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Master's Thesis

Jonathan Pucher

EMBEDDING SUSTAINABILITY INTO THE NEW COMPUTER SCIENCE CURRICULUM FOR ENGLISH SCHOOLS

2016

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ABSTRACT

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The primary goals of this study are to: embed sustainable concepts of energy consumption into certain part of existing Computer Science curriculum for English schools; investigate how to motivate 7-to-11 years old kids to learn these concepts; promote responsive ICT (Information and Communications Technology) use by these kids in their daily life; raise their awareness of today's ecological challenges. Sustainability-related ICT lessons developed aim to provoke computational thinking and creativity to foster understanding of environmental impact of ICT and positive environmental impact of small changes in user energy consumption behaviour. The importance of including sustainability into the Computer Science curriculum is due to the fact that ICT is both a solution and one of the causes of current world ecological problems. This research follows Agile software development methodology. In order to achieve the aforementioned goals, sustainability requirements, curriculum requirements and technical requirements are firstly analysed. Secondly, the web-based user interface is designed. In parallel, a set of three online lessons (video, slideshow and game) is created for the website GreenICTKids.com taking into account several green design patterns. Finally, the evaluation phase involves the collection of adults' and kids' feedback on the following: user interface; contents; user interaction; impacts on the kids' sustainability awareness and on the kids' behaviour with technologies. In conclusion, a list of research outcomes is as follows: 92% of the adults learnt more about energy consumption; 80% of the kids are motivated to learn about energy consumption and found the website easy to use; 100% of the kids understood the contents and liked website's visual aspect; 100% of the kids will try to apply in their daily life what they learnt through the online lessons.

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LIST OF SYMBOLS AND ABBREVIATIONS

ICT: Information and Communications Technology

BCS: British Computing Society

CAS: Computing at School

GHG: Greenhouse Gases

JS: JavaScript

FCPX: Final Cut Pro X

DEFRA: Department for Environment, Food and Rural Affairs

UK: United Kingdom

OECD: Organisation for Economic Co-operation and Development

BAU: Business as Usual

PNG: Portable Network Graphics

JPG: Joint Photographic Experts Group

CSS3: Cascading Style Sheets 3

HTML5: HyperText Markup Language

HTTP: HyperText Transfer Protocol

IP: Internet Protocol

kWh: Kilo Watt Hour

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1. INTRODUCTION

The introduction of this research explains firstly the background of the situation, secondly states the general problems, then the research objectives and goals are detailed, followed by the delimitations of the thesis. Finally, the author explains how this study contributes to the current research and the structure of the thesis is revealed in the last subpart.

1.1. Background

The year 2011 saw the resurgence of Computing in English schools when the British Computing Society (BCS) helped promote the reintroduction of the Computer Science curriculum in the English schools [1]. ICT in schools was considered as a “boring” topic, since it mainly focused on the use of Microsoft Office software. This phenomenon is partly explained by the lack of trained ICT teachers in the United Kingdom [2] [3]. ICT was not considered as a “rigorous academic subject” and children typically could self-teach ICT, thus, ICT was not included in the English high school diploma [2]. Since September 2012, English schools are encouraged to include the new Computer Science curriculum defined by the Department for Education (UK), into their programmes/courses [2]. According to the National Computing curriculum in England, there are four different key stages where students will learn about Computer Science [4]. Computing at School (CAS) explains that five different disciplines need to be taught through the key stages: “algorithms”, “programs”, “data”, “computers” and “communication and the Internet” [3]. Resulting from BCS promotion and support for excellence, Computer Science is now considered as an equal topic to Mathematics or Physics. Additionally, CAS currently offers a unique accreditation for teachers of Computer Science, which will give them professional recognition accredited by BCS [5]. The aim of the new Computer Science curriculum is to help children have a better understanding of the computing world and to appropriately acquire computing related knowledge and skills for their future career [4]. BCS has stated that by 2015, half a million more ICT professionals will be needed in the United Kingdom [2]. Additionally, the new Computer Science curriculum aims to cultivate applied computational thinking and creativity to help students understand and change the world [4]. However, in its current state, this curriculum does not include the concept of sustainable development (which means “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [6]).

1.2. Problem Statement

The importance of embedding sustainability into the Computer Science curriculum is due to the fact that ICT is "both a solution and the cause of the ecological problem" [7]. Thus, it is imperative that the link between sustainable development and Computer Science hardware and software methods is made explicit [7]. "Change the world" [4] can only happen if sustainability is effectively taught at school and user energy consumption behaviour is changed. UNESCO agency shows that education could help raise awareness of sustainability [8]. Including sustainability within the Computer Science curriculum could also help prepare children for the "green jobs" that are currently available in England [7]. The United Kingdom is playing a great role in promoting sustainability issues [9]. Moreover, 54% of the first year students following computing courses in one university are not even aware of the fact that ICT impacts the environment [8].

Question		
	Yes (%)	No (%)
Are you aware of any requirements to demonstrate an awareness of social and ethical issues within your programme of study?	32	68
Were you aware that as a professional practitioner you will be expected to take account of the social and environmental impact of your work?	58	42
Do you consider it is appropriate to include content about sustainable development within the modules you attend on your specialist subject?	45	55
Given your subject of study, do you believe that your subject has any potential impact to any area of sustainable development – environmental, social or other?	46	54

Table 1: students' views on sustainable development

Figure 1: Results of N. Gordon's study

Besides, there is also a decrease in the enrolment of students in sustainability courses [10]. Teaching sustainability from early primary days could better prepare students for universities' academic programmes on sustainability, therefore give professors the opportunity to go further and deeper in their teaching [7]. Besides, sustainability should be included in every Computer Science curriculum at all levels of education to better prepare students for industries and emergent markets [7].

1.3. Research Objectives and Goals

The research objectives of this study are:

- Identifying which sustainable(s) concept(s) to embed in the Computer Science curriculum
- Determining at which key stage (age of kids) the sustainable(s) concept(s) can be embedded
- Investigating how to motivate kids to learn these concepts (which approach and which material(s))

The primary goals of this study are:

- Promoting responsive ICT use by kids in their daily life
- Raising kids' awareness of today's ecological challenges

1.4. Delimitations

There is a need to identify at which key stage(s) sustainability can be embedded into the Computer Science curriculum, since it applies to kids from 5 years old to 16. As this research is conducted in a period of five months, the author implemented the identified sustainable concepts in only one key stage of the Computer Science curriculum (key stage 2, from 7 to 11 years old).

Secondly, there is a need to identify which sustainable concepts can be embedded, since many different topics (water usage, energy consumption, equipment recycling…) could be embedded. Here, the research identifies that energy consumption is the most relevant to the Computer Science curriculum as discussed in the literature review.

For legal reasons, the author could not be directly in contact with schools to evaluate the developed tool and get feedbacks from teachers and kids. The evaluation has been narrowed to adults' feedback as well as kids' feedback, thanks to their parents. As a result, no workshop with teachers and/or kids could be organised.

Sustainability is a topic that should be included in every courses and disciplines and not only in ICT courses, but this is out of the scope of this research and therefore is not covered. This research only focuses on embedding sustainability into the Computer Science curriculum.

1.5. Contributions

This research contributes mainly to three fields of research:

- Embedding sustainability at school
- Motivating kids to learn about sustainability
- Raising people awareness of sustainability

Thanks to the creation of an external material (a website containing a set of three online lessons about sustainability), schools can reuse the contents in their Computer Science curriculum without needing to transform their initial courses and materials.

This research shows ways to introduce kids to sustainability and more particularly to the concept of energy consumption.

1.6. Structure of the Thesis

The first chapter is the introduction of the Master Thesis. The literature review is studied in the second chapter through four different parts: Computer Science Curriculum, Green Curriculum, Pedagogy and Household Energy Consumption in the UK. The third chapter explains the methodology of this research: Requirements Analysis, Design of the Online Lessons, Implementation of the Solution and Design of the Tools for the Evaluation. The fourth chapter shows the results with both adults and kids and discusses these results. Finally, the fifth chapter concludes this research and gives an insight of the future work.

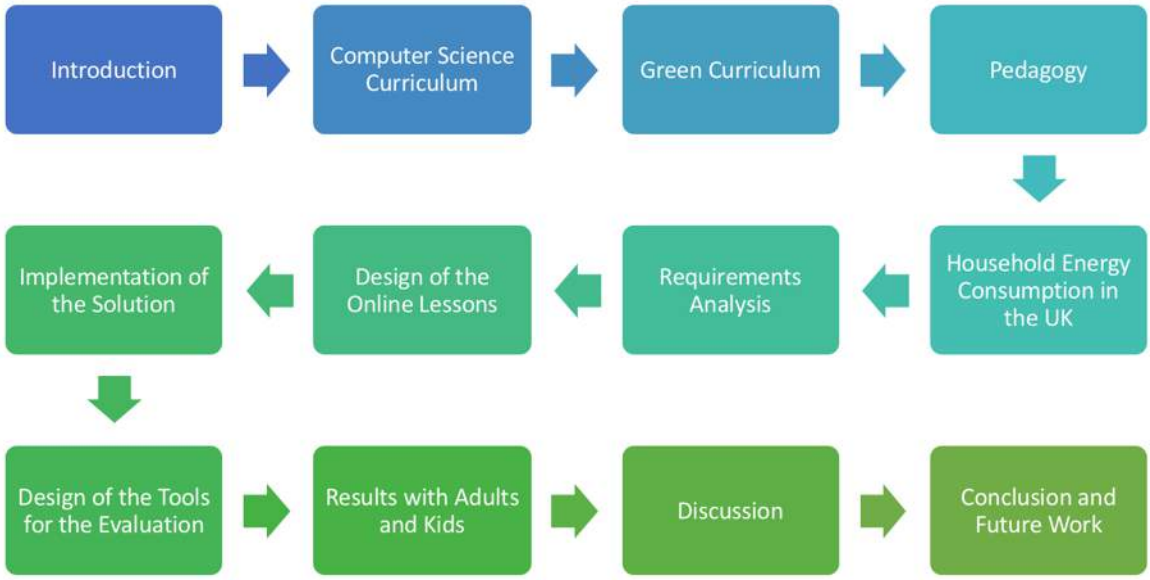

Figure 2: Structure of the Master Thesis.

2. LITERATURE REVIEW

The literature review of this research consists in four different parts: Computer Science Curriculum, Green Curriculum, Pedagogy and Household Energy Consumption in the UK.

2.1. Computer Science Curriculum

As previously discussed, it is necessary to reintroduce Computer Science into the English Curriculum [2]. CAS considers that Computer Science is a discipline like Mathematics or History, and therefore should be taught at school [3]. With the creation of a new Computer Science curriculum, the English Department for Education intends to give the students the resources to understand the world and to be able to contribute to its change [4]. Indeed, it is important to provide the right type of education to kids so that they will not be "passive consumers of an opaque and mysterious technology" [3]. The English Department for Education has defined the Computer Science curriculum for each key stage (1 to 4) which corresponds to the age of 5 to 16 years old [4]. CAS states that these four key stages should take into account five different disciplines: "algorithms", "programs", "data", "computers" and "communication and the Internet" [3]. Therefore, for each key stage, specific notions for each of these disciplines will be embedded into the computing curriculum [3]. CAS emphasises that "programming encourages creativity, logical thought, precision and problem-solving". CAS also mentions that programming "helps foster the personal, learning and thinking skills required in the modern school curriculum" [3].

It is important to note that the suggested contents in the Computer Science curriculum can be implemented in a different way from one school to another one. The English Department for Education details what the students should be taught at each key stages.

During the first key stage, from 5 to 7 years old, according to the English Department for Education, students should discover what algorithms are, be able to understand them, be able to create simple programs as well as understanding the behaviour of these programs, be able to organise and store data on their devices. Students should also be taught how to use technology responsively, how to keep their personal information private and they should be able to look for help by themselves (for example over the Internet). [4] CAS suggests that the algorithms taught to students should describe everyday life activities and must be written

in an understandable way for kids. CAS suggests to teach students that computers do not work like humans and therefore need more accurate information in order to be able to understand a problem, CAS suggests to explain kids that programs are a simple sequence of instructions given to the computer. The students should also become familiar with web browsers and with websites in general. [3]

During the second key stage, from 7 to 11 years old, according to the English Department for Education, the students will acquire deeper knowledge in programming and algorithms and they will learn how to select the right software to create what they need to. They will also be taught the computer networks, how Internet is working and they will be introduced to computer communications. The students will also learn how to search over the Internet more efficiently. [4] CAS suggests the use of visual programming language such as Scratch for kids to become more familiar with programs. CAS also explains that students should be taught the role of the different computer components and the role of operating systems. CAS suggests that kids should learn the different ways to communicate between devices (WiFi, network cables for example). [3]

During the third key stage, from 11 to 14 years old, according to the English Department for Education, the students will learn more about programming and algorithms in general and they will need to use at least two programming languages. They will be introduced to Boolean logic and how to use it in programming domain. They will also be able to understand computer systems in general and understand the way digital data are represented and stored in computers. They will be introduced to online security and privacy. [4] CAS suggests to teach students that there is no single solution to solve a problem and that several algorithms can do the same actions: programs can be different but have the same consequences. The students should also have a better understanding of telecommunications: they should be able to understand what happens when they request a webpage and how data is transmitted on the Internet. [3]

During the fourth key stage, from 14 to 16 years old, according to the English Department for Education, all students should have enough knowledge in computing in order to be able to study Computer Science at a higher level. Therefore, they should be taught advanced knowledge in ICT in general and they should be able to solve problems by themselves and understand how technology can have an impact on security. [4] CAS suggests to teach that

different algorithms and programs can perform differently for the same action. Students should be taught low-level programming languages (C for example), data manipulation and compression (such as image compression) and they should become familiar with basic networking protocols (Internet Protocol (IP) for example) as well as encryption and security basis. [3]

2.2. Green Curriculum

The second part of the literature review helps to identify sustainable concepts to embed in a general curriculum for schools. This research tries to embed the sustainable concepts discovered through the literature into the new Computer Science curriculum for the English schools.

The English government has identified four different concepts that are among the top priority areas: “sustainable consumption and production”, “climate change and energy”, “natural resources protection and environmental enhancement” and “sustainable communities” [11]. In order to embed sustainability into the Computer Science curriculum, the easy part is to identify the sustainable concepts to be embedded [12]. Many examples of relevant concepts could be embedded in the green curriculum: power usage [7], climate change and energy [8], eco-efficiency and ecological footprint [13].

It seems that one of the most important aspects of sustainability to be embedded in a Computer Science curriculum is energy consumption. Indeed, computers definitely have strong links with energy consumption [8]. ICT consumes many resources: electricity, equipment and cooling are only few of them [7]. Additionally, it is important to progress towards a more environmental sustainable ICT by minimizing the energy consumed in the ICT equipment lifecycle [14]. It is necessary for a sustainable ICT strategy to focus on reducing energy cost and promoting efficient and responsible use of ICT [9]. Besides, the International Energy Agency (IEA) states that energy growth worldwide will be 33% by 2040 [15]. Even though OECD (Organisation for Economic Co-operation and Development) countries are trying to make energy use more efficient, some developing countries still assume a business as usual (BAU) trend of growth which is unsustainable and consequently, effect a decreasing trend of available natural resources (for example fossil, fuels, et cetera.) [15]. It is therefore, important to understand the critical situation of energy and be able to

apply best energy saving practice whenever possible [15]. It is necessary for people to understand energy matters, basics of energy and what it represents, link between energy and the world, followed by adhering to good decision making guidelines [16].

The Department of the Environment, Water, Heritage and the Arts of the Australian government explains in its sustainability curriculum framework that it is relevant to gradually teach children from the age of 3 to the age of 12, the different notions: energy use at home/school, energy systems, climate change, different sources of energy, ways of saving energy, consequences of energy choices on the environment and measuring and metering energy consumption [17].

Finally, [18] shows that students in one secondary school could apply knowledge on green buildings in their own homes after having undergone a course on energy saving related topics.

2.3. Pedagogy

The third part of the literature review focuses on how to motivate the children to learn new knowledge and which pedagogical approaches are the most effective.

A challenge is to motivate students and professors to learn about sustainability and apply sustainability-related practices in their daily life [12] [19]. It is imperative that teachers are aware of sustainability [13] and students could see how sustainability matters to teachers who are considered as their role models [19]. Another challenge that arises is a direct embedment of sustainability concepts into existing materials which could ensure that students will stay motivated and yet fail to apply what they have learned, or creating new materials which help raise awareness of sustainability but may discourage students to learn about it [8]. [13] defines four important questions regarding education for sustainability: “does it matter to me?”, “should I do something about it?”, “how can I do something about it?” and “what will I do?”.

In order to motivate students to learn about it, sustainability should be linked with individual professional development [7], where concrete examples of daily life should be given [13], the contents should be contextualised [7] and concrete facts as well as pictures representing bad effects of non-responsible use of ICT should be shown to the students [8].

In order to capture the attention of students, lessons should be student-centered and should generally consist of experiential activities where active learning is the key to motivating the students [13]. Students will better understand sustainability through experimental as well as experiential learning activities and educational games because these approaches will help capture their attention [20]. Computer games can make education more fun, better engage students and consequently, get them more interested [16]. A report from the Royal Society [21] and the curriculum created by CAS [3] also suggest to teach programming to kids with visual tools with colours and animations (Kodu or Scratch for example).

Finally, the use of a video to provide environmental education has been shown very effective for secondary schools. It helped to describe and explain things that could not be explained through traditional learning materials (textbooks). Moreover, traditional materials sometimes result in an inability to apply the acquired knowledge in real life examples. Therefore, a video could help represent real world situations and problems. It could be attractive to students, capture their attention, create anticipation and increase retention. Teaching actively with materials such as videos makes students become real actors who are not mere spectators of knowledge and are more confident to change which thus gives them a feeling of empowerment. [22]

2.4. Household Energy Consumption in the UK

The last part of the literature review focuses on the analysis of the energy consumed for a UK household.

Different sources show different numbers for the typical average energy consumption per English household. Statista shows that the average English household consumed 3567 kWh in 2011, up to 4400 kWh for some houses [23].

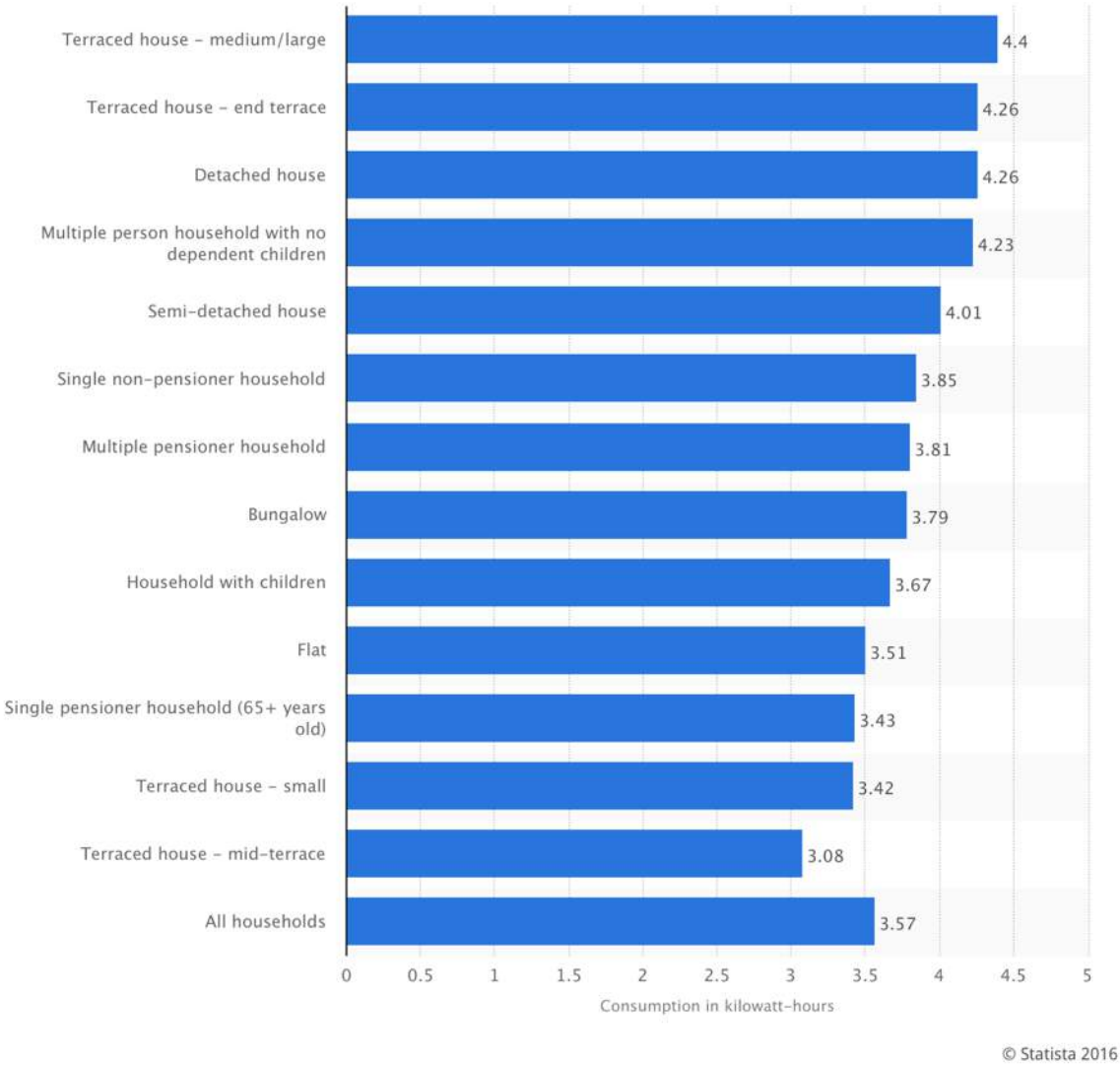

Figure 3: Energy consumption per UK household by Statista.

On the other hand, British Gas shows an average of 1150 kWh per household for 3 months (from December 2010 to February 2011), which represents 4600 kWh for one year. British Gas gives numbers that differ from one area to another one: the average energy consumption per household is the smallest in London, while in Truro it is the biggest [24].

Figure 4: Energy consumption per UK household by British Gas.

Worldbank also shows a different figure for the United Kingdom: around 5400 kWh per household in the year 2013.

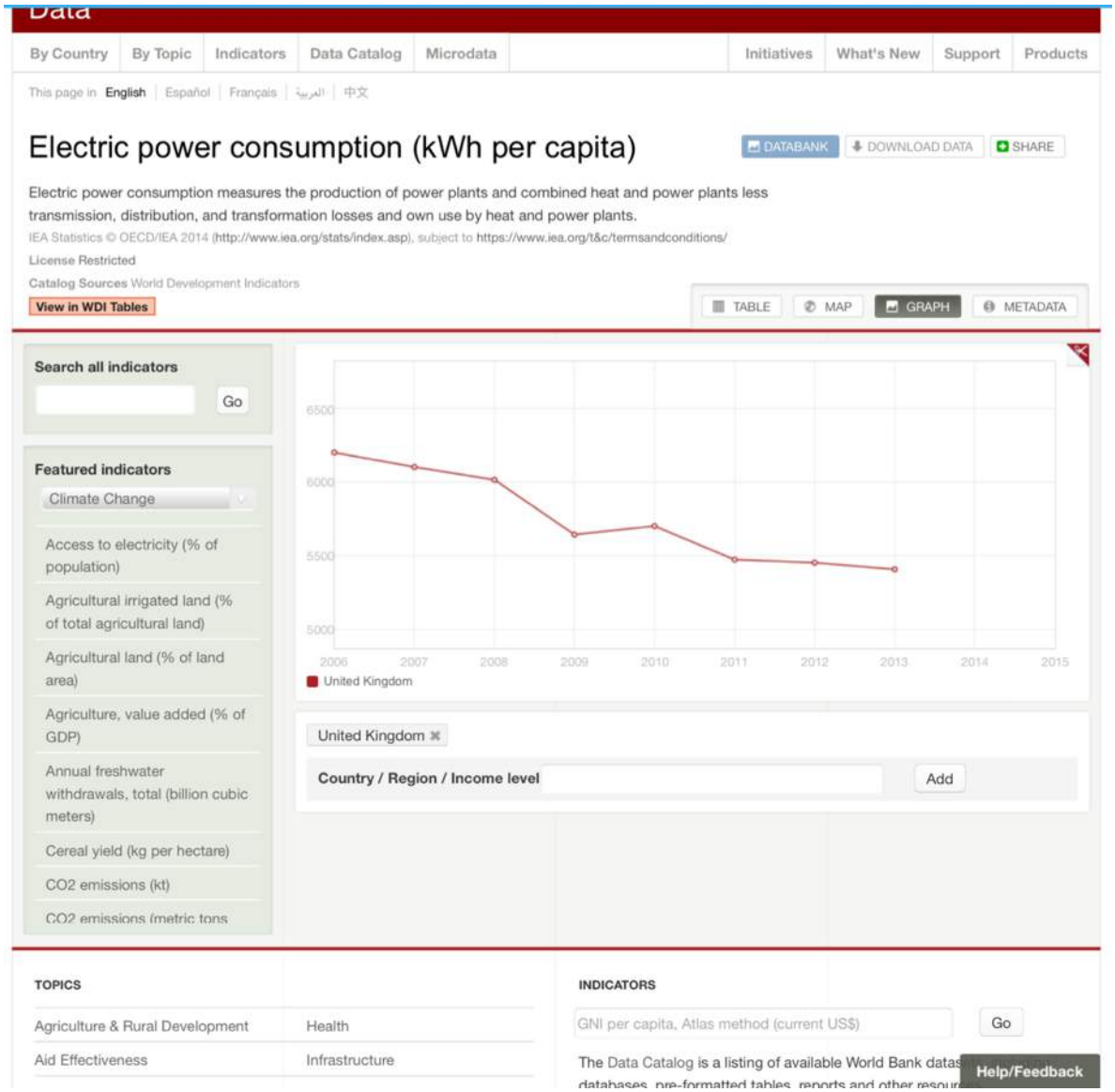

Figure 5: Energy consumption per UK household by Worldbank.

It is important to note that the average energy consumption per English household is decreasing. [25]

Finally, the Department for Environment, Food and Rural Affairs (DEFRA) provides an Excel file to analyse the energy consumption per household per year. Moreover, this document reveals the energy consumed by household sorted by usage (electronic devices or heating systems for example). According to DEFRA, an English household consumes 4100 kWh per year. [26]

Table 3.07: Average domestic gas and electricity consumption, UK, 2008 to 2014

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	Electricity				
		Unadjusted		Temperature corrected[1]	
Year	Number of households (UK)	Final consumption (GWh)	Average consumption (kWh)	Final consumption (GWh)	Average consumption (kWh)
2008	25 885	119 800	4 628	120 440	4 653
2009	26 086	118 541	4 544	119 417	4 578
2010	26 301	118 833	4 518	116 137	4 416
2011	26 491	111 591	4 212	114 358	4 317
2012	26 729	114 667	4 290	114 637	4 289
2013	26 956	113 445	4 209	113 044	4 194
2014	27 210	108 881	4 001	111 962	4 115

Figure 6: Energy consumption per UK household by DEFRA

These data are important for this research because they are fed into the contents for Lesson 3 of the website GreenICTKids.com.

3. METHODOLOGY

The research methodology of this study is based on Agile software development methodology [64]. Indeed, first the requirements were identified and analysed, the design phase started and in parallel the website was being developed regarding the design and the requirements. The different requirements were eventually modified and some new were added during the development process. New parts of the website were presented in average every two weeks. After getting feedback from testers, the product was also improved and the contents modified.

3.1. Requirements Analysis

This study identified three different domains for the requirements: the sustainability, curriculum and technical requirements.

3.1.1. Sustainability Requirements

The first requirements that were analysed are the sustainability requirements. Indeed, this research is about embedding sustainability into the Computer Science curriculum, which means that the priority should be given on the “sustainability” part.

Related work (part 2.2 of the document) has shown that the most important sustainable concept to embed is about energy [7] [8] [11] [17]. ICT in general is highly coupled with energy consumption: without electricity, electrically driven ICT could neither work nor exist. Besides, the ecological problem derives partly from energy consumption and ICT [7]. Therefore, it is also relevant to include the concept of climate change in the online lessons that the author has created [8].

Related work (part 2.2 of the document) shows that it is necessary to teach kids the fundamentals about energy consumption [16] [17]. It is also relevant to briefly introduce the concept of global warming and greenhouse gases (GHG) emissions [17], in order to prepare them for understanding of today’s problems and to appropriately address ecological challenges. Besides, when it comes to energy consumption, it is really necessary to educate

kids about good practices they should adopt when using different electronic devices in their everyday life [4].

Of course, many other sustainable concepts could be embedded into the Computer Science curriculum such as water usage, food wastage or equipment recycling [17]. These have not been included in the GreenICTKids online materials because they are less relevant to the curriculum requirements that will be discussed in the next part.

3.1.2. Curriculum Requirements

The second requirements that were analysed are the curriculum requirements. These curriculum requirements match with the sustainability requirements.

It is firstly necessary to specify at which key stage the sustainability requirements previously identified could be embedded in. Since these sustainability requirements are mainly about energy consumption, good practices with electronic devices and climate change, it appears that embedding these concepts at the first key stage (in other words from 5 to 7 years old) is rather premature.

However, during the second key stage (from 7 to 11 years old), the students need to learn about computer components and communications through the Internet [3] [4]. They will already have acquired an advanced knowledge of using the Internet and technologies in general as well as the basis to understand the way programs work on a computer and how an operating system operates [3] [4]. It appears then that it is necessary to include the sustainability requirements at this key stage, in order for the kids to become familiar as early as possible with energy consumption while learning about electronic devices in general.

3.1.3. Technical Requirements

The third requirements that were identified are the technical requirements.

Regarding sustainability requirements, the curriculum requirements and pedagogical aspects that are covered in the literature review, the author has chosen to create a website with a set of different lessons to embed the identified sustainable concepts. Therefore, it complements the existing Computer Science curriculum and could be appropriately integrated by relevant school teachers. It is an auxiliary material that has been created and schools can use it in

addition to the materials they already have. The website comprises a set of three lessons: a video, a slideshow and a game.

A set of functional requirements has been identified:

- The video should define what is energy and its importance, give examples of daily life and show the good practices to the viewer
- The video should explain the viewer how to have a sustainable behaviour when it comes to using electronic devices
- The slideshow should give a definition of common computer components and their energy consumption
- The slideshow should describe electronic devices and their energy consumption
- The slideshow should describe different usages of computer and their energy consumption
- The game should give the opportunity to the user to decide which electronic devices he or she wishes to use and for how long during one day
- The game should inform the user about the total energy he or she is consuming
- The game should provide instructions to the user to explain how to use the game
- The quizzes should test the users' knowledge regarding the video and the slideshow

A set of non-functional requirements has been identified:

- The webpages should load fast
- The texts should be readable and understandable
- The colours should be visible and should not be too bright
- The number of animations should be reasonable
- The website and its contents should always be available
- The website should try to be responsive on different devices
- The website should be able to handle a high number of visitors at the same time
- The different categories should be easily accessible
- The dropdown menu should be clear and understandable
- The dropdown menu should adapt to smaller devices

These non-functional requirements are highly coupled with web usability requirements [27] [28].

3.2. Design of the Online Lessons

This part details the design of the website, from its contents to the technologies used.

3.2.1. Definition of the Contents

In this part, the research explains the contents of GreenICTKids.com. The sources of contents are given in each part of the implementation.

This website firstly aims to give an introduction to energy and to explain why energy is important in general, followed by providing more detailed energy-related information about electronic devices, computer components and common usages of computer. Finally, users are given the opportunity to play with what they have learned in order to become more familiar with the concept of energy and are also given an insight into a more sustainable energy consumption at home.

The website GreenICTKids aims to help kids gradually progress through the contents about sustainability via a series of lessons. These concepts have been identified and extracted from existing literature by the author (part 2.2. of the document). Subsequently, these concepts are appropriately embedded into the current Computer Science curriculum.

This research has identified that for pedagogical reasons (part 2.3. of the document), creating a video and a game are alternative ways to make learning fun with the aim of inducing positive impact on their behaviour [3] [13] [16] [20] [21] [22]. The slideshow that the author has created helps convey fundamental knowledge that would be too tedious to describe in the video. Besides, some kids may have been aware of energy consumption relating to electronic devices (or usage) and therefore, kids may appreciate the ability to select a particular device (or usage) they are interested in.

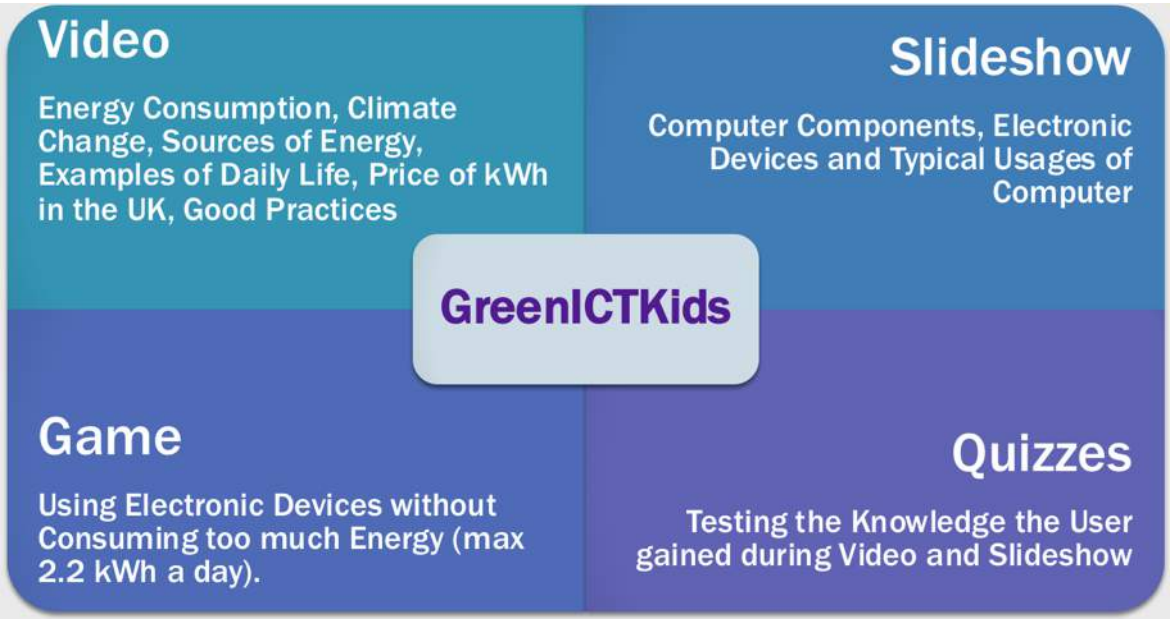

Figure 7: Contents of GreenICTKids.com.

The different contents for each lesson are as following:

Lesson 1 (video):

- Content: climate change.
  - Goal: introducing kids slowly to what are the today's problems and challenges.
- Content: power consumption.
  - Goal: preparing kids for the two other lessons and giving them knowledge they can apply in their daily life.
- Content: sources of energy (primary, secondary).
  - Goal: making kids more familiar with different sources of energy.
- Content: examples of everyday life.
  - Goal: showing kids the equipment that electricity permits to use.
- Content: price of kWh in UK.
  - Reason: mainly English kids will consult the website and it is for English schools which implement the new Computer Science curriculum.
- Content: good and sustainable principles.
  - Goal: it is important to show kids the good they need to adopt as soon as possible when it comes to electronic devices usage at home, at schools or anywhere else

practices (practices such as turning off the devices or at least putting into sleep mode).

Lesson 2 (slideshow):

- Content: definition of computer components.
    - Goal: reminding kids what computer components are briefly and why they are in computers.
- Content: typical usages of computer.
    - Goal: making kids aware of the fact that using a computer does not consume always the same amount of energy: sending an email consumes less energy than playing a 3D game for example.
- Content: different devices that kids can use.
    - Goal: showing kids that a smartphone consumes less energy than a desktop computer for example, making them familiar with the different devices and explaining the energy consumption of all of them.

Lesson 3 (game):

- Content: the limit of energy consumption (sustainable threshold) to not cross in the game.
    - Definition: this has been defined after reviewing the documents from the government and other sources (part 2.4 of the document). This corresponds to the maximum amount of energy that the game allows to consume, in order to maintain a sustainable use and fulfil the sustainable goals according to legal engagements of England.

Because kids probably use these electronic devices quite often and do these activities in their everyday life (such as watching videos or playing games) it is necessary to teach them the fundamentals of energy consumption in order to have an impact on their behaviour.

3.2.2. Web Development Technologies

The languages HTML5 and CSS3 have been used to develop the website. These are the latest and most efficient web development technologies [29] [30] [31] [32]. The framework

Boostrap has been used [33]. In order to create the quizzes and animations in the webpages, the language JavaScript has been used and particularly the jQuery library [34]. Lightbox, a library of JavaScript, has been used to create the slideshow [35]. The libraries jQuery, jQuery UI and jQuery Alert have been used to create the game [36] [37].

3.2.3. Video Producing and Image Editing Tools

In order to create the video for Lesson 1, the software Final Cut Pro X (FCPX) has been used, running on Mac OS X Yosemite [38]. To create all the images for the website, such as the logo, the thumbnails of Lesson 2 and the different slides that constitute Lesson 2, the software Affinity Photo has been used, also running on Mac OS X Yosemite [39].

3.2.4. Green Design Patterns

Greenspector emphasises that it is important to follow green design patterns when developing for the web, in order to minimize the energy consumed by the website [40] [41]. The green design patterns can be applied at different levels: the development of the website and the web hosting platform. Respecting criteria of web usability also helps optimise the website.

- Website Development:

All the pictures have been compressed, in PNG or JPG format, depending on the type of picture. If the picture contains mainly text, PNG format is more appropriate to compress. On the contrary, if the picture contains more graphic contents with many colours, JPG format is better. The image quality has been set to 95% for the JPG pictures with Affinity Photo. GTmetrix.com provided an optimized version of each picture (lossless compression) [42]. Finally, using TinyPNG.com, all optimized versions have been recompressed again to get the smallest possible size without compromising too much image quality [43]. The fully compressed pictures therefore help speed the loading of the pages and reduce the energy consumed while accessing the pages.

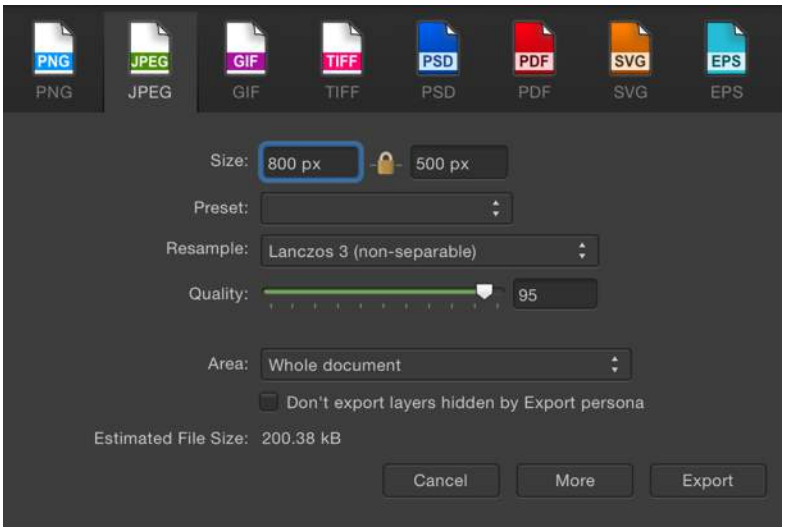

Figure 8: First image compression with Affinity Photo

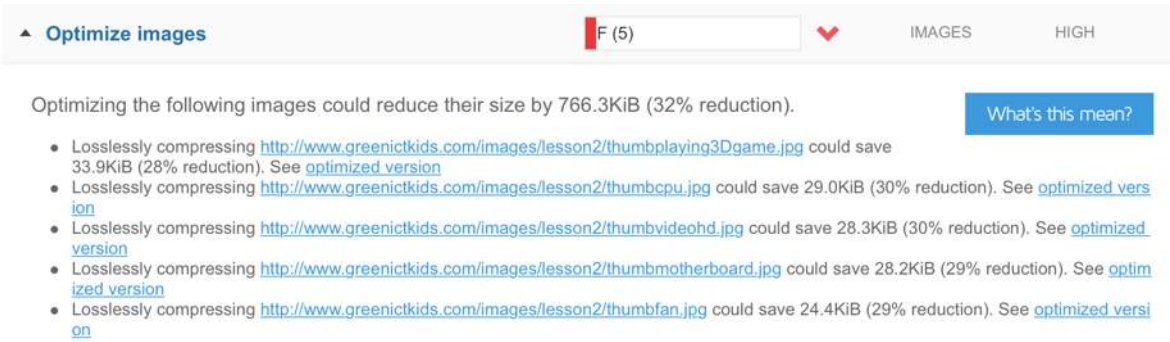

Figure 9: Second image compression with GTmetrix.com

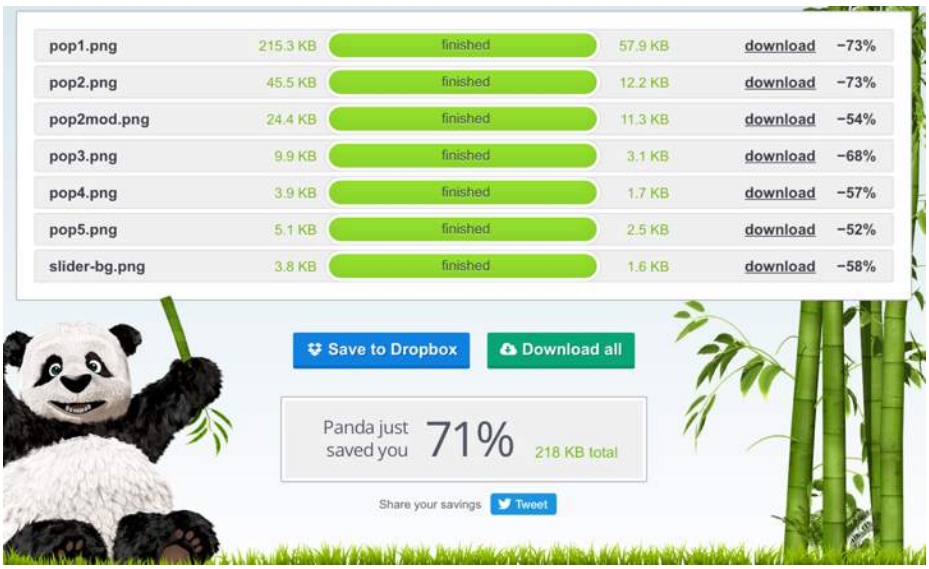

Figure 10: Final image compression with TinyPNG.com

The JavaScript and CSS files are separated from the HTML files. This decreases the loading time and makes the code cleaner. Besides, the JavaScript files are called at the end of the HTML pages so that they will be loaded only once the HTML content is loaded. The CSS files are in the head of the HTML document, otherwise the HTML content would sometimes load without the correct style or the correct style would be applied too late.

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="utf-8">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <meta name="description" content="">
    <meta name="author" content="">
    <title>Lesson N°2</title>
    <link href="css/compress.css" rel="stylesheet">
    <!--[if lt IE 9]>
      <script src="js/html5shiv.js"></script>
      <script src="js/respond.min.js"></script>
    <![endif]-->
  </head>
```

Figure 11: The CSS file(s) are always in the <head> of the HTML document.

All frequently used JavaScript files have been gathered and minimized into one JavaScript file [44]. The same goes for the CSS files [45]. This helps reduce their size, decrease loading time and reduce the number of HTTP requests from client to server. Indeed, having only one or two files to download requires fewer requests than having ten files to download. Thus, this optimizes the loading time and response time which reduces energy consumption.

```
    <script type="text/javascript" src="js/hide.js"></script>
    <script type="text/javascript" src="js/jquery.js"></script>
    <script type="text/javascript" src="js/bootstrap.min.js"></script>
    <script type="text/javascript" src="js/lightbox.min.js"></script>
    <script type="text/javascript" src="js/wow.min.js"></script>
    <script type="text/javascript" src="js/main.js"></script>
</body>
</html>
```

Figure 12: All JS files not compressed.

```
    <script type="text/javascript" src="js/hide.js"></script>
    <script type="text/javascript" src="js/compress.js"></script>
</body>
</html>
```

Figure 13: Main JS files are compressed into one.

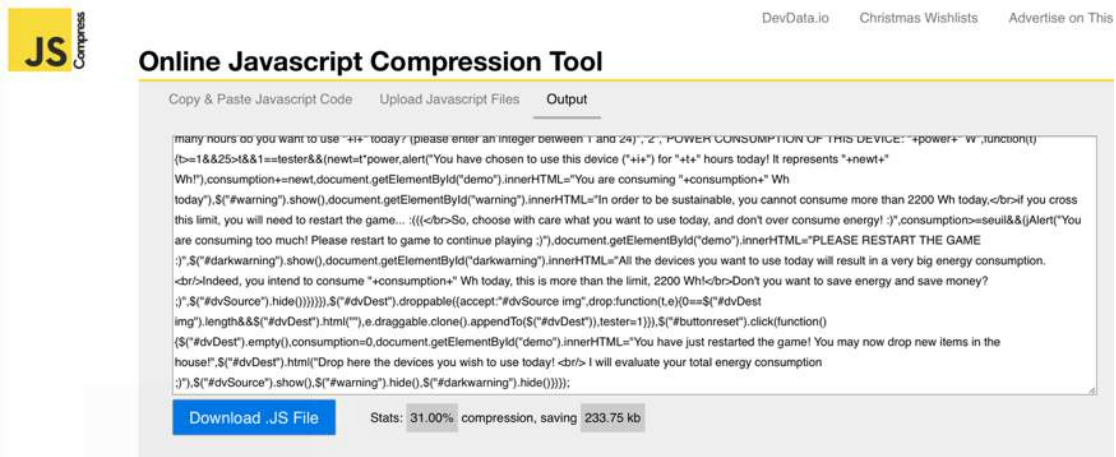

Figure 14: JS Minifier tool.

- Hosting Solution:

The author decided to use a caching policy of one year on the web browser: after the first access, the web browser will not need to again download the pictures, CSS and JavaScript files for one year. The HTML is cached for a shorter period of time. This reduces the loading time and the energy consumed in general.

Figure 15: .htaccess of GreenICTKids.com.

The website GreenICTKids.com is hosted on a 100% powered by renewable energy platform: iPage.com [46].

Figure 16: iPage.com, a 100% green web hosting platform.

The Content Delivery Network (CDN) Akamai is used to replicate a particular set of data all around the world and minimizing the requests to original servers in Boston [47]. This reduces the loading time and the energy consumption.

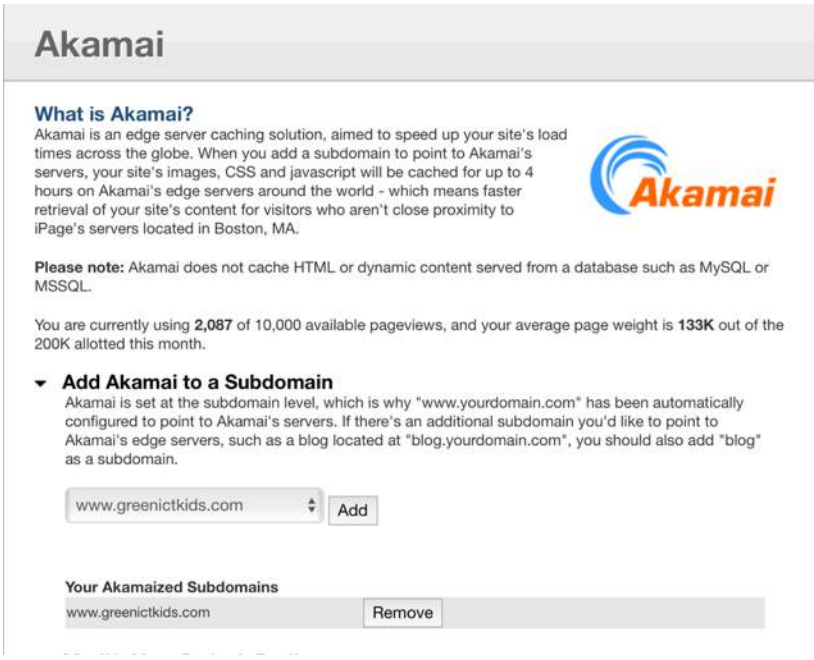

Figure 17: GreenICTKids.com uses Akamai to help speed up loading time.

- Web Usability:

Attempts have been made to make the website responsive on mobile phones and tablets. The menu and categories are responsive on smaller devices. Lesson 2 is responsive. The embedded video in Lesson 1 is also responsive. Lesson 3, however, does not support drag and drop on tactile devices.

Figure 18: The menu is responsive on small devices.

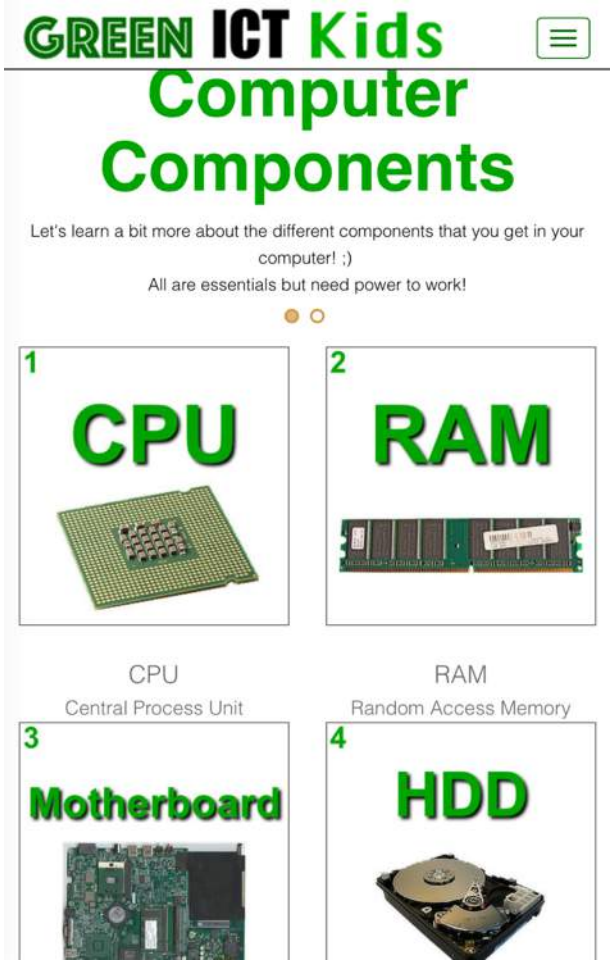

Figure 19: Lesson 2 is responsive on small devices.

Colours, font and images are basic and do not alter the user experience. If a client cannot display the text in the font “Helvetica”, the font “Arial” will then be used.

```
body {
  background: #fff;
  font-family: 'Helvetica', 'Arial', sans-serif;
  font-weight: 300;
  font-size: 14px;
  line-height: 22px;
  color: #000;
  margin-bottom: 120px;

}
```

Figure 20: Fonts used for the body of the website.

Web usability is important because if the website is difficult to use, the clients would spend more time trying to view the contents, thus consuming more energy.

3.3. Implementation of the Solution

This part describes how the website GreenICTKids.com has been developed, with which tools and which softwares.

3.3.1. Website

Figure 21: GreenICTKids.com Welcome Page.

The author has modified a template based on the Bootstrap framework. The languages used are HTML5 and CSS3. All animations have been created using jQuery, a JavaScript library. The general contents of the website are colourful in order to attract the attention of kids and to make it more appealing.

3.3.2. Lesson 1: The Video

The first part of the implementation is Lesson 1, where a video has been created as a means of introducing energy consumption to the kids. Before creating the video, the author wrote the script of the video (see appendix II) and collected all relevant sustainable notions to be embedded in the video. In order to produce the video, the author used different free video

clips and pictures from the Internet [48] [49] [50] [51] [52]. The video has been created with the software FCPX.

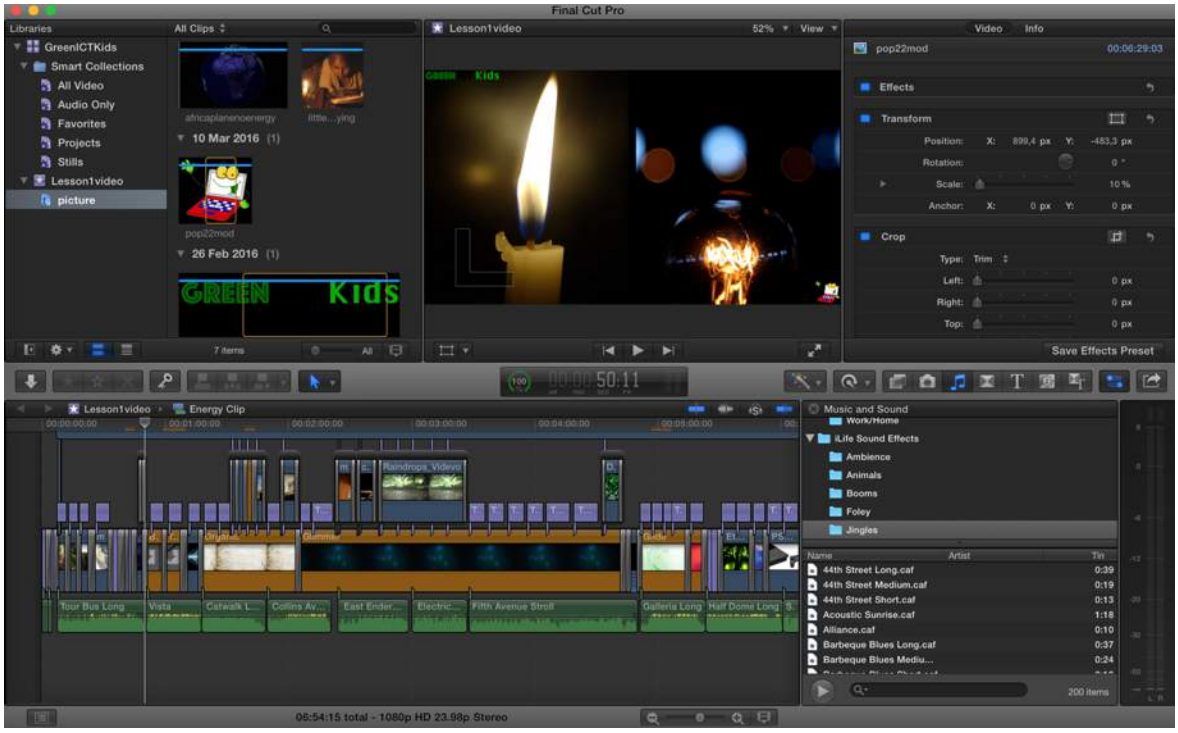

Figure 22: Producing a video with Final Cut Pro X.

The audio part of the video is directly imported from the audio libraries of FCPX.

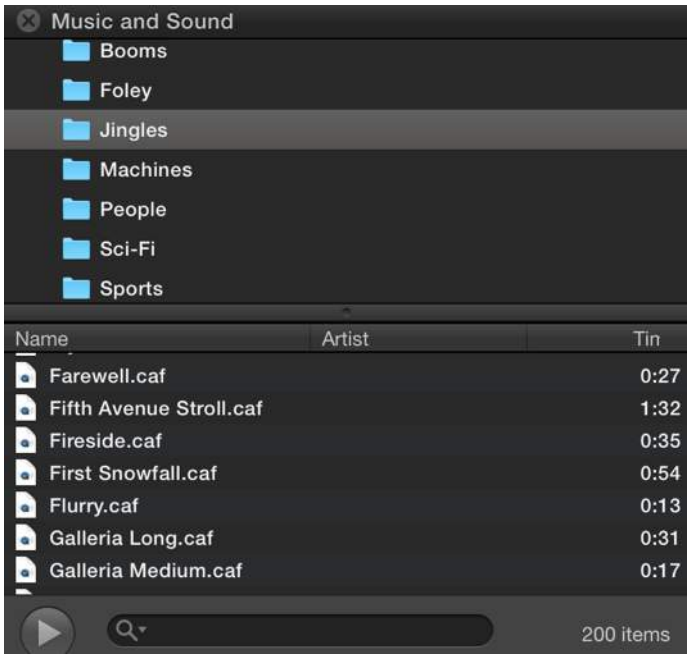

Figure 23: Audio library of FCPX.

The video has been produced in 1080p (full HD resolution) at 24 frames per second (cinema standard). Due to features, as well as convenience and accessibility reasons, the video has been uploaded on YouTube [53]. This made it easy to embed and to be responsive on the webpage. YouTube also helps GreenICTKids' video to be more visible on the Internet. Thus, the website is potentially more likely to be visited by kids or schools.

The sustainability-related facts used in the video have been taken from a broad variety of sources on the Internet [54] [55] [56].

3.3.3. Lesson 2: The Slideshow

The second part of the implementation is Lesson 2, which consists of a slideshow of pictures describing energy consumption related to different forms of usage, electronic devices and computer components, as well as their definitions. The slides and thumbnails have all been created with the software Affinity Photo.

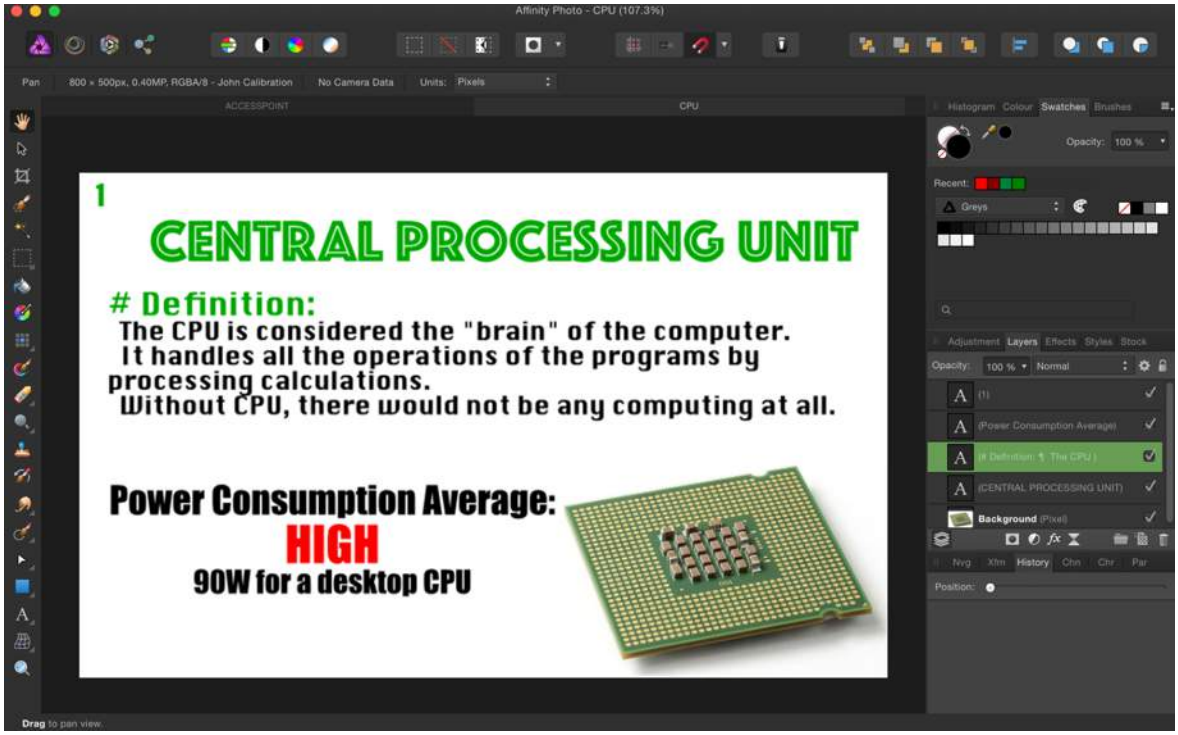

Figure 24: Editing an image with Affinity Photo.

Some of them have been saved in the PNG or JPG format. The choice of a particular format depends on the type of pictures, number of colours per picture and amount of text. All the pictures have been recompressed thanks to the website GTMetrix.com which gave an optimized version of each picture, and then each of these optimized versions have been compressed again with TinyPNG.com, to occupy as less space as possible on the webpages. The slideshow has been embedded in the website with the use of Lightbox and animation capability of jQuery.

```
hide.js
function unhide(divID) {
  var item = document.getElementById(divID);

  if (item.className=='unhiddencc') {
    item.className='hiddencc';
  }
  else{
  document.getElementById('computercomponents').className='hiddencc';
  document.getElementById('networktransmissions').className='hiddencc';
  document.getElementById('deviceshome').className='hiddencc';
  item.className='unhiddencc';
  }
};
```

Figure 25: Animation mechanism of the Lesson 2.

All the information about energy consumption of the devices, the computer components and the different forms of usage come from different online sources [57] [58] [59] [60] [61]. Clicking on the thumbnails which represent each slide reveals the picture with definition, goal and power consumption of the desired device or usage.

3.3.4. Lesson 3: The Game

This part describes the implementation of the final lesson, Lesson 3, which consists of a game with a drag and drop mechanism. Here, kids need to drag items from the shop and drop them in the house after specifying their usage duration. They will then be able to see the total of their energy consumption of the day which cannot exceed a prescribed threshold. This drag and drop mechanism is facilitated with the use of jQuery and some other related libraries such as jQuery-ui and jQueryAlert.

```
$(function () {
  consumption = 0;
  testercancel = 0;
  seuil = 2200;

    $("#dvSource img").draggable({
        revert: "invalid",
        helper: 'clone',
        refreshPositions: true,
        opacity: '0.6',

        start: function(event, ui) {
        tester=0;
    },
```

Figure 26: Drag mechanism.

```
$("#dvDest").droppable({
  accept: '#dvSource img',
    drop: function (event, ui) {
        if ($("#dvDest img").length == 0) {
            $("#dvDest").html("");
        }
         ui.draggable.clone().appendTo($("#dvDest"));
         tester=1;
    },
});
```

Figure 27: Drop mechanism.

```
if (tester==0){
  alert("Drop me in the house if you wish to use me ");

}else{
  jPrompt('How many hours do you want to use '+ image +' today? (please enter an integer between 1 and 24)', '2', 'POWER CONSUMI
    if( t>=1 && t<25 && tester==1 ) {
          newt = t*power;
          alert('You have chosen to use this device ('+ image +') for ' + t + ' hours today! It represents '+newt+' Wh!');

          consumption = consumption + newt;
          document.getElementById("demo").innerHTML =  "You are consuming " + consumption + " Wh today";

    }
    $("#warning").show();

    document.getElementById("warning").innerHTML =  "In order to be sustainable, you cannot consume more than 2200 Wh today,</bi
    if (consumption >= seuil){
      jAlert('You are consuming too much! Please restart to game to continue playing ;)')
      document.getElementById("demo").innerHTML =  "PLEASE RESTART THE GAME :)";
      $("#darkwarning").show();
      document.getElementById("darkwarning").innerHTML =  "All the devices you want to use today will result in a very big ener

      $("#dvSource").hide();

    }
```

Figure 28: What happens when the drop is successful.

This research has defined a limit of energy consumption that should not be exceeded in the game. Indeed, it is necessary to be more sustainable and to understand the need of gradually

reducing the energy consumed every day. The literature review concerning the energy consumed in the United Kingdom, which has shown that the current trend is to decrease the general energy consumed in each UK household [25] [26], permits the author to determine that ICT appliances represent on average 20% of the energy consumed by a UK household. The DEFRA documents have identified a decrease in the energy consumption every year between 2008 (4653 kWh in average) and 2014 (4115 kWh in average) [26]. In order to continue to be more sustainable, it is relevant to assume that an average energy consumption of 4000 kWh per year would be a good target. It would represent around 11 kWh per day. As mentioned, ICT appliances represent around 20% of the daily energy consumption, therefore ICT appliances would consume around 2.2 kWh per day. The threshold of Lesson 3 is set to 2.2 kWh per day of energy allowed for the ICT equipment available in the game.

Figure 29: Instructions given to the user when playing with the game of Lesson 3.

Finally, kids cannot over consume energy while using their devices in Lesson 3. If they do consume more than the limit of 2.2 kWh a day, the game will ask them to restart the drag and drop process.

Figure 30: Message inviting the user to restart the game if the user crosses the energy consumption limit.

3.3.5. Quizzes 1 and 2

The final part of the implementation explains how the two quizzes have been implemented in the website and which technologies have been used.

Figure 31: Quiz 2 related to Lesson 2.

The two quizzes are based on an existing example of quiz from Jeremy Rue [62]. They are developed using JavaScript. The style of the quizzes is defined by a CSS file. It is important to note that both quizzes have their own JavaScript file and each JavaScript file contains

questions that the kids are asked. Both quizzes are directly linked to the lessons. Quiz 1 is naturally linked with Lesson 1 and the same goes for Quiz 2 and Lesson 2. Both quizzes contain relevant questions concerning both lessons, and are a means for kids to self-assess their knowledge and understanding of Lessons 1 and 2.

3.4. Design of the Tools for the Evaluation

Two Google forms have been created to collect feedback about the website from the adults and kids. The following subparts describe how the questionnaires for adults and kids have been designed.

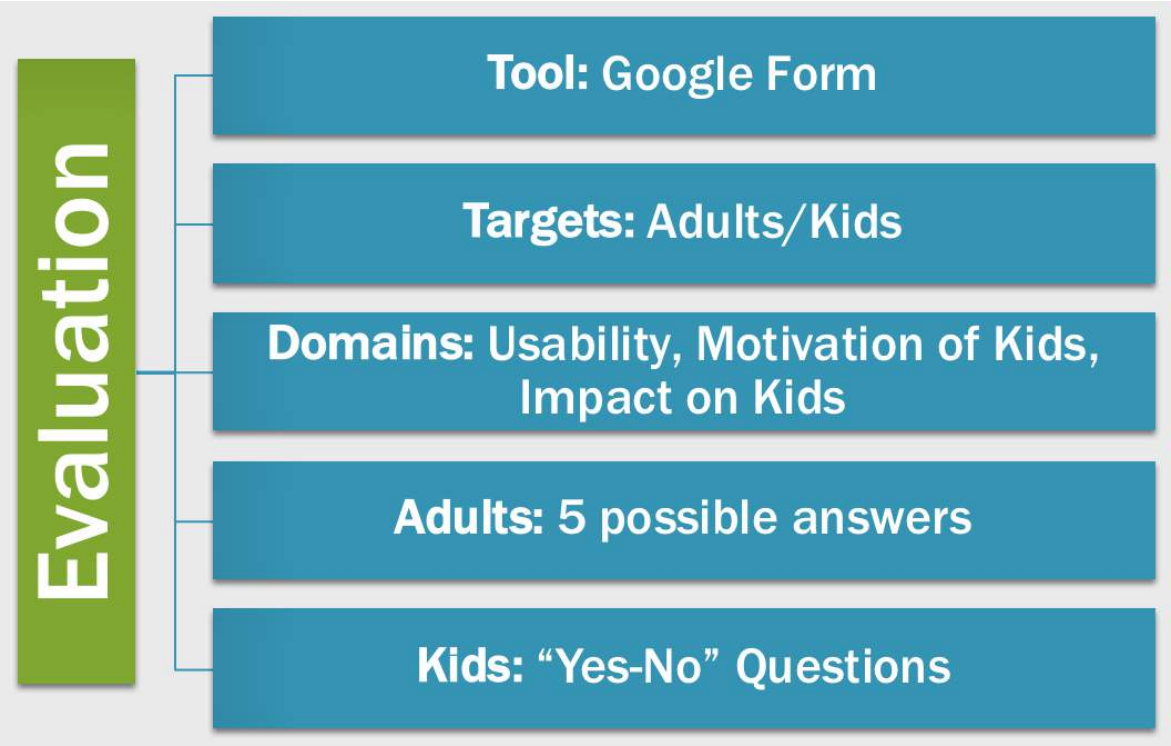

Figure 32: Design of the evaluation.

3.4.1. Design of the Questionnaire for Adults

This questionnaire is targeted at adults who have gone through the lessons and quizzes in the GreenICTKids website. The questionnaire for adults focuses on three different domains: usability, motivation of children and impact on children. Each area has a corresponding set

of questions. To obtain quantitative data, the questions have been formulated in the form of declarative sentences and the adults are supposed to choose an answer from the following set of possible responses: “strongly agree”, “agree”, “neutral”, “disagree” and “strongly disagree”. One optional open question has also been asked (see appendix III for the questionnaire for adults).

3.4.2. Design of the Questionnaire for Kids

This questionnaire is targeted at kids who have gone through the lessons and quizzes in the GreenICTKids website. The questionnaire for kids also focuses on the three different domains previously mentioned. However, the questions have been differently phrased. A majority of the questions require a “Yes” or “No” response while the rest offer a simple multiple question with two or three options. An open question has been asked too. Two additional questions are also asked to provide insight into the kids’ performances in the two quizzes (see appendix IV for the questionnaire for kids).

4. RESULTS

The first part of the evaluation took place with adults and the second part with kids. The results have been collected through Google forms and the data gathered are anonymous.

4.1. Evaluation with Adults

13 adults from different countries have answered the questionnaire for adults. Among them, 3 have answered the optional open question. Overall, all the adults who responded to the questionnaire agree with the statements made by the author.

<u>Results concerning the usability of the website:</u>

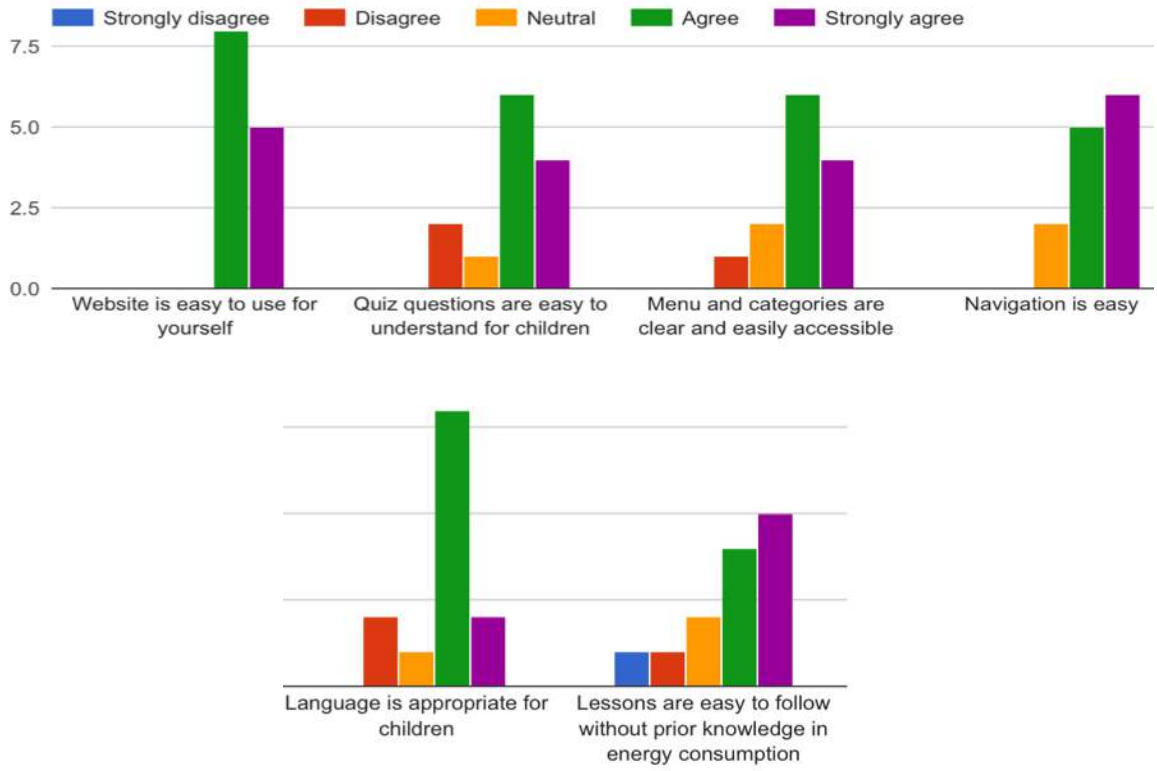

Figure 33: Usability of the website reviewed by adults.

100% of the respondents find the website GreenICTKids.com easy to use for themselves (38% “strongly agree” and 62% “agree”). 77% of the respondents think that the quiz questions are easy to understand for children if they have gone through the the corresponding

lessons (31% “strongly agree”, 46% “agree”, 8% “neutral” and 15% “disagree”). 77% of them think the menu and categories are clear and accessible (31% “strongly agree”, 46% “agree”, 15% “neutral” and 8% “disagree”). 85% of them find easy to navigate into the different parts of the website (46% “strongly agree”, 39% “agree” and 15% “neutral”). 77% of them think the language is appropriate for children (15% “strongly agree”, 62% “agree”, 8% “neutral” and 15% “disagree”). 69% of them think that the lessons are easy to follow without prior knowledge in sustainability and/or energy/power consumption (38% “strongly agree”, 31% “agree”, 15% “neutral”, 8% “disagree” and 8% “strongly disagree”).

Results concerning the motivation of children:

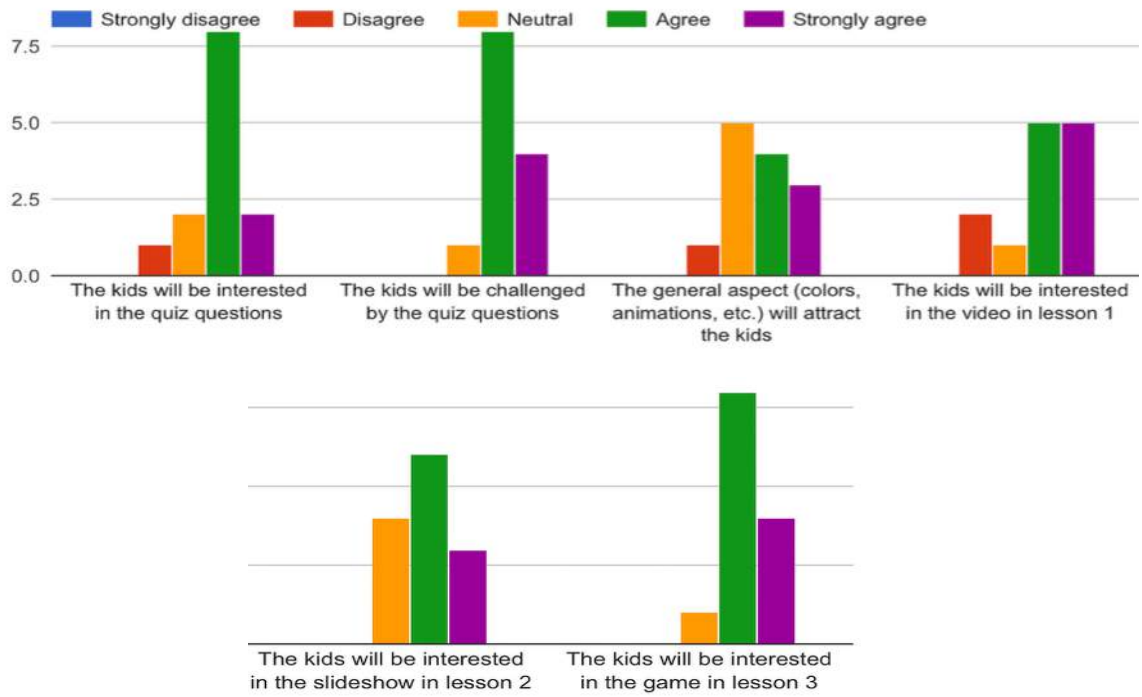

Figure 34: Motivation of children predicted by adults.

77% of the adults who responded think the kids will be interested in the quiz questions (15% “strongly agree”, 62% “agree”, 15% “neutral” and 8% “disagree”). 92% of the respondents think the kids will be challenged by the quiz questions (31% “strongly agree”, 61% “agree” and 8% “neutral”). 54% of them think the general aspect (colours, animations) will attract the kids (23% “strongly agree”, 31% “agree”, 38% “neutral” and 8% “disagree”). 77% of them think the kids will be interested in the video from the lesson 1 (38% “strongly agree”,

38% “agree”, 8% “neutral” and 16% “disagree”). 69% of them think the kids will be interested in the slideshow in the lesson 2 (23% “strongly agree”, 46% “agree” and 31% “neutral”). 92% of the respondents think the kids will be interested in the game in the lesson 3 (23% “strongly agree”, 69% “agree” and 8% “neutral”).

Results concerning the impact on children:

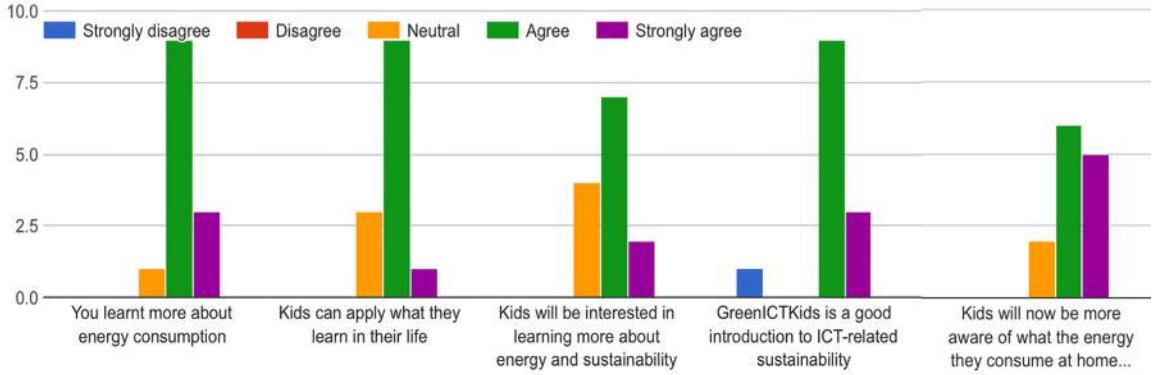

Figure 35: Impact on children predicted by adults.

92% of the responding adults learnt more about energy and power consumption (23% “strongly agree”, 69% “agree” and 8% “neutral”). 77% of the respondents think the kids can apply what they will learn in their everyday life (8% “strongly agree”, 69% “agree” and 23% “neutral”). 69% think the kids will be interested in learning more about energy and sustainability (15% “strongly agree”, 54% “agree” and 31% “neutral”). 92% think GreenICTKids.com is a good introduction to technology and ICT-related sustainability (23% “strongly agree”, 69% “agree” and 8% “strongly disagree”). 85% of the respondents think the kids will now be more aware of what the energy they consume at home, at school or at their friend’s places (39% “strongly agree”, 46% “agree” and 15% “neutral”).

In addition to these results, some adults have left additional feedbacks regarding the contents of the website.

Video:

Two persons think the video is of a very high quality and very easy to follow, with a good sound background. They emphasise that the video will attract the kids. One of them wrote: “Vivid, realistic, changing pictures, videos and music attract attention and not let you lose

your focus or interest. The video from the first lesson not only gives information to the children, but also tells them how they can help the nature, how they can decrease the consumption of energy at their level and even explains to parents those easy rules."

Slideshow:

One person thinks the written words in the slideshow are not so interesting for kids and therefore this person suggests for the future to use curves and images to replace some of the written information.

One person not familiar with technologies neither sustainability-related ICT thinks the slides in the lesson 2 give "useful information" in a "simple and understandable way" with pictures that "give an idea how, for example, different components of computer look like".

Game:

One person wrote that the game "makes the kids curious about their daily device usages" and makes them "think about the associated energy and planet costs that come with using them".

Another person thinks the lesson 3 is "the most interesting part because it's given in the form of game through which they can apply their knowledge learnt in the previous lessons in practise". This person emphasises that the lesson 3 is about learning through playing.

An expert also left a feedback about GreenICTKids.com:

"Some nice resources developed so far. The video looks very professional. Suggest some grammar checking (esp. in the quiz questions/answers), and that the source of material (e.g. US car videos, music etc.) be more clearly/explicitly cited. But with a little more development, this would be nice to share with schools (perhaps via the Computing at school network)."

At this time, the website was still under development, so the grammar has been checked and corrected.

4.2. Evaluation with Kids

5 kids from different places in the world, different ages and different backgrounds have answered the questionnaire for kids. Since only 5 kids answered, it cannot represent the

majority of kids in the United Kingdom. It was more difficult to find kids to respond to their questionnaire due to several factors: kids need to understand English, kids need to be between 7 and 11 years old and the parents need to agree to show the website to their own children. Despite the small number of respondents, a pattern among the answers can be clearly identified.

Results concerning the usability of the website:

80% of the kids who responded to the questionnaire found the website GreenICTKids.com easy to use in general. 80% of them understood everything (lessons and quizzes).

Results concerning the motivation of children:

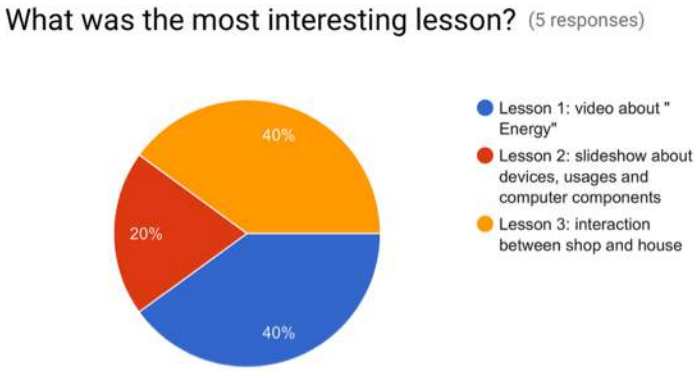

Figure 36: The most interesting lesson according to kids.

100% of them liked the colours, images and animations. 40% of the respondents think the most interesting lesson is the Lesson 1 and 40% of the respondents think the most interesting lesson is the Lesson 3. 100% of the kids got at least 4 correct answers out of 10 for both quizzes.

Results concerning the impact on children:

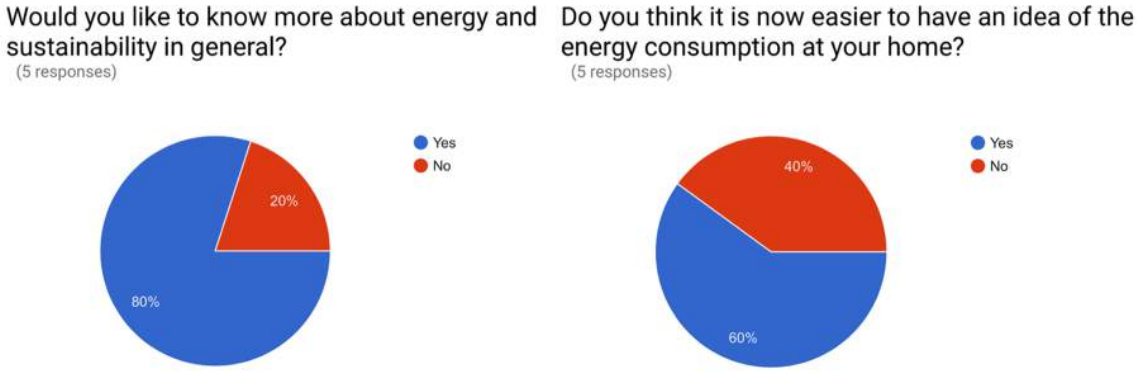

Figure 37: Sustainable impact on kids.

40% of the kids who responded did not really have knowledge about energy consumption and sustainability in general before using GreenICTKids.com. 100% of them will try to apply what they have learnt in their everyday life. 80% of them would like to know more about energy and sustainability in general. 60% think it is now easier to have an idea of the energy they consume at home.

4.3. Discussion

This part is a reflexion on the link between the pedagogic approach used by the author to implement the material, the results collected from adults and the results collected from the kids.

The results of this research show that the website GreenICTKids.com has content that can motivate kids to learn about sustainability and energy consumption, as well as applying their newly acquired knowledge in their daily life. Indeed, 100% of the kids will try to apply in their daily life what they have learnt through the three lessons and 80% of the kids are willing to learn more about energy and sustainability in general. Besides, 100% of the kids liked the visual aspects of the website. Both adults and kids declared the website is easy to use and navigating between sections is easy.

According to the results collected from the kids, although 60% of the kids had prior knowledge about energy consumption and sustainability, 100% of the young respondents have understood the lessons and quizzes in general. It is therefore interesting to note that the

adults expected less of children regarding their understanding of the material (77% of adults think quiz questions are easy to understand for kids if they have gone through the lessons and only 69% of adults think lessons are easy to follow without prior knowledge in sustainability). In general, the kids have been challenged by the quiz questions.

Another interesting point to note is that 85% of the adults think the kids will be more aware of their energy consumption at home, but only 60% of the kids declared that it is now easier to figure out how much energy they consume at home.

Finally, these results show that the approaches suggested by the literature review, such as teaching with a video, visual contents and learning through playing are efficient and can have a positive impact on students. In particular, the results collected from both adults and kids reveal that children are more interested by the game in Lesson 3 and by the video in Lesson 1 than by the slideshow in Lesson 2. The results collected from the adults also emphasise that the video can have a positive impact on the kids' behaviour.

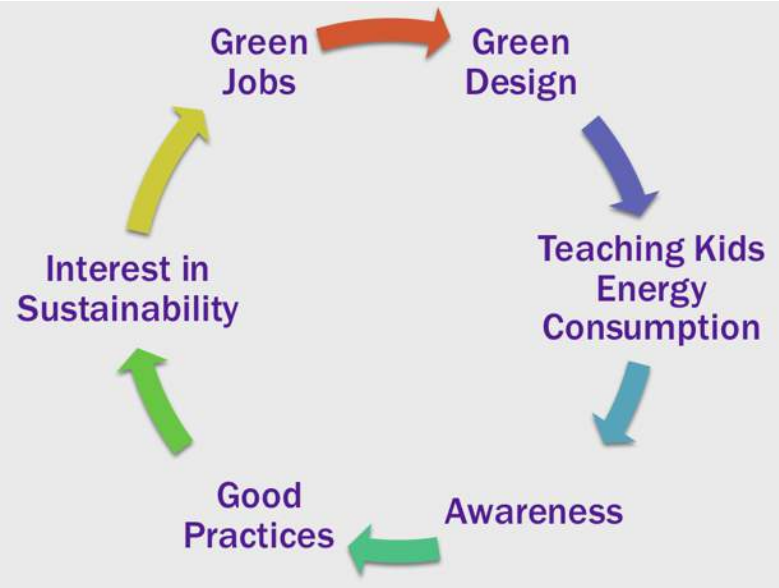

Figure 38: Sustainable contribution.

While decreasing the amount of energy needed to explore GreenICTKids.com, kids' awareness of sustainability has been raised, thus resulting in a potential positive sustainable impact. Indeed, applying in their daily life what kids have learnt can lead to a reduction of the energy consumed at their home and at the places they study. It can help reduce their carbon footprint.

5. CONCLUSION AND FUTURE WORK

In summary, the results of this research show that kids were motivated by the website GreenICTKids.com to learn about energy consumption and about sustainability in general. The most important objective of this research was to have a positive sustainable impact on kids' behaviour and according to the analysis of the results, all the kids will try to apply their newly acquired knowledge in their daily life. Through the video, the slideshow and the game, while learning about computer components, about the usage of computers and the electronic devices they have at home, the kids learnt the fundamentals of energy and power consumption. In addition to this, they have been introduced to the notions of climate change, global warming and greenhouses gases, which are key factors in the understanding of the ecological challenges of today's world.

These pedagogical approaches are student-centered and differ from the traditional textbooks and teacher-centered lessons. Visual materials such as video and slideshow helped to motivate kids to learn about energy. Interactive material such as drag and drop game helped to involve kids in learning about energy consumption of their electronic devices. The kids who participated in the study were able to learn more about sustainability while having fun but being challenged by quiz questions as well and are now better equipped for their potential future studies in ICT and in sustainability. This research shows that it is possible to embed sustainability into the Computer Science curriculum and to create an impact on students' behaviours. This also helps to prepare students for "green jobs" in England.

As future work, in order to make the website even more attractive and appealing, it may be interesting to improve the quality of the game in Lesson 3 for example by implementing some visual indicators of energy consumption, adding new features, options and items and creating a 3D visualisation of the shop and the house. Then it could be relevant as well to transfer the website to online educational platform in order to increase its visibility over the web and potentially have a wider sustainable impact. Finally, to help teachers convey the contents of GreenICTKids.com to their students, it could be also interesting to give teachers some additional materials and recommendations, such as providing them with instructions in order to create sustainability-related ICT projects for kids. This will also motivate students to refer the website and use their newly acquired knowledge in their projects at school.

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APPENDICES

Appendix I: Script of the Video

What is energy? Where does it come from? Why is it important?

The challenges of today's world are mainly about energy

This is certainly your life...

BUT...If you don’t have access to energy...

You can see that these are two different worlds...

Energy gives you Internet access, powers your lights, music, fridge, oven, computer, TV, video games...

Thanks to electricity

There are two sources of energy:

- Primary sources

- Secondary sources

The primary sources consist of...

Nuclear energy

Fossil energy:

oil, coal, natural gas

Renewable energy:

wind, solar

Renewable energy:

hydropower, geothermal

The secondary sources consist of...

Electricity, obtained after transformation of primary sources energy.

Why is it important to use energy carefully?

Because energy isn't infinite, even renewable energy: it is necessary to manufacture the equipment to harvest it (their production uses fossil resources and materials).

Because energy costs money: every home pays an energy bill at the end of the year...

Due to fossil resources exploitation, there is pollution: in the air, in the soil and in the water.

Because using energy contributes to the general "Climate Change".

Some cold places tend to be warmer while warm places tend to be colder... This is "Global Warming"...

The GreenHouse Gases (GHG) help to trap solar energy inside the atmosphere: without them, the planet would be too cold and humans couldn't live.

But too much GHG causes global warming and problems for humans, animals and plants...

Energy consumption is the n°1 factor in climate change: every activity requiring energy causes GHG emissions.

The Information and Communications Technologies (ICT) are responsible for 2% of worldwide GHG.

All the devices (computers, tablets, phones etc.) that people have at home represent 47.2% of ICT's GHG.

The networks and communications represent 24% of ICT's GHG.

The data centers represent 28.8% of ICT's GHG.

We can try to make "Greener ICT": by reducing energy consumption of computer components, by writing code that will be easier to process for the computers...

We can also try to ”green by ICT” by implementing small computers and/or sensors in everyday life objects (house, fridge, car...).

If you use ICT in a smarter way, you will help reduce GHG.

An example… Your parents are driving back home... What do they do?

After parking the car, they turn off the engine and the lights (if they were on).

Why? I'm sure you know the answer...

Because they want to avoid pollution, to avoid wasting money, and because the car wouldn't start the next day due to the battery being drained during the night.

At home, you should do the same with TV, computer, videogames, lights, oven, etc.

When you don't use them, turn them off.

You will save electricity & money

Your devices will have longer life

How can you measure the energy consumption of your devices?

How can you estimate the energy cost of them?

Power: Watts (W)

Energy consumed: Watts-hours (Wh)

A light bulb of power 100W used for 1h consumes 100Wh.

The price per kWh depends on the country.

For example, in UK, it is around 11p/kWh.

If you play 4 hours per day and leave the PS4 in IDLE mode the rest of the time:

876 kWh for 1 year = 96 pounds

If you play 4 hours per day and leave the PS4 in STANDY mode the rest of the time:

285 kWh for 1 year = 31 pounds

If you play 4 hours per day and leave the PS4 SWITCHED OFF the rest of the time:

222 kWh for 1 year = 24 pounds

In all three scenarios you play 4h, but in the last two scenarios, you save a lot of energy and money!

Remember this! If you consume energy with care and if you don't waste it, you will help solve the challenges of today's world ;)

A movie created by Jonathan Pucher, during his Master Thesis at Leeds Beckett University. Video clips come from videvo.net, videezy.com and clipcanvas.com. Pictures come from Wikimedia commons and Gatesnotes.com. GreenICTKids

Appendix II: Questionnaire for Adults

1. Usability *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) This website is easy to use for yourself.	○	○	○	○	○
b) The quiz questions are easy to understand for children if they have gone through the the corresponding lessons.	○	○	○	○	○
c) The menu and categories are clear and easily accessible.	○	○	○	○	○
d) It is easy to navigate into different parts of the website.	○	○	○	○	○
e) The language is appropriate for children.	○	○	○	○	○
f) The lessons are easy to follow without prior knowledge in sustainability and/or energy/power consumption.	○	○	○	○	○

2. Motivation of children *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) The kids will be interested in the quiz questions.	○	○	○	○	○
b) The kids will be challenged by the quiz questions.	○	○	○	○	○
c) The general aspect (colors, animations, etc.) will attract the kids.	○	○	○	○	○
d) The kids will be interested in the video in lesson 1.	○	○	○	○	○
e) The kids will be interested in the slideshow in lesson 2.	○	○	○	○	○
f) The kids will be interested in the game in lesson 3.	○	○	○	○	○

Motivation of children: please provide reasons for your answers in d) to f).

Your answer

3. Impact on children *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) You learnt more about energy and power consumption.	○	○	○	○	○
b) The kids can apply what they have learned from the lessons in their life.	○	○	○	○	○
c) The kids will be interested in learning more about energy and sustainability.	○	○	○	○	○
d) GreenICTKids is a good introduction to technology and ICT-related sustainability.	○	○	○	○	○
f) The kids will now be more aware of what the energy they consume at home, at school, at their friend's places etc.	○	○	○	○	○

Appendix III: Questionnaire for Kids

Did you find the website GreenICTKids.com easy to use in general? *

- ○ Yes
- ○ No

Did you like the colors, the images and the animations? *

- ○ Yes
- ○ No

Did you understand the lessons and the quizzes? *

- ○ Yes, I understood them all
- ○ Yes, despite there were some things I didn't understand
- ○ No

What was the most interesting lesson? *

- ○ Lesson 1: video about "Energy"
- ○ Lesson 2: slideshow about devices, usages and computer components
- ○ Lesson 3: interaction between shop and house

How many questions did you pass sucessfully for Quiz n°1? *

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

How many questions did you pass sucessfully for Quiz n°2? *

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

Did you have knowledge about energy consumption and sustainability in general before using the website GreenICTKids.com? *

- ○ Yes
- ○ Not really
- ○ No

Will you try to apply what you have learnt in your everyday life and how will you do it? *

Your answer

Would you like to know more about energy and sustainability in general? *

- ○ Yes
- ○ No

Do you think it is now easier to have an idea of the energy consumption at your home? *

- ○ Yes
- ○ No