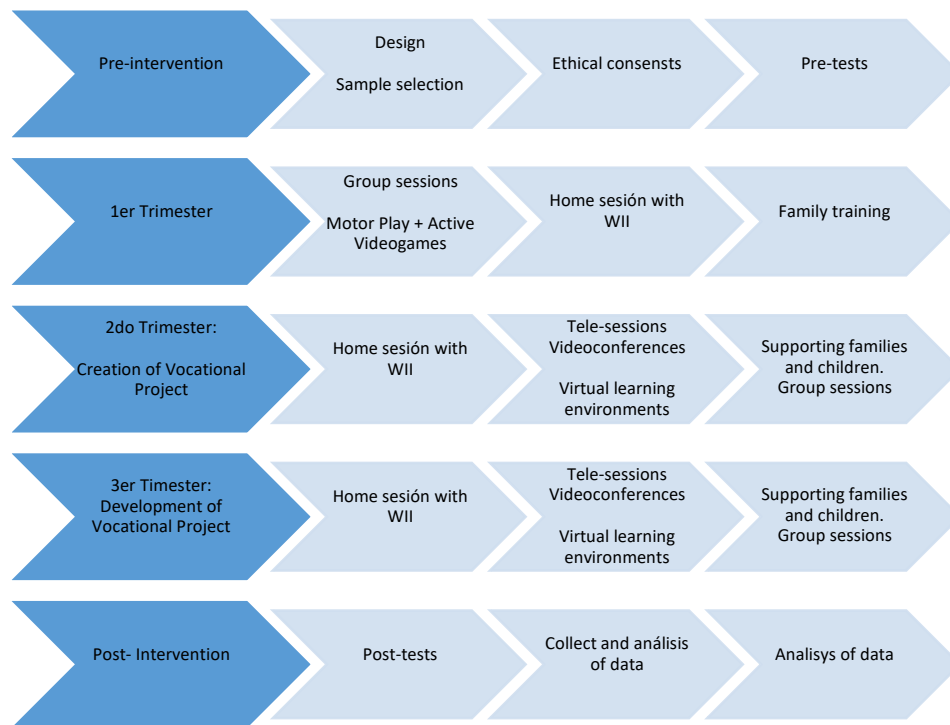


Figure 1. Stages and instruments used in each annual phase.

## Educational Intervention

### First trimester

During the first quarter of the intervention, the educational program was developed for the participating children, with a total of 12 sessions. All sessions were designed from a playful point of view, this meant that after each theoretical content a game was played to reinforce it (using motor games and the active video game TANGO:H as a review before each session), thus each session included a motor game designed explicitly for that content and its emotional impact was evaluated with the EMODIANA before and after the session.

For the different activities that were worked on with the children, expository and participatory methods were used, through group dynamics, the use of debates and games, and the use of the EMODIANA.

For the development of the sessions, different types of formative exercises (physical and cognitive and free) were created and adapted in TANGO:H Designer to work on healthy lifestyle habits in individual, collaborative, and competitive mode. In addition, a gamification module was added to TANGO:H Designer to be able to assign and create prizes and gifts, exercises with difficulty levels and time restrictions.

During this phase, two weekly physical exercise sessions were also requested at home, using the Wii Balance Board with the Wii Fit Plus videogame, favoring physical activity

in the family context. For this purpose, the sessions with the Wii were selected and planned to work different body areas with each session.

In addition to the immediate feedback provided by the activities (score in TANGO:H, Wii; knowledge of point gains in the other face-to-face activities), their scores were transferred to a general ranking, which was made public to the group in the face-to-face sessions to gamify all the activities carried out in the intervention. On the other hand, serious mobile games and other Internet activities were recommended to promote healthy lifestyle habits to be carried out at home, such as: Diana eats healthy, Activilandia, Healthy heroes, Cool-E's revenge, among others.

The place where the sessions were held was the sports facilities of the Aneja School, in La Laguna. The group sessions were held in the afternoon from 5 to 7 pm.

For fathers, mothers and/or guardians, a single 120-minute educational session was established, where three topics were addressed: healthy lifestyle habits in nutrition and physical activity, obesity as a disease, and false beliefs about video games.

### **Second and third trimester**

During the second and third trimester, the intervention was individual and home-based, supported by technologies and focused on the creation by the children themselves of a vocational project related to the discovery of healthy activities that they might like in their environment (change of habits towards healthier ones). The development of this phase consisted of programming a physical activity (second trimester) that they had to carry out autonomously (third trimester). Aspects such as resistance to change versus openness to experience and the perception of self-efficacy and the discovery of the resources of the immediate environment to implement healthy behaviors were worked on. This activity was tutored through a weekly videoconference session, accompanied by sessions on the Moodle platform where the work team guided, supported and dynamized the behavioral change of the children, in collaboration with their parents.

Activities with the children included discussion of videos and podcasts related to change or resistance to it, dynamics to promote self-esteem within the group, dramatizations/role-playing, discovering their environment using computer applications and narratives. The gamification of this phase was carried out by awarding points according to the fulfillment of the activities and participation in them (for example, 10 points were awarded if they carried out an activity and 5 points if they participated in the forum) and at the end of each quarter a diploma was awarded with the different roles of the narrative used (pirates).

The search for healthy activities organized by the municipalities and in the children's environment was not favorable, since, except for sports, there is a lack of free public offer of physical and healthy activities throughout the year that are appropriate to the interests of the children. This posed a difficulty for the development and execution of the healthy vocational project that could remain when the research team withdrew the direct intervention, as planned in this phase. Therefore, monthly meetings were included to reinforce the social component and commitment to the project and its objectives.

During the third quarter, monthly group sessions were held with the children in the experimental group, in which cognitive and social skills were addressed, focused on problem solving with peers, given the high frequency with which they are related to childhood obesity.

For parents, training and orientation activities were carried out on a monthly basis, these appointments coincided with the monthly meetings of the participating children. The purpose of this activity was to support the development of the children's vocational project, as well as to resolve doubts regarding the use of the different technological tools (videoconference, Moodle platform, Clasdojo). This led the research team to contact the town councils and associations in the area where the children lived to find out about the resources and healthy activities available when the parents reported the difficulties encountered, or to hold a workshop with the parents on the bullying suffered by some of them in their environment.

The sessions of this phase were held at the School of Engineering and Technology of the University of La Laguna in the afternoon from 5 to 7 p.m. according to the availability of the families.

In phase 2, the children were given the activities in a notebook in order to facilitate access to the activities as some parents reported connection problems (for example, not having a computer and it being difficult to do the tasks from a cell phone).

### **Workshops in schools**

Focused on the topic of dissemination and promotion of healthy lifestyle habits and the importance of preventing childhood obesity, educational and interactive training workshops were held with students and teachers in the different schools that participated in the project. The schools where the workshops were held were the following: CEIP Las Mercedes, CEIP Agüere, CEIP Aneja, CEIP San Rosa de Lima, and CEIP La Verdellada belonging to San Cristobal de La Laguna, Tenerife, Spain. The activities were carried out for grades 3 to 6 of primary school (boys and girls from 8 to 12 years old). A total of 581 students and the teachers responsible for each class (16 teachers) from the five 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 who participated 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: teaching hours and 45 minutes and gamified theoretical-practical activities, which 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 a group setting (4-5 students per digital tablet) and continued with the performance of motor games and active video games using TANGO:H on an individual basis. In total, 17 Kahoots related to healthy eating were passed. Taking into account the reports of the gamified questionnaires that were passed, the knowledge about healthy eating in schools is 51%. The children had difficulties in the questions about the food pyramid, in the frequency of eating certain foods such as olive oil, or difficulties in distinguishing the types of meat (red, white). After conducting the group Kahoots and analyzing the knowledge and myths about food, we moved on to active games, which had physical exercises with content related to healthy eating. As an active video game we used TANGO:H. 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 related to satisfaction with the intervention were: time (4.69), session duration (4.44), use of Kahoot (4.67), educational content (4.63), program objectives (4.63). Variables related to dynamization were also measured, such as the knowledge of the facilitators (4.88), communication skills (4.63), their ability to answer questions (4.67) and their ability to create interest (4.75).

## RESULTS

### Nutritional knowledge throughout the study

In this section, we analyze participants' responses involving their knowledge of healthy nutrition. In all cases, higher scores indicate better habits, knowledge and satisfaction. All variables involved in these analyses exhibit a normal distribution, according to the Kolmogorov-Smirnov test. Comparison of the means of the two groups at baseline indicates that both presented similar scores at the beginning of the study in the four indices studied. For each indicator, repeated measures analysis is performed, with group as an inter-subject factor and an intra-subject factor with three levels that we have named "Follow-up". Each level is defined by a phase of the intervention: the baseline (measures taken before starting the intervention), the immediate follow-up (evaluation carried out at the end of the face-to-face intervention phase), the long-term follow-up (evaluation carried out after the end of the intervention with the children and the withdrawal of the follow-ups). When the sphericity of the variance-covariance matrices is not met, the epsilon correction is performed using the Greenhouse-Geisser method. In the case of main effects of the intrasubjects factor, a posteriori analyses are performed with Bonferroni adjustment, likewise, if the main effects analysis does not meet the homogeneity of variances criterion, the Welch robust test is performed. The interaction between the Follow-up factor and Group is not significant ( $F(2,50) = 2.582$ ;

$p = .086$ ;  $\eta^2p = .094$ ;  $P = .492$ ), nor is there a significant effect of Group ( $F(1,25) = 0.503$ ;  $p = .485$ ;  $\eta^2p = .020$ ;  $P = .105$ ). In contrast, there is significant effect of the Follow-up factor ( $F(2,50) = 28.647$ ;  $p = .000$ ;  $\eta^2p = .532$ ;  $P \geq 0.999$ ), attending to pairwise analyses with Bonferroni adjustment, we find the scores at long-term follow-up are significantly different from those at baseline ( $t(23) = 7.002$ ;  $p \leq .001$ ;  $d = 1.2$ ) and immediate follow-up ( $t(23) = 6.234$ ;  $p \leq .001$ ;  $d = 0.99$ ). Analyzing the evolution of the means considering the two groups jointly, in both cases the highest means in knowledge occur in the long term.

## Adherence to the Mediterranean diet

In this section we analyze the responses of the children in the questionnaire on the quality of the Mediterranean diet (KIDMED). We will analyze the data from the preliminary questionnaire and post questionnaire in the short term (after the face-to-face intervention). As the data show, at baseline both groups had an average KIDMED index of 7 (average adherence). However, after the intervention, the experimental group showed a slight improvement in this index, while in the control group it decreased. The differences in the KIDMED index are not significant. Therefore, we decided to analyze each item of the KIDMED questionnaire, as shown in Table 4, with percentages of compliance, both for the control group and the experimental group. These tables show significant differences in the intake of vegetables (one or more) and the consumption of fish, pasta and cereals. Also significant is the number of children who have stopped eating industrial pastries for breakfast. Regarding the impact of the program on eating habits, as Table 5 shows, in the experimental group, the KIDMED index shows a slight improvement that is not significant, while the control group sees a worsening in its KIDMED index that is significant. When analyzing all the items that make up the KIDMED test according to the group to which they belonged, it became evident that there were improvements in the experimental group such as in the consumption of vegetables, pasta or breakfast cereals, and that all participants stopped eating industrial pastries for breakfast. In contrast, the control group stopped eating vegetables regularly and also showed worse indicators related to industrial bakery and sweets. Then, the t-test for related samples was performed, which allowed us to confirm whether there were significant differences between the pre-test and post-test of the test, both in the experimental group and in the control group. In both cases, we must accept that the measure in the population in both the experimental group (0.72) and the control group (0.563) is the same, and no significant differences were found when the values were greater than 0.5. Subsequently, the t-test for independent samples was performed, first relating the pretest in the experimental and control groups. This revealed no significant differences in the questionnaire between the experimental and control groups (0.54). Thus, we started with a sample with homogeneous measures in relation to the quality of the Mediterranean diet, but after the intervention, we found significant differences in the post-tests of the experimental and control groups (0.23). So, we can affirm that the children who participated in the experimental group managed to improve the quality of their diet.

## Single case of obesity-diabetes

To exemplify the different activities carried out and their impact on health, we will present a single case study. The patient is an 11 year old female who was referred to the study from the Pediatric Outpatient Clinic of the University Hospital of the Canary Islands with a diagnosis of obesity and insulin resistance (prediabetes type II), under pharmacological treatment with Metformin 850mg.

Family history: Mother and father both overweight. The mother suffers from obesity and Diabetes type II. Father is asthmatic, smoker, suffers from psoriasis. Maternal grandmother: Diabetes type II, asthma, uterine cancer and Lupus. Maternal grandfather: hypertension, type I diabetes, nephropathy, and heart disease. Paternal grandmother: AHT. Paternal grandfather: Lung cancer.

Personal history: This is an asthmatic girl who requires treatment and has been followed up in the Pneumology Department of the University Hospital of the Canary Islands (HUC) since birth due to respiratory problems, the main reason for a continuous demand for care during most of her childhood due to bronchial asthma, upper respiratory tract catarrh and laryngitis on multiple occasions.

Regarding obesity, this pathology was detected for the first time in the Primary Care consultation with her pediatrician at the 3-year check-up. This increase in weight above the 97th percentile was maintained in all health controls up to the time of the evaluation in this project, maintaining normal percentiles with respect to her height. The first data available in the electronic medical record in this regard is at the 3-year check-up, where her weight is 21.800kg (greater than 97th percentile) and her height is 94.5cm (25th-50th percentile). It was not until the 4-year check-up that the alarm bells rang, and she was diagnosed with Obesity II. At that visit the child weighed 29g (percentile >> 97), was 103cm tall (percentile 50-75), and her body mass index (BMI) was 27.3; her mother said that "she eats everything and a variety of foods". At that time, strict dietary control is prescribed (avoiding fatty, fried foods and refined sugars, ensuring a balanced diet by teaching the use of fresh fruits, vegetables, salads, grilled or broiled meats, etc.), regular sports, and weight and height control in 3 months. However, the child did not attend the control.

In later years, weight and height controls were resumed and the nursing and pediatrician's office insisted on the measures to be taken to improve lifestyle habits and help control weight gain, in spite of this, most of these controls are punctual in time and do not prove to be effective. After the 7-year check-up, and for a short period of time (between January-June 2011), periodic visits and controls are made that seem to achieve an improvement in eating habits and weight control (reduction of 1.6kg in 2 months), but these controls are interrupted again and it is not until the 9-year check-up (June 2013). She joined the PROVITAO Experimental Group in October 2014 and underwent anthropometric and analytical controls pre and post intervention, the follow-up at 6 months and the last control at one year after the start of the intervention. The results showed an improvement both in BMI and in behavioral and motivational indicators.

## Other results

Within the PROVITAO research project, other variables and measures taken throughout the intervention have been analyzed and are briefly detailed below with the intention of giving an overall view of the whole program.

- Regarding the habits reported by the minors. We analyzed the responses in the questionnaires on habits related to the physical activity performed on a daily basis, the self-perception of their motor competence (MC), their opinion on the usefulness of Physical Activity or Sport (PA or Sport) and their perception of their health and well-being.
- The results show no statistically significant improvement between the control and experimental groups in the behaviors referred to physical activity, their CM or their opinion about the usefulness of AFoD, as well as with perceived health and well-being. This suggests that there has not been a significant increase in physical activity in their daily lives, which could be justified as we saw in the development of their vocational project involving physical activity. During the search for resources, we found that in some participants' areas of residence there were no accessible and affordable resources for children that were also attractive to them. In some cases, there were public facilities that allowed the performance of activities (parks, avenues with equipment for physical activity, playgrounds), but it implies that children have the motivation to perform these activities and this group stands out for being little motivated to perform physical exercise.
- As for the parents' questionnaires. The responses were analyzed and organized into five indexes according to their content. In four of them, the highest scores indicate better habits, better attitude or more knowledge, as appropriate: eating habits of children; knowledge of parents about food; attitude of parents towards video games; and adherence to the Mediterranean diet of their children as measured by the KidMed questionnaire. In the case of the index, healthy habits and leisure time habits of their children, higher scores indicate worse habits from the point of view of health promotion.
- According to the information provided by the parents, the two groups of participants presented similar profiles at the beginning of the study.
- They report an improvement in healthy habits during the intervention, but that eating habits are lost in the long term (perhaps due to forgetfulness or lack of continuous training or lack of motivation towards healthy behaviors), these changes could have been influenced by the holiday periods prior to long-term follow-up, which can alter daily routines.
- There was an improvement in the free time habits of the children in the experimental group compared to the control group, although this did not reach statistical significance.
- Regarding the attitude towards video games of the parents, we found a better attitude of the experimental group compared to the control group during the intervention, probably one of the benefits of the activities developed during the intervention phase with the children. In this sense, we would have succeeded in transmitting to the parents that video games can be a playful tool that allows them to put into practice, educate and/or reinforce good habits. However, this



improvement is lost in the long term in both groups, and at least in the experimental group it can be justified in the return to the purely recreational use of video games.

- As for the anthropometric and analytical measurements, no significant differences were found between the control and experimental groups or between the different times. Both groups, control and experimental, decreased BMI after the intervention and increased at follow-up. Therefore, we cannot conclude that the decrease is a product of the intervention performed.
- In the case of the behavioral assessment, where the BASC was applied in its self-report modality. In terms of the group means and medians, these are generally within the "normal" scores in both the clinical and adaptive scales. On the other hand, if we look at the large standard deviations and the maxima and minima in most of them, we can see that scores indicative of poor fit are represented. This is largely due to the presence of scores in the risk ranges and/or clinical significance of several participants in both groups at different assessment times.
- Focusing on changes over the study time, we find that in the control group attitudes towards school improve as they vary throughout the study, which coincides with the development of the school year; in spite of this, the measures of central tendency do not identify a general negative attitude towards school or its usefulness. There are no significant changes in any other indicator or scale in the control group. There are more changes in the experimental group. For example, the presence of unusual thoughts, behaviors or thoughts decreases throughout the intervention, and the experimental group develops a sense of responsibility and control over issues related to their lives. Social stress, i.e., negative feelings associated with social interactions, are modified throughout the evaluated phases and although the central tendency is maintained, the averages are decreasing. Something similar occurs in the depression index, which decreases the variability of the scores with central tendencies.
- As for the group intervention based on games, the results of the emotional analysis carried out on the participants at the entrance and exit of the face-to-face sessions provide an indicator of the motivation with which they attended the intervention, but we are especially interested in the informative nature of the emotional impact of the intervention. Thus, to assess the emotional effect of gamification, the game dynamics carried out and the training. The children generally attended the sessions feeling positive emotions that were maintained at the end of the sessions, with little representation of negative or neutral emotions both at the beginning and at the end of the sessions. The intervention shows a tendency to favor positive emotions and based on the justifications made we see that these are related to the elements of the activity carried out (games, participants, companions, learning), in addition to making reference to personal motives, highlighting the verbalizations of having fun and having a good time. These results reaffirm the motivational value of the face-to-face sessions, especially the motor game and the training games, which manage to establish positive expectations from one session to the next. With respect to the physical activity developed during the face-to-face interventions through motor games, the effort perceived by the children was analyzed through the application of a self-report scale. At the end of the session, each participant individually indicated

how the physical activity had gone, selecting the label that best defined him or her from a scale with 10 levels ranging from "Very, very easy" to "So hard that I have to stop". According to the information provided, the motor games performed were perceived to be of medium and/or low intensity, mostly (88.9%) within the categories of easy to very easy. However, the data collected by the sensors show that the activity performed in some cases was moderate to intense, reaching peaks close to 200ppm. in some cases. Therefore, although the activities demanded a medium effort, for some children it was an intense physical activity and some of them expressed this in their perceptions (8.2% a little effort and 3.4% higher intensity effort). This observation was also made by the professional team, indicating that some of the children really showed evidence of "intense" physical activity and of enjoying the activity, and still considered that the activity had been easy (to some degree). In addition to individual differences, which can vary the impact of the same activity for different participants, motivation and the adequate adjustment of the skills required for the performance of motor games can be determining factors so that the physical effort that may have been made does not negatively affect the perception of effectiveness and therefore of the ease of the physical activity performed.

## CONCLUSIONS

Throughout the phases of the study, we observed a significant improvement in the knowledge of both groups about healthy eating, reaching higher levels in the long term than in the two previous evaluations. On the one hand, this common trend may be reflecting the benefits of formal family and health education, which was available to both groups in the community and access to which was promoted by the Project. Focusing only on the moments before and immediately after the face-to-face intervention, we find a different trend in the scores of both groups. Looking at the media, we see that the experimental group's knowledge of healthy eating is higher than that of the reference group, while that of the control group remains stable. From that moment on, the knowledge of the two groups increases with a similar profile, evolving in parallel. Having participated in the experimental group seems to be a benefit, since the gap in the knowledge acquired by the experimental group after the face-to-face intervention remains present in the long term. Likewise, we observed a significant improvement in adherence to the Mediterranean Diet (MD) of the experimental group compared to the control group. In addition, we observed that the control group worsened in some items compared to the experimental group. This result is important because the MD is traditionally a heart-healthy dietary model characterized by a high consumption of vegetables, legumes, fruits, and cereals using mainly olive oil in for cooking or food seasoning. It is probably one of the healthiest dietary patterns currently available. Numerous epidemiological studies highlight the beneficial effects of this type of diet in combating cardiovascular disease, diabetes, certain tumors and other associated pathologies. In this sense, DM is related to a longer life expectancy and a

lower incidence of chronic degenerative diseases, which shows that a small increase in the rate of adherence to DM leads to a significant reduction in the risk of mortality and in the incidence of these diseases.

This study, however, has a number of limitations. We should bear in mind that we had a sample of 46 participants during the two phases; however, the withdrawal of participants from the study over the months meant the loss of data, with no new participants being able to be included. In addition, participants came from different socioeconomic backgrounds, so we had to adapt the recommendations on dietary habits and physical activities to the economic possibilities of each family. In Phase 1, participants attended private and public schools, so there was no homogeneity in educational options. Finally, the children had different leisure interests and attention spans, so we had to work quickly to create a circle of trust among the participants.

On the other hand, we have presented the study of a single case, an 11-year-old female patient referred from the outpatient pediatrics department of the HUC with a diagnosis of obesity and insulin resistance (type II prediabetes). The patient joined the EG in the first phase of PROVITAO. Therefore, anthropometric and analytical controls were performed pre and post intervention, the follow-up at 6 months and the last control at one year after the start of the intervention. Weight, abdominal perimeter and BMI improved in the post-intervention control and at the 6-month follow-up. The values increased when no intervention was performed. The blood tests showed normal basal glucose and basal insulin values when the patient was treated with Metformin 850mg daily. In relation to cholesterol and triglycerides, we found an improvement in HDL levels at the end of the intervention, which we believe is due to physical activity during the intervention. We also see a long-term improvement, as the patient developed a vocational project related to moderate physical activity (zumba), and developed healthier eating habits. No alterations in TSH levels were found.

The group face-to-face sessions motivated her and increased her emotional well-being, manifesting joy with a high to very high intensity. This may be due to the motivational effect of physical activity based on motor games and active video games, the social environment and gamification. We emphasize that, although the physical activity developed has been moderate and intense in some cases, as can be observed through the data collected by the biometric sensors, the patient perceives it as low intensity, being immersed in the games developed.

In addition, we have checked the effectiveness of the treatment in individual cases, seeing that, in nutrition, health and personal well-being, attitude towards video games, it has had a large effect (100%), in the self-perception of motor competence and adherence to the Mediterranean diet a medium effect (66.67%) and a weak effect in the states of physical activity (16.7%) and free time (33.3%).

We believe that there is a need for greater awareness and mobilization of society regarding the problems derived from sedentary lifestyles, overweight and obesity in

children. We also believe that in the short term it is necessary to introduce in the educational curriculum for children a space for education in healthy lifestyle habits. And that 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 as a whole.

As different strategies are also needed to achieve a real change in the lifestyle habits of minors, we consider that in educational centers it would be 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, since it is a program that educates and motivates behavioral change from an early age using the dynamics of games, so close to children.

The interest of the educational intervention program presented does not intend to promote interaction with active video games or exergames for its purposes, however, with the right motivation, they can awaken the students' awareness of the health problem in question, therefore interaction with exergames can be an effective tool to generate a motivating environment that can be translated into effective changes in the lifestyles of the people who interact with it as we have already been able to see.

Although the limitations of the study in terms of sample size and lack of homogeneity, as well as the added complexity of the differences in context (school, family and socioeconomic) meant that the results of the study could not be extrapolated to the rest of the population, being necessary the analysis by cases, we can conclude that the intervention has proven to be effective in motivating minors to improve their habits to healthier lifestyles, promoting satisfactory social relationships and increasing the perception of control over their own lives, that is, favoring their integral health.

Finally, although it was not the aim of this paper to describe the overall intervention program and all its results, we will highlight its strengths:

The PROVITAO project has developed a gamified educational program for healthy habits, based on active video games and motor games. It has created and validated a reference framework for game-based emotional, biomedical, interactive, social, psychological and educational intervention, monitoring and evaluation, applied to the treatment of childhood obesity and the prevention of associated complications. It has also produced several technological products (exergames, serious games, web applications, sensory libraries, wearables, etc.).

The program developed consists of a specifically designed activity plan on healthy habits with motor games, commercial video games (Wii Fit Plus and apps) and internally developed games such as TANGO:H, which can be presented at home and in groups. Face-to-face sessions.

PROVITAO was applied to a total of 46 children with childhood obesity and their caregivers during the school year, in two phases.

The research design used was of the mixed quasi-experimental type, with two control groups and two experimental groups.

The research group has participated in various activities at the local level (talks in schools, conferences, workshops, etc.) to promote healthy habits.

This study was conducted over three years, from 2014 to 2017, thanks to the joint work carried out by a multidisciplinary team of professionals in the areas of Physical Education, Psychology, Pedagogy, Health Sciences and Computer Sciences who designed, supervised, executed and studied the program proposed in this work.

Despite the limited scope of this study, it has a great potential to obtain knowledge about the child population with obesity because:

- It is developed in one of the autonomous communities with the highest obesity rates in Spain and in Europe.
- It provides information on the healthy habits of an intercultural population.
- It involves an age group where healthy lifestyle habits can be promoted more easily.
- It educates and creates awareness in the entity responsible for children's eating habits and physical activity, and in the family.
- It is one of the first programs to use gamification tools focused on non-formal educational learning involving obesity and lifestyle and its long-term evaluation.
- Several entities have participated, such as: the Canary Health Service (University Hospital of the Canary Islands, Pediatrics Service, Child Psychiatry Service, Primary Care Centers), the Engineering Department of the Institute of Technologies and Renewable Energies, the General Directorate of Public Health through the Health Promotion Service, the Ministry of Education of the Government of the Canary Islands through the Territorial Directorate and the different schools that participated in the project: CEIP Santa Rosa de Lima, CEIP Las Mercedes, CEIP La Verdellada, CEIP Agüere, CEIP La Aneja and CEIP Samoga.
- The project has led to different international collaborations with research groups from USA, Brazil, Mexico, Colombia, Ecuador, Canada and Portugal, as well as with other national groups of video games, health and education.
- It has allowed collaboration with the PACES program (Partnerships for Active Children in Elementary Schools), an American program for the promotion of physical activity in schools, pioneer in the field.

In addition, as future work, the following main lines of this doctoral thesis can be established:

- To extend the sample and develop the intervention program in the whole Canary Islands archipelago, as well as in other places, beyond the autonomous territory.
- To validate by health professionals the effectiveness of the program in the long-term treatment of childhood obesity, especially with regard to the maintenance of healthy behaviors.
- Design and develop new educational sessions based on active video games and other gamified technological tools.
- Extend and introduce the formation of healthy lifestyle habits in schools in a cross-cutting manner.
- Develop new tools for the creation of gamified activities that promote healthy lifestyle habits in children in all areas.
- Create a training program for families, given that children depend on the decisions of their fathers, mothers or guardians, and their habits are derived from those of their families.
- Create programs for municipalities on healthy lifestyle habits.
- Raise awareness through the results obtained on the importance of motor games and physical activity, related to active video games and technologies.
- Contextualized to the pandemic derived from COVID-19 [34-37] and knowing how it has affected the physical activity and mental health of the population, it would be interesting to study whether this type of active video games can help to maintain a healthy physical activity and, at the same time, help people's mental health.

## CONTRIBUTIONS OF THE DOCTORAL THESIS

Contributions to this thesis were previously published in the following peer-reviewed conferences and indexed journals listed below:

### Journals

1. González-González, C.S.; Gómez del Río, N.; Toledo-Delgado, P.A.; García-Peñalvo, F. (2021). Active game-based solutions for the treatment of childhood obesity. *Sensors* 2021, 21(4), 1266 (**JCR, Q1**).  
DOI: <https://doi.org/10.3390/s21041266>.  
Available at: <https://www.mdpi.com/1424-8220/21/4/1266>
2. Gómez del Río, N.; González-González, C.S.; Toledo-Delgado, P.A.; Muñoz-Cruz, V.; García-Peñalvo, F. (2020). Health Promotion for Childhood Obesity: An Approach Based on Self-Tracking of Data. *Sensors* 2020, 20, 3778. (**JCR, Q1**)  
DOI: <https://doi.org/10.3390/s20133778>.  
Available at: <https://www.mdpi.com/1424-8220/20/13/3778>

3. Gómez del Río, N., González-González, C.S., Martín-González, R., Navarro-Adelantado, V., Toledo-Delgado, P.A., & García-Peñalvo, F. (2019). Effects of a gamified educational program in the nutrition of children with obesity. *Journal of medical systems*, 43(7), 1-12. **(JCR, Q1)**  
DOI: 10.1007/s10916-019-1293-6  
Available at: <https://link.springer.com/article/10.1007/s10916-019-1293-6>
4. González-González, C.S.; Gómez del Río, N.; Navarro-Adelantado, V. (2018). Exploring the benefits of using gamification and videogames for physical exercise: a review of state of art. *The International Journal of Interactive Multimedia and Artificial Intelligence*, 5(2), 46-52. **(ESCI)**.  
DOI: 10.9781/ijimai.2018.03.005  
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5. González-González, C.S.; Gómez del Río, N.; Navarro-Adelantado, V.; Cairós González, M.E.; Quirce González, C.; Toledo-Delgado, P.A.; Marrero-Gordillo, N. (2016). Learning healthy lifestyles through active videogames, motor games and the gamification of educational activities. *Computers in Human Behavior*, 55, 529-551. **(JCR, Q1)**. DOI: [10.1016/j.chb.2015.08.052](https://doi.org/10.1016/j.chb.2015.08.052)  
Available at: [https://www.sciencedirect.com/science/article/pii/S0747563215301266?casa\\_token=l3H9s19Wx5EAAAAA:2\\_YAhYfbB7Nyg\\_8199wt2ttfVecBfgTu57w6DUdviRYMrcnsXwAA5Wrv82MIJcpK6ukRd5EynQ](https://www.sciencedirect.com/science/article/pii/S0747563215301266?casa_token=l3H9s19Wx5EAAAAA:2_YAhYfbB7Nyg_8199wt2ttfVecBfgTu57w6DUdviRYMrcnsXwAA5Wrv82MIJcpK6ukRd5EynQ)
6. González-González, C. S., Gómez del Rio, N., Navarro Adelantado, V. (2018). Programa De Intervenção Educativa Para O Tratamento Da Obesidade Infantil Baseado Em Vídeojogos Ativos. *Revista Da FAEBA - Educação E Contemporaneidade*, 25(47), 155-172. DOI: 10.21879/faeeba2358-0194.2016.v25.n47.p155-172

### International Conferences

7. G Gómez del Río, N.; González-González, C.S.; Martín-González, R.; Navarro-Adelantado, V.; Toledo-Delgado, P.A.; Marrero-Gordillo, N.; Gacia-Peñalvo, F. (2019). Treatment of children obesity and diabetes through gamification: a case of study. In *Proceedings of the Seventh International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 452-458). Indexada en Web of Science.  
Doi: <https://doi.org/10.1145/3362789.3362935>  
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9. Gómez del Río, N.; Martín González, R.; González-González, C. S.; Navarro Adelantado, V.; Toledo-Delgado, P.A.; Navarro Campillo, L.; Quirce González, C. (2017). PROVITAO: a research program based on active games for help the ambulatory treatment of childhood obesity. In *1st Workshop on Gamification and Games for Learning (GamiLearn'17)*. Universidad de La Laguna. (GamiLearn'17). 2017. ISBN: 978-84-697-3570-1.

Available at: <http://riull.ull.es/xmlui/handle/915/4786>.

### Chapters:

10. Gómez del Río, N., González González, C. S (2021) Videojuegos activos en la escuela para el fomento de hábitos de vida saludables. Editorial Octaedro. [En prensa]
11. González-González, C.S.; Gómez del Río, N.; Martín González, R.; Barrios Fleitas, Y.C. (2015). Gamificao em aplicativos móveis para educar em hábitos de vida saudáveis. In *Jogos digitais e aprendizagem* (pp. 245-268). Alves, L. R. G.; Coutinho, I. (Org.) 1. ed. Campinas: M.R. Cornacchia Livraria e Editora Ltda. Papyrus Editora, 2016. v. 1. 320p. ISBN: 978-85-449-0148-9.

### Other contributions:

12. Gómez del Río, N. (2017). Intervención educativa para el tratamiento de la obesidad infantil. Valoración cuestionario KIDMED. En *Workshop 2017 de Investigación en la Educación en Canarias*.

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