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Our digital education habits in the light of their environmental impact: the role of green computing in education

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Abstract. With the increasing use of IT tools, the environmental impacts they generate have also increased. Education is increasingly relying on digital tools to become a major emitter of CO_2 itself. Therefore, the task of education is to teach future generations how to use IT tools efficiently while being environmentally aware. In addition to some forms of green computing, we show the level and ratio of those teachers who have corresponding IT knowledge in the Hungarian education. In this study, we present the justification of the problem through a case study, which estimates the Internet traffic of a website streaming popular educational resources. In addition, we will examine the extent to which national and international educational organization and guidance documents address the development of digital environmentally aware thinking. Based on the content of this study, we suggest some considerations for content developers to decide if they really need to create the digital content.

Key words and phrases: green computing, education, environmental impact.

MSC Subject Classification: 97P99, 94-06, 94-02.

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About the dangers of the environmental impact of the digital transformation in education

Since the turn of the millennium, special attention has been paid in developed countries of the world to developing an educational environment that fits the requirements of the information society (Molnár, 2011). The digital transformation of schools (Racsko, 2017) plays a key role in this, in which the development of infrastructure, human resources, pedagogical-methodological culture and content, as well as school management are all key factors. Moreover, the digital transition with the right quality requires, in addition to the above, the environmentally conscious design of infrastructure and thinking.

There are basically three areas in which digital pollution can occur. The first area is the classical meaning of Green Computing, when we look at how much energy is actually consumed by the work done by each program (CPU and memory usage, efficiency of the used algorithms, ...). At the present, we cannot provide exact solutions for measuring this problem, most of the literatures are based on estimates. The second area relates to the use of physical devices. Their preparation requires the production of a large amount of raw materials, and the energy used in their production is also to be taken into account. These devices are most hazardous in the form of waste, as they lose their relevance in a few years, fail in hardware. Most of the time these may not end up in a waste treatment facility where they can be properly disassembled, reused, or neutralized. Just think of the educational and curriculum development projects of the past decade, when the main criterion for purchasing a device was simply getting digital tools like tablets, digital tables, mobile phones, etc... for schools. Unfortunately, most of these now are obsolete or have become unusable. The third, and perhaps most imperceptible form of environmental load is the unnecessary data traffic generated by the usage of digital tools and cloud based solutions. In this article we focus on this kind of problem. E-learning portals are now widely available and used all around the world. It is not a question of this article to elaborate on their relevance, but some interesting statistics are worth exploring to understand our motivation.

We were first interested in this topic by reading the article of ovoenergy (ovoenergy, 2019), whose authors surveyed the number of emails sent in the United Kingdom, and in particular emails with no meaningful content. The study found that sending one useless message a day by every email user in the United

Kingdom would save around 16.433 tonnes of carbon dioxide per year. Just to illustrate its magnitude, it has been calculated that it corresponds to 81.152 flights between Heathrow Airport and Madrid. The main purpose of this study is to point out that the education system that is increasingly relying on the potential of digital solutions is also a major contributor of the global CO_2 emissions.

In recent years, in addition to the integration of information and communication technology into education (Rugelj, 2018; Jedrinovic, 2019), there has been an increasing emphasis on the pedagogical-methodological culture required for successful implementation. Based on this practical experience (Kjellsdotter, 2020) many areas still need to be developed, as methodological solutions mostly cover the first three levels of Bloom's taxonomy (memory, evaluation, use), while higher cognitive levels have not been achieved due to the lack of competence of teachers in this field (Almerich & Díaz-García, 2016).

In connection with the above, there have been numerous school experiments in Hungary (Czékmany, 2017; Kis-Tóth, Borbás, & Kárpáti, 2014; Herzog & Racsko, 2016; Kis-Tóth, Gulyás, & Racsko, 2017), which initially following the Hype curve connected to digital tools, and then increasingly moved towards methodological solutions (Racsko, 2017; Molnár & Orosz, 2019) and content development. Thus, the role of IT tools in education has gone beyond the emergence of a new subject, the development of digital competences has become an interdisciplinary task and due to its cross-curricular nature it has become an educational tool linked to the everyday formal education environment. In parallel with trends linked to the increasing uptake of digital tools (Pólya, Göncziné Kapros, Herzog, & Tóthné Parázsó, 2014), the dangers of digital devices have been addressed in a number of forums over the past decade, and most of them covered its mental impact (Carr, 2014; Gyarmathy, 2013; Tari, 2010; Pléh & coworkers, 2014; Twenge, 2018). However, in the field of information communication, the regular application of digital tools, and in particular their virtual dimension (Komenczi, 2009), also involves another hazard factor that goes beyond individuals and is a more global context issue. In fact, the use of digital devices generates significant Internet data traffic, which, although not spectacular, entails significant energy consumption, but the extent and effect of it is not known by the users. At the same time, developing and following a green environmental policy is an urgent requirement in almost every type of organization, institution, or business, be it public or private, profit-making or non-profit, small or large, production-based or service-oriented.

Thus, we can conclude that digital competence, and the concept of responsible digital citizen, has undergone a major transformation in the recent past. Its former meaning has been broadened to go beyond technological knowledge to include the cognitive and social aspects as well as awareness and sustainability (Tongori, 2012).

The aim of this study is to introduce the concept of green compting ("green ICT"), which has become known today, and to point out the pedagogical relevance of the topic, its appearance in international reference models (DigComp 2.1 and DigCompOrg), and the basis of educational regulation in Hungary, the National Core Curriculum (Kormány, 2020).

From the point of view of research, we use a deductive research strategy, among the qualitative methods we consider non reactive methods (Sántha, 2006), during which the researcher makes an indirect observation and thus provides an explanation, description of situations and documents. In the present work, we use a qualitative method of content analysis of texts, based on educational regulation documents. During the analysis, the search and description of the idiographic, i.e. individual characteristics is typical.

During sampling, I use the typical intensive strategy of the qualitative sampling selection strategies (Sántha, 2006), which was the multidimensional consideration of the sampling procedure. Thus, in the temporal dimension, we analyze the most current documents, and according to the spatial and geographical scope, we consider the European Union and domestic sources as the basis for analysis. The qualitative data corpus of the analysis consists of the international strategies DigComp 2.1 and DigCompORG reference framework systems and the official document of the Hungarian education regulation NAT 2020.

The tools of the research, in addition to the descriptive nature, are qualitative content analysis, the results of which are citation matrices, which are textual qualitative outputs from the analyzed sources. Among the validity criteria we used the method of manual text analysis with the help of personal, data and theoretical triangulation. Among the reliability criteria, in the present research we used the elements of Text Fidelity, application of low inference descriptions and consistent data management, tables, quantification, complete documentation and transparency (Sántha, 2007).

The concept and fields of green ICT and green computing

The concept dates back to 1992, when the United States Environmental Protection Agency (EPA) launched the Energy Star campaign, which promoted and encouraged the use of monitors, air conditioners and other technologies to increase energy efficiency (Saha, 2014). Similar initiatives were expected to spread worldwide until the 2000s. In the European Union, an action plan for green computing was released in March 2009, which requires a 15% reduction in total carbon dioxide emissions by the IT industry by 2020 (Krauth, 2009).

The term (green computing, green ICT, green IT), which exists in several versions in the IT (and telecommunications) industry includes all of the followings. 'The full spectrum from anomalies in Internet usage (spam, spyware overprocessing) and cutting-edge technologies (video on demand, increased bandwidth due to 'software as a service') to energy and cost-focused transformation of enterprise computing centers (virtualization, adaptive cooling systems) the power supply and disposal of recyclable equipment.' (Krauth, 2009) According to the International Federation of Global and Green ICT (IFGICT), it is the umbrella term for research in green information technology, environmentally sustainable computing, information and communication technology and good practices. Its goals are similar to the goals of green chemical industry: reducing the use of hazardous substances, maximizing energy efficiency over product life, recycling or biodegradability of spoiled products and factory waste (Mittal, 2014). The closest terminology to our topic is the following: 'Green computing is the environmentally friendly use of computers and their resources. In a broader sense, it also includes studying the design, manufacture, use and disposal of computing devices that reduce their environmental impact.' (Technopedia, 2017)

Translations of green ICT and green computing are widespread in Hungary. The education subsystem and systemic initiatives play an important role in this. From the bottom up, publications on the subject are already available in many areas (Smith, 2013). However, most of the research focuses on the design of infrastructures and the technical implementation of the field, while the areas of higher education, including information technology and engineering, are less prominent (Paul, 2013).

It is interesting to note that public collections, as one of the main leaders in CSR, have long been involved in the development of the Green Library. Thus, it is clear that this aspect of the digital revolution is not yet systematically embedded

Searching term	Results	Max rating	100. rating*	Min rating	Full time (hour)	Full storage (GB)	CO_2 (ton)	London flight
C	362	n/a	n/a	n/a	1 327.33	2 163.55	43.27	184.21
C beginner	61	n/a	n/a	n/a	223.67	364.58	7.29	31.04
C++	1 541	38 719	22	19	5 650.33	9 210.04	184.2	784.17
C++ beginner	666	3 242	0	0	2 442.00	3 980.46	79.61	338.91
C#	4 078	68 190	357	0	14 952.67	24 372.85	487.46	2 075.17
C# beginner	1 062	30 328	36	0	3 894.00	6 347.22	126.94	540.42
opengl	73	991	17	2	267.67	436.30	8.73	37.15
opengl beginner	25	368	n/a	5	91.67	149.42	2.99	12.72
unity	5 620	68 190	255	0	20 606.67	33 588.87	671.78	2 859.84
unity beginner	2 323	9 883	36	0	8 517.67	13 883.80	277.68	1 182.10

Table 1. Some of the popular courses and their measures

in the education systems, with digital sustainability and green computing still appearing in the vast majority of cases as white patches.

Case study of a video sharing portal offering online learning materials

To illustrate the importance of what has been discussed above, we have prepared the following case study. One of the most popular educational websites on the Internet is Udemy. The following statements are made solely on the basis of the information published on the site and the data that we have read during the manual browsing of the courses. Udemy basically offers video courses that you can watch through its own streaming service. Based on this, the data transfer is generated again for each view. According to energuide.be calculations (energuide.de, n.d.), an average e-mail (1 Mb) produces about 20 grams of CO_2. Our further calculations are based on the same volumes for data traffic. Based on the public informations on the Udemy website, there are currently 150 000 courses available, and this is about 33 000 000 minutes of video. Let's consider an average video format these days! A one hour MPEG-2 3.7 Mbps fixed rate video with 24 FPS and with the resolution $720x468$ is approximately 1.63 GB. In fact, most of the time much higher resolution and higher quality videos are available, so in our opinion we underestimate the amount of traffic on the page. Let's take a look at (Table 1), where based on public data from the website we calculate with an average 3.6 hours of video for each course.

The values in (Table 1) are based on the results obtained from a web search engine. The Results column shows the number of courses found for a given search term. For each course, we were not able to examine the number of applicants. Instead of this we checked many of the courses that met the search criteria were rated, which reflects the number of users who viewed them. For each evaluation, we looked at how many ranks are taken to the first, the last and the $100th$ most ranked courses. In the cases marked with * there were no 100 courses, so we looked at the $50th$ one.

The first question that should be considered is, is there any justification for creating such a large amount of curriculum in a given topic? Of course, we are not able to view all of them, but ratings show that the number of courses we use regularly is only a fraction of the total. If an instructor creates curriculum content that is contained in previous courses and does not offer any significant innovation in methodology, the resulting instructional manual can be a significant burden on the environment with the CO_2 emissions it generates. We say in conditional mode, because if the given material is really valuable in terms of content or methodology, the ratio of environmental load and utility naturally changes. To illustrate the estimated calculated results, based on the quantities used in the article of ovoenergy, we show a comparison of another Budapest-London flight which is $1450km$.

Lack of IT professionals and teachers with ICT competence

The Digital Economy and Society Index (DESI), developed by the European Union, measures the development of the digital economy and society by examining Member States' preparedness for the digital switchover. According to the data collected, the digitalisation of individual countries is wide-spread across the EU and national borders continue to hamper the completion of the Digital Single Market. DESI aggregates the results of more than 30 indicators and ranks the member states according to a digital performance weighting system and also provides data for the development of the Digital Single Market Strategy.

Hungary ranks $23rd$ among the 28 EU Member States (it has been measured before Brexit). Overall, it has developed at an average rate over the past few years. Hungary is performing well in the field of interconnection due to the widespread availability and high utilization of high-speed and super-fast broadband. In the field of human capital, Hungary is below the average, with half of the population lacking basic digital skills and a low number of graduates in science, technology, engineering and math (STEM).

In parallel, statistics published by the Hungarian Office of Education (Hivatal, 2019) also indicate that the number of educators in education who have the appropriate IT qualifications or who are self-sufficient in IT haves stagnated for many years ago.

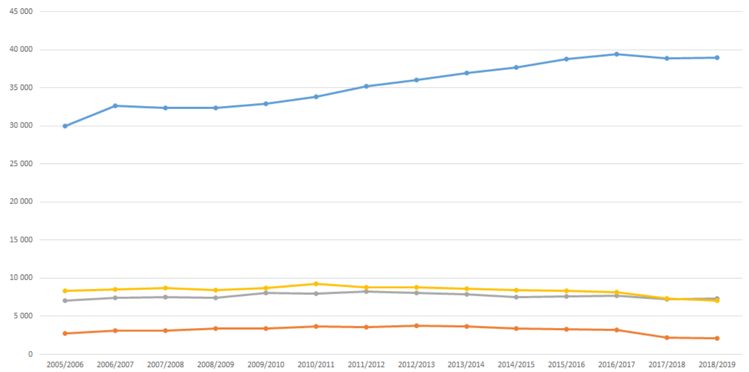

Figure 1. Teachers in Hungary with ICT competence (blue - primary schools, yellow - vocational high school, gray - high school, orange - secondary school).

Only the number of elementary school teachers has improved slightly since 2005, but from 2017 their amount is also decreasing in this area. This is all the more worrying as the emergence of digital tools and digital learning materials in the classroom is becoming increasingly prominent. Instructors use mobile devices to transfer knowledge or to complete a test. These solutions are available in large quantities, but their effectiveness or even their relevance is often questioned. Just keep in mind that WikiPedia pages can be edited and validated by anyone without a well-defined revision process. Although the information contained herein does not provide adequate stability, viewing it generates data traffic for each client. Deciding whether a given online curriculum is appropriate is the task and responsibility of the teacher. While educators with inadequate qualifications or knowledge may not appreciate the relevance of information and portals, they are not necessarily aware of the harmful effects of using them. Demonstrating this and highlighting its importance is a difficult task even for experienced IT educators, as in contrast to classically polluting devices and facilities, electronic devices are separated spatially and in time from the place of the usage. Nowadays, there is a growing space for unskilled workers in the teaching profession. The obvious reason for this is the shortage of manpower observed in the teaching profession. This tendency implies that an instructor who does not have the appropriate level of knowledge for the given subject (in this case informatics) not only does not teach the problems discussed in the article, but also does not take them into account. Hence, it develops a greater amount of bad IT habits in students. Therefore it can increase the rate of environmental destruction caused by digital devices and content consumption.

As a result, measures to improve the IT skills of non-IT teachers has a highly and primary importance. Eszterházy Károly University takes a prominent role to increase the number of those teachers whom IT skills are not sufficient within the project $EFOP - 3.1.2 - 16 - 2016 - 00001$ (Methodological training of teachers to prevent uneducated school leaving - Complex Basic Program). Through online and contact trainings in the Digital Subprogram of the project, participants will acquire basic IT skills and frameworks that will greatly contribute to addressing the above issues.

International and domestic embeddedness of the topic

In our research, we were interested in the context in which EU ICT frameworks incorporate green ICT elements, as well as in DigComp 2.1 for European Union citizens and DigCompOrg for 74 digitally competent educational institutions. In addition, we will examine where and how this topic appears in domestic education regulation, which will be examined in the National Core Curriculum adopted on January 31, 2020.

DigComp and DigCompOrg (as well as DigCompEdU) have been developed as part of the Digital Education Action Plan to regulate how education and training systems can make the most of innovation and digital technology and support developing digital competencies for life and work in an age of rapid digital change. The Action Plan pays particular attention to basic and vocational education and training systems and extends to schools, vocational education and training (VET) and higher education.

National Core Curriculum

The current National Core Curriculum (Kormány, 2020), which defines the guidelines for the education strategy for the coming period, can be found in the $17th$ issue of the Hungarian Bulletin. In addition to declaring the basic knowledge of each subject, the document identifies the skills and key competencies to be developed in each area.

In connection with the topics of green computing, we investigated the section 'II.3.8. Technology' in the National Core Curriculum. Our primary concern is the role of conscious use and critical thinking in environmental awareness, besides basic digital competencies and IT knowledge. The following statement can be found in the introduction to this chapter. 'The knowledge and skills acquired support informed participation in decisions that have consequences for the environment, sustainability and culture as a whole.' Although there are some topics that deal with this topic, there are in fact very few expectations.

From the subsection 'Main topics on year $3-4$.' we would highlight two topics. These are 'Getting information in the e-world' and 'Protecting against the dangers of the digital world'. While these topics can provide an important place in environmental awareness education, the first focuses on the technical implementation of appropriate search procedures, while the second focuses on avoiding potential threats (prohibited content, online harassment).

In year $5-6$. we also find some topics that can be embedded in this topic. These are 'Online Communication', 'Information Society, e-World' and 'Using Digital Devices'. Online communication, as we have seen in the case of the problem itself, is capable of generating such a large amount of data traffic that awareness of its reduction is essential. At the same time, prosperity in the information society, on-line data exchange and orientation in this space are all fundamental to students' lives and should also include environmental awareness.

In year $9-12$. the previous topics will be re-published, with the addition of 'Publication on the World Wide Web'. Perhaps the most important of all the previous ones is the possibility of actually publishing the finished product. As we have seen, if we are merely consumers of the content, we will also be emitting CO_2, and by publishing the content we will be the ones who encourage other members of society to consume it.

In addition to the above, it is noted that in the section 'Learning Outcomes' we can find the topic of the emergence of environmental awareness just in one place. As we read to the end of the year $5-8$. the student 'displays the text documents in multiple layouts on paper, and is aware of the environmental impact of printing.' Therefore, it can be stated that only the awareness of the tangible environmental impact in time and space at the moment of action continues to appear in the National Core Curriculum.

The place of green informatics in education

Due to the complexity of the topic, the teaching of green informatics cannot be reduced to the material of informatics lessons. If this happens, its credibility will be lost, we will not have well-established good habits that have developed in everyday life.

The aim of this article is not to present specific curriculum or lesson plans, but in connection with the thematic units of the subjects found in the National Core Curriculum, we show in which areas we can imagine the teaching of green informatics, or as a reference to it as an example.

Technology - technology and design, digital culture

Due to the nature of the topic, we can of course deal with the topic in classical informatics classes. Problem sensitivity should be developed primarily here. Through computational tasks, we can show how much less storage space a video (now considered to be of poor quality) previously published ($4-5$ years ago) generated and therefore network traffic than the 4 K videos that are becoming more prevalent today. This is a good time to think about comparing the resource requirements of streaming and one-time downloads in the classical way. These figures are staggering enough to deal with the seemingly minor problem of correspondence afterwards. In fact, correspondence is only a transfer to estimates of the large amount of information exchanged on social portals.

On the other hand IT provides the right space to search for online contents and information. So we can give the students classic data collection tasks here, even as part of project work. Tasks of this kind can be immediately connected to the problem of filtering out false information that also appears in the National Core Curriculum.

Mathematics

In math class, we can perform similar computational tasks as the calculations presented in the case study above. These tasks may be based on information and quantities obtained in other subjects. Therefore, we can also weave the topic into classic text tasks.

In addition, the topic of graph theory and probability calculus provides an opportunity to discuss the same problem. We can perform calculations based on network topologies learned in computer science lessons. Imagine a complex, interconnected graph with a multi-star or circular topology. The cost of the edges should represent the probability of information exchange between the given endpoints. Designate different peaks as information transmitters, and then examine to which peaks the information is likely to reach. Such and similar tasks are a good illustration of the importance of generating information and publishing it.

Science and geography - Biology, Chemistry, Environmental Education, Geography, Natural Sciences, Physics, Integrated Science

In the case of the present subjects, the most important thing is to clarify where our digital devices, as well as the server parks and network devices that exchange data between them, get the energy used. physics and chemistry provide an opportunity to understand the environmental impacts of each energy solution in terms of energy investment and gains. Comparing individual power plants (coal-fired power, hydropower, wind power, nuclear power, etc ...) is also a great opportunity to use either group or project work.

In addition to geography lessons, we can compare which countries rely on each type of power plants to extent. Then we can estimate which areas cause a more or less environmental impact with the same amount of data traffic.

Of course, green informatics can be present not only in the above-mentioned subjects. However, we found the above subjects and the mentioned possibilities to be the most important in order to develop the appropriate problem sensitivity.

DIGCOMP 2.1

The first version of DigComp (Carretero, Vuorikari, & Punie, 2017) was launched in 2013 as the European Framework for Understanding and Developing Digital Competence, which describes the content of digital competencies that are currently considered relevant to EU citizens in the form of learning outcomes. The latest version was released in 2017 (Carretero et al., 2017). It includes a self-assessment table that proposes digital competence areas for four skill levels (foundation, intermediate, advanced, highly specialized), a framework that defines related competencies for each area, and a general description of each competence along with the descriptors at 4 levels, respectively. It provides examples of knowledge and skills elements, attitudes and applicability for different purposes.

We meet green ICT in the Security Competency area, which includes Device Protection, Personal Data Protection, Health, Digital Wellbeing, and Environment. This latter competence covers the following areas of competence.

We meet green ICT in the Security competency area, which includes

(1) asset protection,

(2) personal data protection,

(3) health, digital welfare and

(4) environment.

The latter competence covers the following areas at the following skill levels. People with a basic level of digital competence are able to recognize the simple environmental impacts of digital technologies and their use with the help of, and mostly on their own and occasionally, the right help.

People with intermediate digital competence

- On their own, when solving clear problems, they are able to point out the well-defined, routine environmental impacts of digital technologies and their use.
- On their own, according to their own needs, when solving well-defined, non-routine tasks, images discuss how to protect the environment from the effects of digital technologies and their use.

Advanced people

- They can even help others by presenting different ways to protect the environment from the effects of digital technologies and their use.
- According to their own and others ?needs, they are able to select the most appropriate solutions in complex situations to protect the environment from the effects of digital technologies and their use.

People with a master's level digital competence

- They are able to integrate their knowledge to develop professional practice and knowledge and to help others in environmental protection.
- Able to share organizational information in the course of his or her work using social media.

People at the highest master level

- Able to develop a solution to complex problems that are not fully defined in detail, how to protect the environment from the effects of digital technologies and their use.

DIGCOMPORG

DigCompOrg (Kampylis, 2015) was first published in 2015 (following a decision of the European Commission in 2011) which identifies a total of 15 subtopics across 7 topics which define 74 descriptors, providing the school's digital maturity areas. Based on this framework, several countries have developed self-assessment tools to measure school digital maturity. The indicators below include some elements of green ICT, end-user awareness, green use and environmentally friendly power management.

The focus of the dimension of "teaching and learning practice" is to encourage and measure the development of teachers and students digital competencies. This sub-area highlights the need for students and teachers to have advanced digital competencies in order to use technology appropriately in learning, teaching, assessment and management.

It sets out the institution's responsibilities for safe use. In this area, safety, risk awareness, responsible behavior descriptor describes that security is part of the digital competence of educators and learners and that they are aware of the risks and standards of behavior in the online environment.

The dimension of "infrastructure" describes how physical and virtual learning spaces support learning in line with the digital age. The physical and virtual space of learning reflects the educational philosophy of the institution and the pedagogical trend they follow. The learning environment itself influences the way of learning, is able to shape it, so it is shaped with great care and according to the planned ways of learning and teaching.

Related to this The planned and efficient acquisition of assets descriptor deals with how consciously the general and special needs of the digital learning environment are designed (e.g., subject-specific or professional software, special workstations) and the provision of appropriate services. The framework describes that an ideal solution would be to make a plan for the procurement of the network, devices, and software based on life-cycle calculations of the devices.

Conclusion and good practices

Based on the sources analyzed in the study, it is clear that the topic is embedded in education regulation documents in the international regulatory environment, but at the domestic level, it still does not pay sufficient attention to raising environmental awareness through the use of digital tools and IT systems. At the same time, a conscious, critical approach can be developed to reduce the amount of education and CO_2 emitted by those involved in education. While not exhaustive, we recommend that you consider the following criteria when using online learning materials!

- Before creating new content, make sure you are not creating redundant material! In terms of content or methodology, does the newly created material add any new value?
- The main strength of online learning materials is overcoming distance and time. Let's consider whether the target audience is really out of reach from these points of view?
- For online, automated test completion applications, is it worth considering whether the time it takes to create, edit and complete the test will really reduce the time and energy you spend on it?
- Instead of streaming or regularly downloading, it is advisable to download the content once and store it on a local medium.

If we take the above criteria into account, we can be sure that we have done at least as much as we selectively collect household waste to protect our environment and reduce CO_2 emissions.

At present, in the domestic context, interdisciplinary research based primarily on empirical data is not available on the topic. In the near future, we would like to fill this gap with a large-scale basic research based on a combined paradigm focused on the knowledge and attitudes of domestic public educators about green ICT. This study was prepared in preparation for this by presenting and analyzing the theoretical background and the current domestic and international situation.

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