PHD DISSERTATION

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TEACHING DISRUPTIVE TECHNOLOGIES IN A VIRTUAL EDUCATIONAL ENVIRONMENT USING THE EDU-COACHING METHOD

PHD DISSERTATION

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1 Introduction

1.1 Goals and Structure of this Dissertation

Scientific progress, technological innovations and disruptive technologies will fundamentally determine the conditions and the quality of human life in the next decades. Since the beginning of the 21st century, an increasing number of studies have focused on forecasting development of informatics and technology created by the dynamic evolution of the information and knowledge society.

Forecasts predict the acceleration of scientific and technological advances – a process that is already tangible today. Raymond Kurzweil drew up the generalisation of the Moore's Law in his essay „The Law of Accelerating Returns" published in 2001. He extended the exponentially increasing pattern concerning the complexity of integrated circuits drawn up in the law so that it is valid both for the technologies prior to the appearance of the integrated circuits and those appearing in the future.

It describes that as a technology approaches the boundaries of its potentials, a new technology appears which facilitates the continuously accelerating development which triggers the more and more frequent ranges of paradigm shifts. According to Kurzweil essay: „The analysis of the history of technology points out that the technological change is exponential in contrast with the present 'intuitive-linear' views. Thus, in the 21st century, we will not experience a progress of 100 years, but –with the present pace – a progress of 20 000 years. The benefits and results of the progress, such as chip speed and cost efficiency will also increase exponentially."

More and more new fields of science are appearing, among which the Cognitive Infocommunication (CogInfoCom) [7] [8] searching the trends of the progress in informatics calls the attention to the significance of the necessity of access to infocommunication. In the near future, the internet will become a network of not the computers but of the people using them, the interlocking of the telecommunication, the informatics and the media will occur. Such informatics systems will be created which will implement the communication between humans and the control of systems where the human and the ICT are not separable. This is particularly specific to the students belonging to the CE generation [7] who already live in a „human computer interaction reality of life", in this human-ICT combination. My research focuses on the pedagogical implications of CogInfoCom.

While the plastics changed the 50s, television the 70s, microelectronics and computers the 80s, 90s, today it is difficult to distinguish one specific era in advancement. Nowadays numerous different technologies are present at the same time and are changing our society, the opportunities and the living space of the growing-up generations, the requirements of the labour market, our educational system, all aspects of our lives.

In many areas we can see a technological breakthrough and that those business actors can survive in our fast changing world which can adapt to the appearing technologies with due flexibility or which can achieve to be able to affect the future technological innovations.

In the globalizing economy, governmental leaders, market actors and employers are hungry for innovation – so as to enhance efficiency and productivity -and increasingly require a global integration of technological innovations in educational material, and in the training of innovative, creative, problem-solving production and developing engineers. There is a growing demand to create a high quality higher education, and in accordance with this, for supervising the development of learning material content and methods applied in higher education for engineering. This includes a much wider application of up-to-date technologies and more direct influences from new scientific developments.

Motivation

As Head of the Faculty working in the higher education of engineering, day after day I experience it that the globalizing economy, the mobility of the workplaces, the acceleration of the technical and technological development have put the institutions of the higher education in a competitive situation. The service providing role of the higher education due to the market-oriented character of the higher education for engineering has appeared and become more emphasized. Service towards the students as future employees and towards businesses in the market sector as employers. Nowadays it has become inevitable to provide new solutions for the new types of market challenges in the global system of education, thus in the higher education of engineering, too.

More and more disruptive technologies appear every year on Gartner's Hype curve, so the competitiveness of higher education for engineering can be maintained if it can provide this extra knowledge for students necessary for innovation in this fast changing world. In engineering training, the efficient teaching of disruptive technologies bursting into the market requires the application of new ways of pedagogical methods, efficient time use, the application of techniques and technologies suitable to the digital life space of CE generation

students studying in the higher education. This is why I chose to study the appearance of the disruptive technologies - which have appeared more and more frequently from the end of the 20th century - in the teaching materials and educational environment of generation Z engineers.

1.1.1 Objectives

My objective was to explore the effects that disruptive technologies have on higher education and at the same time to create an educational environment and method serving the needs of CE generation students in engineering higher education. My objective was to shift the present frameworks of this domain to the Cyber educational space and to justify the grounds for existence of this VR environment.

To reach the above-mentioned goal, I am analyzing the effects the disruptive technologies have on the educational environment and methods applied in the higher education, and I am studying how the disruptive (creative destructive) effect prevails in the higher educational environment. I am trying to find answers to whether the new technologies will transform the current model of higher education in the future, whether and how they will replace current educational methods and scenes. Currently a strictly restricted knowledge material focusing on the field of engineering is in the centre of learning material. I search for IT solutions which facilitate teaching the disruptive technologies by combining the above knowledge material with the mainly project-based and multidisciplinary knowledge appearing in market practices. I place all this into an enjoyable educational space acceptable for the CE generation students and try to implement an even more efficient knowledge transfer.

1.1.2 The current actuality of the topic

Nowadays two factors influence the role of higher education, the business sector and the innovative technologies. The basis of the economic performance of a country is provided by the educational system. The education and the professional preparedness of the population determine the settlement of the manufacturing companies and the launch of the production.

According to the higher educational strategy „The shifting in the higher education – The trends of developing the performance-based higher education", one of the objectives of the economic strategies of the Hungarian Government is to make Hungary - with the strengthening of its industrial manufacturing central role – into an innovational centre in the future. Thus, Hungary should move from being a manufacturing centre producing traditional

products in the region towards production requiring high value-added research and development. The industry demanding high value-added research and development potentials requires the engineers to have high innovational skills. One of the most significant type of the industrial innovation is the disruptive innovation. Thus, the indispensable prerequisite of the appearance of the investments in Hungary is that the investors find valuable work force in the given region.

By valuable work force they more and more often mean creative, motivated, innovative engineers with problem-solving and good presentational skills suitable for team work who are well-informed about the world of technological innovations and the disruptive technologies. The companies - in contrast to the present practices - require more experience and „ready engineers" on receiving their degrees whose professional training they do not need to spend either time or money on before they start to work. In the society of the 21st century, the emphasis is on fast, efficient, complex problem-solving, flexible work, good communication skills, appropriate information management, aptitude for team-work, creative and productive use of technology, and the ability to produce new knowledge [28].

The political objective of the European Union is to support the implementation of the national operational plans and to facilitate the solutions of the common challenges. The Europe 2020, the ten-year-long growth strategy of the European Union - beyond the developmental objectives - deals saliently with the sustainable development of education, research and innovation. As part of the 2020 strategy, the framework of the successful cooperation in the global competition, the technological development and the resupply of qualified work force was drawn up in the Education and Training 2020 strategy (ET 2020) whose 4 salient objectives are:

- creating life-long learning and mobility
- increasing the efficiency and the quality of education and training
- integrating innovation and creativity – including business innovation and creativity – in education
- facilitating social cohesion and active civil involvement.

In today's technologically and economically fast changing, globalizing world both the governmental leaders and the business sector demand the need for change concerning the higher education more and more dynamically. The business sector is trying to react to the fast changing environment by developing more and more radical innovations. The radical innovations lead to disruptive technical and industrial development [70].

According to the results of international studies, amid the continuous and rapid expansion of knowledge, a significant change can also be seen in education [96, 107]. The reason for a gradually occurring paradigm shift is that the new technologies have fundamentally changed the access to information so it is not locked up between the walls of the institutions. The world is just a few clicks from the students which they can access with their smart mobile devices regardless of space and time. They can develop their knowledge in a personalized informal learning environment [30]. At the same time, the actors of the business sector criticize the preparedness of the employees graduating in the higher education so it has become necessary to investigate the cause of the lack of preparedness and to specify the appropriate strategies.

1.1.3 The structure of the study and the methodology of the research

In my empiric research I applied the inductive, correlation-exploratory research strategy. I accomplished the written survey with questionnaire surveys chosen from the exploratory methods. I tried to find out whether my hypotheses were correct or false by analyzing the collected data, investigating the statistical correlations, then applying interview surveys. To create the theoretical bases I studied the national and international academic literature. The theoretical base deriving from the academic literature was supplemented by the 20-year-old experience in higher education related to the methodology of informatics education which I have gained as a lecturer working with educational methodologies, particularly Problem-based learning, Project-based learning and methods developing student's creativity, such as Creative-productive learning method in the education of engineering and informatics.

The study consists of 4 major parts.

The first part is the introduction which contains the objectives of the study and the presentation of the actuality of the topic.

Chapter I: deals with the brief and comprehensive analysis of the scientific fields affected in the research. Due to the interdisciplinary feature of the topic I am presenting the research results of the scientific fields seemingly independent of one another. I surveyed the academic literature concerning the disruptive technologies of the research work. Following that my study of the academic literature deals with presenting the relevant methods applied in the science of the future research. In the sub-chapter titled „The technology-based society" I dealt with the brief presentation of the academic literature related to the generation theories, in particular with the digital life of the different generations. As a closing of Chapter I: I

continued to study the effects the technologies have on pedagogy, the results of thinking about the future of education, the academic literature related to the didactical paradigms also including the opportunities offered by the Virtual spaces and summarizing the learning theory justifying the Cyber Learning solutions.

Chapter II. of the study contains the presentation of the theses and the results. The results of the lecturers' deep interviews applied in the research and the questionnaire surveys used in the research, the developed edu-coaching method and the VR learning environment applied in the education of the disruptive technologies accomplished as a pilot project are presented. In chapter 2.1 the international questionnaire is presented which I made based on the questionnaire titled „The future of higher education: How technology will shape learning" published in „The Economist Intelligence Unit in 2008 whose aim was to collect objective information concerning the appearance of the disruptive technologies in the higher education related to thesis I. Chapter 2.3 presents the questionnaire concerning the digital life of generation Z students studying at the Faculty of Engineering and Information Technology at the University of Pécs which was based on the research questionnaires used by the American Common Sense and the EU Kids online research carried out in 2011-2012 initiated by the European Union. As a next methodological element I am presenting the results of the lecturers' deep interview I carried out. The results of the generation questionnaires and the lecturers' deep interview facilitate the verification of thesis 1.1. and 1.2. In the next part, to justify thesis 2., the results gained by applying the Glenn's Future Wheels method are presented.

Chapter II: contains the results of the development of the edu-coaching method. As the closing of chapter II: a pilot project is presented.

In the third part, the study deals with the summary of the research results, their utilization, application and with the presentation of the further research fields serving the sustainability of the research. I present the connection between the dissertation and the CogInfoCom research.

1.2 Antecedents – Theoretical Results

The theoretical background of the study is based on several pillars: besides overviewing the disruptive innovation based on the disruptive technologies, the innovation-spread, the life-cycle analytic background of the technologies and the acceptance models, the international educational developments make up the basis of my empiric research.

1.2.1 Disruptive innovation

From the end of the 20th century, more and more studies have been dealing with the more and more numerous disruptive innovations, and within these with the targeted disruptive technologies and their effects made on the society.

The word disruptive, - which Clayton M. Christensen, the professor of Harvard University created in 1997 and later published in his book titled 'The dilemma of the inventor', refers to the creative destruction. An expression used for applying solutions in which the new technologies and business models fundamentally transform or replace the existing methods and this way they influence the business value of the products and services.

Innovation is a relatively new concept. Hardly any studies were made about it until the end of the 20th century, however the topic has become significant recently. The most often used definition of the word innovation originates from Schumpeter, that is innovation means the new combination of the production factors [135]. This definition later served the basis for OECD where a more comprehensive definition was created for innovation.

According to the definition of the European Union: „Innovation is the process of knowledge application, reforming and increasing the products and services and their markets, applying new procedures in production, in distribution, in the market labour, in management, in organizations and working conditions, the expansion and reform of the professional knowledge of the labour force" (*EC, 2004.*). Innovation, by which we may mean satisfying the customers' demands at a higher and higher level, can mean product development, technology development and organization development, can be a continuous development or skyrocketed, comprehensive strategic innovation [21].

The Innovator's dilemma [23] refers to the decision between development based on the known methods or the paradigm shift. According to Christensen, innovation has two forms depending on its circumstances:

- Sustainable innovation which wants to provide a greater performance to the target-oriented customers with high demands, usually at a high price. These innovations are usually developed by big companies. They have financial, technical and human resources for development, for improving the already existing technologies.
- Disruptive innovation is where creating markets for satisfying new customer demands determined by new rules and not creating old markets is happening. Typically the start-up businesses have „specialized" for the disruptive innovations.

1.2.2 Disruptive technologies

Radical technical innovation, especially the so-called disruptive technological development usually evolves with a longer research. Very often a long time elapses between the birth of the theory and its proving and implement. Rather a lot and often costly experiments, test production and testing prove that the technological solution is really possible. And after a shorter or longer time the disruptive innovative technologies typically change into a sustainable cycle.

The word technology was added to the Hungarian word usage with the German meaning „manufacturing procedure". In economical and market circles this meaning has been changed for the English meaning which is „The system of professional knowledge and tools that makes satisfying the needs possible" [123].

Concerning the objectives of the technological development we can distinguish two groups.

The first is to maintain sustainable development, that is the better utilization of scarce resources such as the alternative energy resources, waste usage, environmentally-friendly architectural technologies, or the development of the environmentally-friendly informatics devices suiting the criteria system concerning the informatics devices of the EU GPP [46].

In the second group we can find the innovations aiming at improving the quality of life, the devices serving speed and parallelism [43], such as in transport the driver's navigational, PDA-NDA, robotized systems, nanotechnology, the memristor, the Internet of Things and we could still continue the list with the disruptive technologies grounding the disruptive innovations.

It is clearly visible that today these technologies have a mostly digital characteristic and are expected to ground the technical cycle change.

The life cycle of the technologies

During studying the diffusion they fundamentally investigate the process when innovation spreads in the society in a communicational channel in a given time. The studies of diffusion have made it possible to follow the changes caused by the innovations in the society and the effects of the social forces on innovation and its spread. Everet M. Rogers and Frank Bass are the first representatives of the innovation spread models [39]. According to Rogers' definition, the spread, diffusion of the innovation is the temporal process during which a new product becomes gradually accepted in the target market by the potential customers and in the

entire society [130]. Following their work, numerous technological life cycle models try to measure and then demonstrate the evolution of the new technologies.

The diffusion model describes the spread of innovations with a so-called S-shaped curve (Figure 1). The S curve shows the frequent spread pattern of the innovations. Initially, the number of users increases only in a low pace, then a significant boom comes which is followed by another slow-down after reaching the saturation level. In the initial phase of the spread, the so-called Innovators (2.5 %) start to use the new technology. They are usually more open to innovations, and attribute a special value to the innovations. They are followed by the Early Adopters (13.5%), then by the Early Majority (34%) whose joining in the process of diffusion suddenly increases. As groups of different sizes are concerned, the technological spread is not a linear process [130, 39]. The so-called Adoption Curve (Figure 1.) shows the market adoption of the technology in relation to time. The life cycle of the disruptive technologies and the disruptive innovations is most typically shown in the Gartner's Hype Graph (Figure 1.), so in my study this is presented and applied.

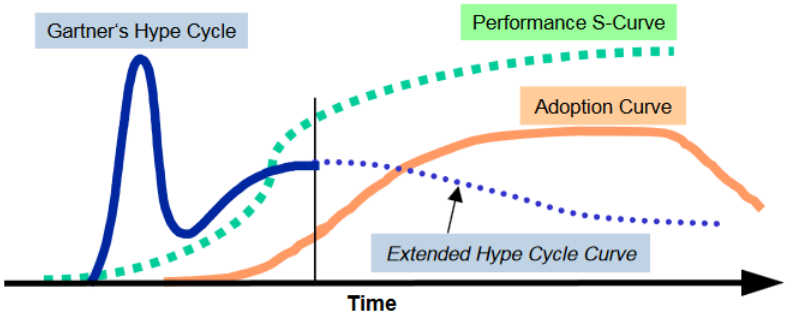


Figure 1:The life cycle of the technologies, [54].

The Gartner advisory firm introduced the so-called HYPE Curve (Figure 2.) in 1995 which presents the developing cycles of each technology. On the horizontal axis of the curve we can find the maturity or development in relation to which the curve shows the adoption of the given technology. The Hype Graph takes a new dimension into the model compared to the other life cycles, as besides the technological maturity it also reflects the human attitudes to technologies (Figure 2). At the beginning of the cycle, the companies and businesses almost do not know anything about the new technology, so they cannot make grounded decisions about the investments, their benefits. However, by the end of the curve, the technology is widely known, although the risk of investment is low, there are a lot of investors on the market, so the expected profit is less promising. The business and social significance of the technology also depends on a secondary factor, namely how attractive the given technology is, and how useful it is for other applications and services. Thus, it is understandable that for

the developing companies, for other service providing companies it is vital to have prepared engineers concerning understanding the more and more numerous disruptive technologies, and measuring their feasibility, or even implementing their own developments.

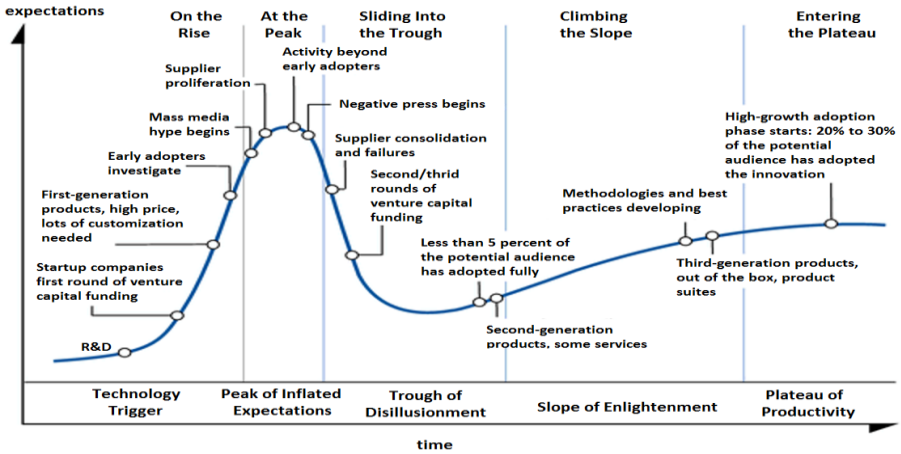


Figure 2:Gartner Hype Cycle for technology, [54]

The hype cycle provides a graphical and conceptual presentation of the maturity emerging technologies through five phases.

Each disruptive technology goes through a similar cycle. After the Technology Trigger, which means the development, due to the Peak of Inflated Expectation a „hype" is made around it. The „Technology Trigger" is the technological launch or breakthrough. A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist (and commercial viability is unproven.) the product is in an experimental phase, as a laboratory prototype. With the increase of the peak, higher and higher expectations appear. The media deals with the technology more and more, the professional public discusses it, so it has a potential effect on the society. The first generation products appear which are often very special or their use is very cumbersome, mainly due to the lack of adjusting the technological environment. The technology is then characterized by a high price margin, the selling price is significantly higher than at the end of the cycle. The venture capital investors closely cooperate with the manufacturers, they set „individualized" requirements for the market launch of the technology.

With the visibility of the first generation products, the first problems, the deficiencies are also published. The failures are always publicized greatly, so the „Trough of Disillusionment" happens. Due to the initial disillusionment, the technology is significantly less published, or for a short or long time, it even disappears from the media. The investors are interested in the production, so the developments continue. They usually find a solution for most of the

problems, so viable and efficient products are born. After overcoming the difficulties, a wider and wider circle of the businesses tries to understand the application of the technology, the risks and the benefits. After this, more and more use the technology. This is the phase of the Slope of Enlightenment, then in the Plateau of Productivity phase technology is operated more and more efficiently.

The particular disruptive technologies do not move at a constant/steady speed on the Hype Graph. The progress of some technologies lasts for decades, for example object orientation which was in the scope of the universities and research centres for decades, and after a long preparation phase the development started.

In contrast, the so-called „accelerated technologies" find their place in the market in 2-4 years. The accelerated technologies are characterized by simple use, both on the business and the users' side, high value, the support of several strong manufacturers and their fitting to the present infrastructure. Such accelerated technology is for example the SMS (Short Message Service). The „Long-fuse" technologies can get into focus of attention more often. Figures characteristic to them are for example the sci-fi type of attraction of the technology, as they usually precede their time. Due to their complexity, development is fundamentally scientific and technical, and dependence on competences is high. Acceptance towards the new infrastructure is a long process after which usually significant changes are made in the business processes. The „Long-fuse" disruptive technology is for example an artificial intelligence (AI).

As the prevailing time of the technologies is not at all uniform, so it is justified to integrate them in the training material of the future engineers within the shortest possible time after their appearance.

1.2.3 The effects of the disruptive technologies on higher education and social processes

In the next chapter I am reviewing the studies which scrutinize the effects the disruptive technologies have on the society, education, and especially on the higher education.

Academic literature concerning the acceptance of technologies and the spread of innovation date back to several decades. Publications dealing with the appearance and the spread of ICT devices try to describe the interaction of technology and society with different scientific models from which TAM (Technology Acceptance Model) [38] has an outstanding role. The aim of the TAM model (Figure 3.) - which investigates the acceptance of new technologies,

and the effects the digital environment has on the customers and their habits - is to forecast the user objectives and the social acceptance of the technologies, and to determine the necessary changes for the acceptability of the technology. According to Davis' TAM theory, acceptability is influenced by two factors, utility and simple use, then, if the social intention is given for the use, the use of the system actually becomes a part of every day life after a short time.

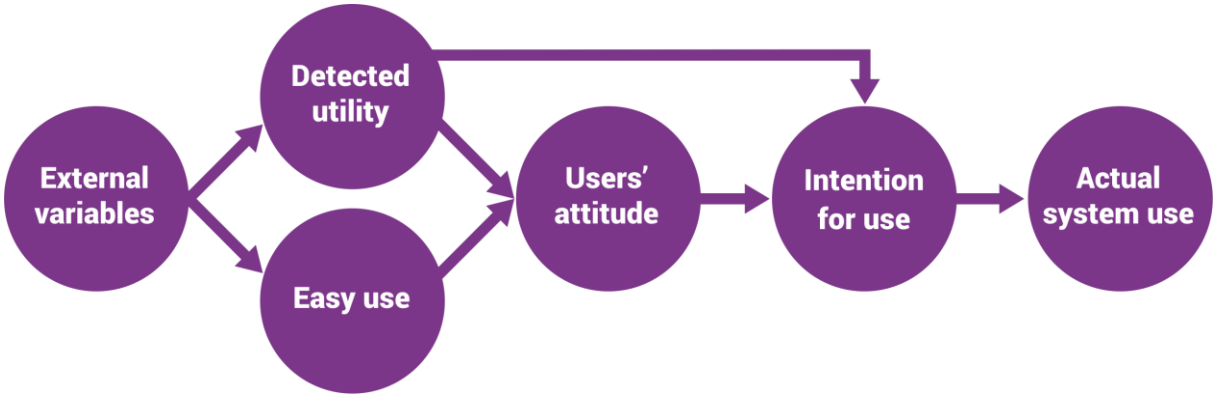


Figure 3:Technology Acceptance Model Source: personal editing based on [38.]

Many of the methods used in the science of future research are suitable to forecast the social acceptance of the technologies. The modern participative methods appeared in the future research from the middle of the 20th century in many different forms [61], however their use has only become widespread in the last decades.

The Futures Wheel [62] is suitable to identify and categorize the secondary and even the further effects and consequences of the events.

The method, as a technique of the systematization of our thoughts and questions concerning the future, can also be interpreted as a structured brainstorming [68].

The Futures Wheel can have several objectives, such as existing trends, considering the possible effects of the potential future events, systematization of thinking about the future events and trends, making forecasts, presenting complex interrelations, visualization of another kind of future research, elaborating multilateral approaches, strengthening the future-oriented point of view, supporting the team brainstorming [63].

During the STEEP - Sociological, Technological, Economic, Ecological or Environmental and Political – analysis, they group the effects to be considered, then based on the analysis they determine the effects of the innovations.

According to the professionals dealing with future research, the Futures Wheel can also be successfully applied in case of the lack of preliminary future-methodological knowledge, if we would like to collect and systematize the effects of an event which has already happened

or is to be expected to happen. It is one of the popular analyses due to its simplicity and easy interpretability. Its main advantage is that it can be applied at any point of the research to understand trends and further events. It is easily adaptable to investigate different situations.

Technology-based society

In the 21st century, more and more studies deal with forecasting the occurring informatics and technological developments. According to Charlie Gere's essay about data processing in the Digital Culture, the network culture extends the informatics era of the digital data processing. In his analysis, he considers the digital change just as much a social economical phenomenon as a technological development. By the 20th century, besides the digital culture the development of the network culture has a more and more significant role. Unlike digital culture, in the network culture information is not so much the result of the relations between the separate processing units, but the result of relations between the humans, the machines, and the humans and the machines. The evolutionary Hype curves after 2010 refer to the fact that the primary technological components shift towards a dynamic technological integration [8].

Producing immaterial information and transmitting it through the network is becoming more and more the dominant organizing principle of the global economy.

The appearance of the new generations in the new generational network

In his work „The Rise of the Network Society" Castells suggests that the result of the series of the technical and technological changes: the change of the capital and the change of the personal behaviour.

In accordance with the networking of the society, several international and national organizations deal with the functions and the research of the Future Internet, as the Future Internet among the infocommunicational technologies as the key technology („Key Enabling Technology") of the 21st century has an effect on the innovation and the efficiency of each area.

The Japanese National Institute of Information and Communications Technology (NICT) presented its vision for the New-generation Networks – NWGN in 2008, which aimed to draw up research objectives and technological requirements to facilitate the implement of future knowledge society. The ITU, the institute of the UN specialized for ICT has made its recommendations in the ITU-TY series for the foundation of the standardization of the future

network. The recommendations of the ITU-T Y.3000 (especially the 3011, 3021, 3031) identify objectives which do not get enough attention during the planning of the present networks to realize the Future Internet.

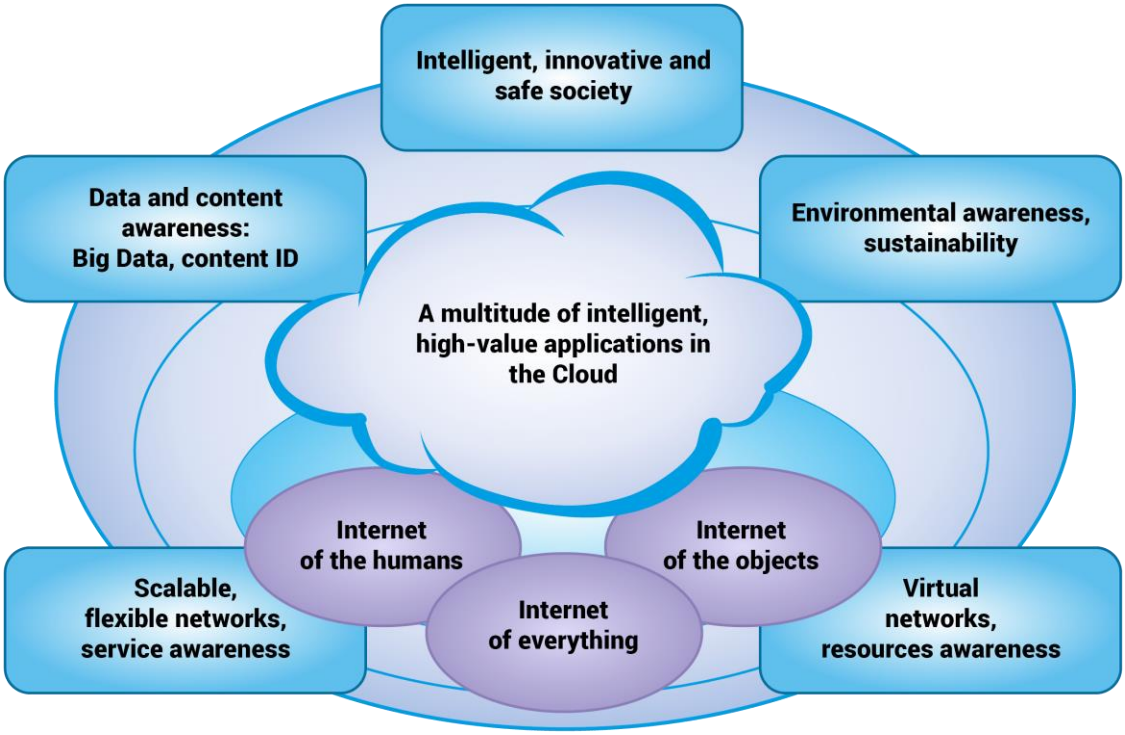


Figure 4:The visions of the Future Internet based on NWGN, FN and FIA, [49].

The European Union pays a special attention to the new generation internet research to which Hungary also joins with an active participation. In 2011, in Hungary the Future Internet National Technological Platform was established and in 2013 for its initiation the Future Internet National Research Program was created organized by the Future Internet National Research-Coordinational Centre. An extensive interest is shown by the fact that 34 institutions joined the programme and 132 research topics were registered by the beginning of 2014. The 2014 FIRCC report shows the results of 83 research from the almost complete collection of the national internet research where the „3D internet and the Cognitive Infocommunication, and „The future internet social applications" topics have a prominent role as the 21st century is an age when the human and the ICT are interwoven. This fusion opens a new age in the digital and network life, creates new disruptive technologies, inspires the creation of new scientific areas. The Cognitive Informatics, or ConInfoCom [7, 8] is a new scientific area which publishes research results spanning through a large scale of several scientific areas. In their focus is the investigation of the cognitive processes created by the close interaction of the human mind and the ICT devices. It makes the generation groups (Baby-boom, X, Y, Z, α) already known in the classical generation theories more complete by

the appearance and defining the newer so-called CE [8], and CCE [145] generations suitable for the spirit of the present era.

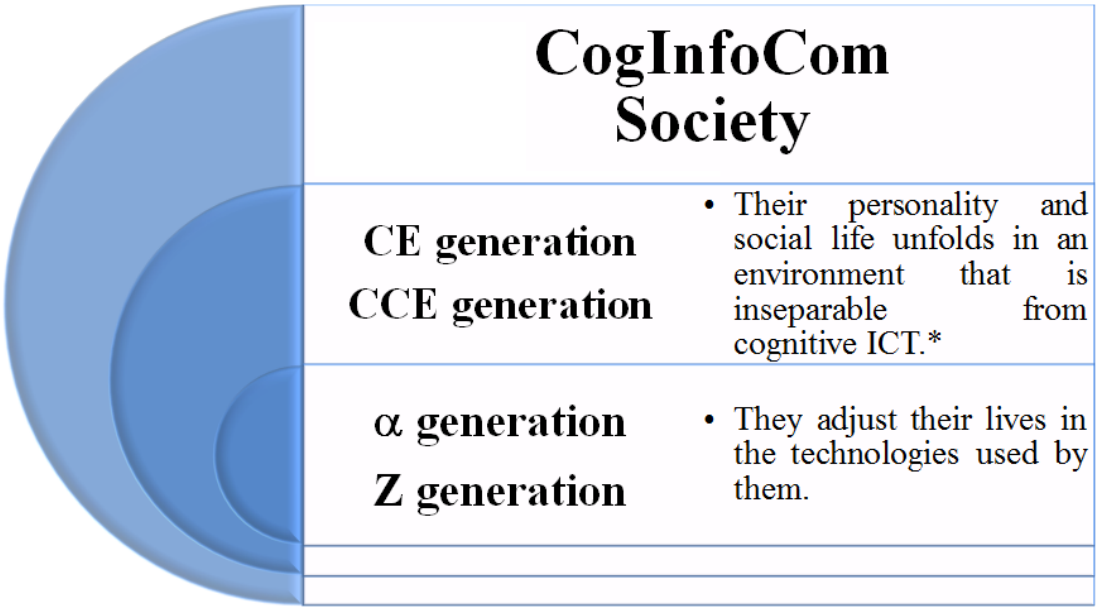


Figure 5: The CogInfoCom society, Source: personal editing based on P. Baranyi and A. Csapó [RC-2]

The skyrocketed acceleration of the technological development and the rise of human average age – primarily in the developed countries – result in the fact that even 5 generations totally different in technological preparedness, skills and even point of view live together which naturally inspires the generation research.

It can be observed that all over the world the researchers deal more and more with the habits and the digital life of the youngsters belonging to the CE, CCE and within that the generations Z and α. The reason is to be searched on the one hand in the numbers, on the other hand in the lifestyle and habits so significantly different from the earlier generations. As a numerical support, I am relying on the different research results as the present generation Z in the USA will amount to 40% of the population by 2020, and with the α generation following them they mean the larger proportion of the society [84]. In Australia, by 2025 more than 35% of the employees will belong to the generation Z [81] and these figures show a similar proportion in Europe, too. The generation which was born between 1995 and 2010 belong to the generation Z who are the students of the present higher education. This generation is significantly different from the earlier generations. They are the „digital integrator" generation. Their life suits to the technologies used by them, they live in an „open book" digital environment where all information is a click in a world without boundaries. They have grown up by being socialized in the world of electronic media devices and technologies, primarily the

opportunities provided by the internet, where short texts, mainly videos and pictures provide information fast, even parallelly and straightforwardly. „While in the life of the earlier generations an easily distinguishable real and online identity existed, for the youngsters today there is only one identity, that is for them the offline and online existence are completely intertwined. For the young generation these two are inseparable, and technology is only the tool of expressing the identity" [142]. The generations belonging to the older social strata are amazed and do not comprehend the phenomenon that is why there are so many research results published in this topic worldwide. The generational differences do not only appear in the family but there is a very serious generation gap even in the educational environment. „It also raises the current issue of what skills and abilities are needed to be developed for the more efficient knowledge imaging of the new generations and what methods can lead to success [122].

Concerning the habits of the generation Z, the researchers particularly deal with the internet usage and media using habits, but also their relation and requirements to learning and work are in the focus of attention in several international surveys, like the EU Kids online research carried out by the European Union in 2011-2012 and the research questionnaires used by the American organization Common Sense. In several national and international articles we can also read about the investigation concerning the digital competences of the lecturers and students studying in the higher education and about the Digital Life Gap shown as a result of investigations. „Digital immigrants" and „Digital natives" are expressions spread by Marc Prensky. [124]. The table below shows the characteristics of these two groups.

	Digital immigrants	**Digital natives**
Stimulus intake	limited number of sources, linear, fixed route	several sources, hypelinks, random discoveries
Stimulus processing	putting in context	insufficient conceptual frame
Attention	concentrated, focused	multi-channelled, shared, multitasking
Emotion handling	frustration tolerance	emotional incontinence
Time management	preparing for any case, able to retain	finish just in time, but getting prompt confirmations
Language use	formed	slogan-like , situative
Network	few strong connections	several weak connections
Learning	tiring	embedded in process, natural
Knowledge	lexical and red-letter day knowledge	promptly usable, entertaining
Attitude to authority	respect	media stars, celebrities

Table: 1: The characteristics of the digital immigrants and the digital natives, [11].

The effect of technological development on pedagogy

The technological development undoubtedly has an effect on the social processes, on the labour market requirements, thus on education. The appearance of the new technologies, the more and more widespread use of the internet and its social acceptance have an effect on the educational environment and also on the contents of education. Amid the rapid, continuous expansion of knowledge a significant change can be seen in education [15], [107]. The cause of the paradigm shift is that the new technologies have changed the access to the information, thus that is not closed between the walls of the educational institutions. The world is only a few clicks, moves away from the students which they can reach with their mobile smart devices regardless of time and space.

The Schooling for Tomorrow project of the OECD was launched in 1997 at an international conference organized in Hiroshima, then the OECD - in cooperation with the Centre for Educational Research and Innovation (CERI) - with a wider and wider international participation is trying to create a systematized knowledge base and tool park for the decision-makers in education politics for thinking about the school of the future, for the realization of the educational innovations. Pointing out that nowadays the new technological bases facilitate new learning forms, expanding the requirements concerning learning itself. The program of the OECD helps building out the decision-making strategy and at the same time it widens the chance of comparing the developing trends and experiences with the involvement of international expertise not only in space but also in time.

In 2003 Benő Csapó, one of the Hungarian researchers, wrote in his study that the appearance of the ICT technologies strongly influenced the education, as it claimed new needs for education, on the other hand it provided an efficient toolkit system to increase efficiency. Affected by these, the learning scenes shifted from the formal education towards informal education.

At the beginning of the 21st century, the „learning society", or better known „lifelong learning" appears as a political objective worldwide. The lifelong learning is a leading principle according to which the educational system has to be transformed so that the necessary learning opportunity could be available for every European citizen at any time of their lives, which makes it necessary to rethink the forms and dimensions of learning.

The ISTE (International Society for Technology in Education) has worked out so-called standards for the learning and educational processes of the digital age which the competence family called NETS (National Educational Technology Standards) contains [88]. Its

members: for teachers the NETS for Teachers – NETS-T, for students the NETS for Students – NETS-S, for informatics teachers the NETS for Computer Science Educators – NETS-CSE, but it also contains standards for the administrators NETS for Administrators – NETS-A and for the educational assistants the NETS for Coaches – NETS. The ISTE NETS-S specifies the skills which are necessary in the global, digital world for efficient learning and productive lifestyle, such as digital citizenship, critical thinking, communication and collaboration, creativity and innovation or technology operations.

As a result of thinking together about the future of education, many scientific publications have been published. As their summary, I would like to highlight some cardinal changes which have a great significance in the future education. The realization of learning in diverse places and time, the need for personalized learning, the students' chance for free choice becoming stronger, the intensification of the short-term, project-based learning views, involvement of personal experience facilitated by the modern technologies, the ability of successful learning, the change of the pedagogist's role.

From the modern pedagogical methods developed to achieve the above-mentioned goals the gamification, the flipped classroom, the mobile learning, the virtual learning environment are the „disruptive technologies" – based on informatics development -, of the education today whose position, besides many other technologies, in the Hype curve in 2016 are shown in the Figure 6.

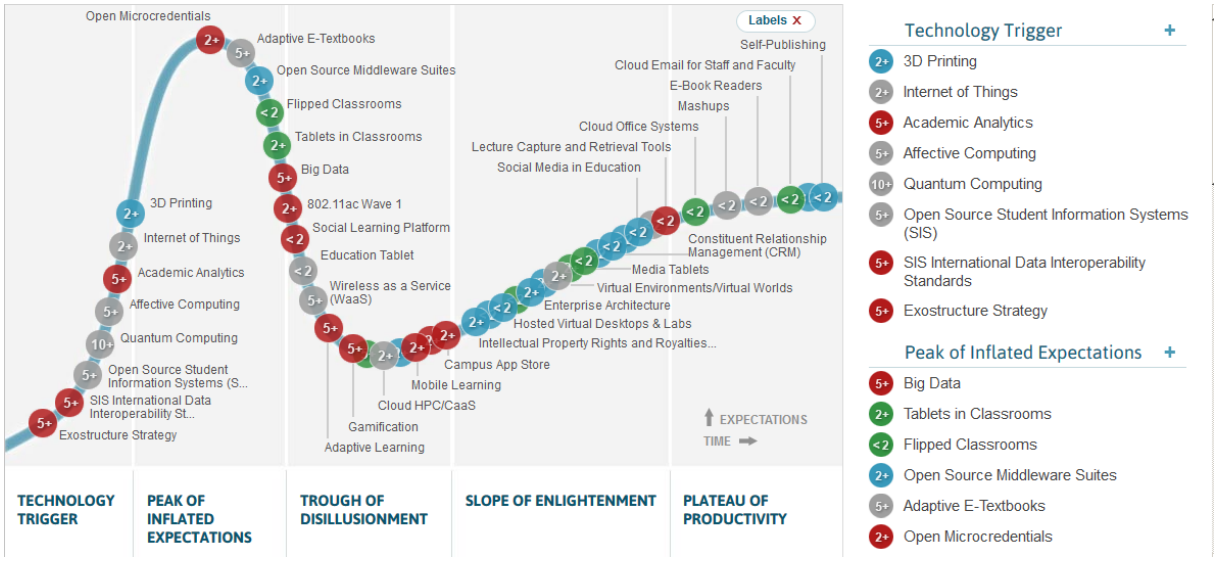


Figure 6: Hype Cycle, The education today [152].

The flipped learning applied in the Flipped Classroom shown in the Trough of Disillusionment phase of the Gartner's Hype curve is a pedagogical approach in which the instruction moves from the learning space of the team to the learning space of the individual, and the group space developed this way changes into a dynamic, interactive learning environment where the lecturer leads the students as they deal with the different concepts while they participate creatively in processing the topic [134].

The international institutions of higher education have highlighted the following motivational factors for applying the flipped learning (each point shows the level of significance):

1. Developing the students' critical thinking, creative problem-solving and understanding ability, and the professional skills of the 21st century
2. Students' participation, commitment and motivation
3. Team-based skills and improvement of interaction between each other
4. Personalized, differentiated learning
5. Being student-centered, motivating the students to possess the learning process
6. Developing contacting skills, the ability for freedom, they should enjoy learning, improving the results of studying
7. Handling absence, ability for collaboration, compensating the disadvantages due to the limits of the classroom [78].

Among the disruptive technologies of the education today, the Gartner's Hype curve predicts a longer cycle for the different realization of the technical-based learning, such as the Virtual environment, the Mobile learning, or the Gamification. Technical Based learning – TBL means the electronic technical based learning, including the internet, the intranet, the satellite programmes, the audio-videoconferences, the chat rooms, the web contents and the lecturers' CD and DVD applications, but the technical based learning also includes the complete range of the learning supported by the ICT devices and the online learning, including the today so fashionable expression of e-Learning. The technical based learning facilitates the opportunity to access learning regardless of space and time by merging technological innovations appearing in higher and higher number – among them the disruptive technologies -, the realization of individual learning progress, thus it gives space to the spread of the disruptive innovations.

While the studies dealing with the educational appearance of the disruptive technologies primarily write about educational use of the technologies, as new devices, such as in Clayton Cristensen's book titled „Disrupting Class, How disruptive innovation will change the way the world learns" published in 2008, several studies deal with the future of higher education,

the education-shaping effects of the modern technologies. One of these is the study titled „The future of higher education: How technology will shape learning" published in the Economist Intelligence Unit in October 2008, supported by the New Media Consortium which presented a global online corporate survey and detailed interview. Of the 289 executives responding to the survey, 189 participants came from higher education and 100 came from corporate settings. The US accounted for slightly over one-half (154) of all respondents, with the remainder distributed through Europe (69), Asia-Pacific (43) and the rest of the world (23). The respondents agreed that the technological innovation which has been present in the university research for a long time will tangibly change how the universities teach and how the students study. Nearly 63% of survey respondents from both the public and the private sectors say that the technological innovation will have a major influence on teaching methodologies. 60% of the respondents said that the technological changes happening nowadays will change the views of the campuses from a one-dimensional, so-called physical concept to a multi-dimensional (physical and virtual, - online) concept. Thus, online learning will become stronger/more dominant, more and more universities will react to globalization. The American respondents said that overseas presence will be the norm for most American universities. 52% of the respondents said the devices supporting online cooperation will mostly contribute to the improvement of the quality of education. These opinions mean that the school of today has to work in a completely different way than a few decades ago. The concept of learning and education have changed which has to be followed also by the educational methodologies, as successful learning, the marketable knowledge are still the primary didactical aims in the higher education.

Didactical paradigms

István Nahalka [89], distinguished three significant didactical trends by the middle of the 1900s. These can be found in the academic literature as the pedagogy of knowledge transfer, of illustration and of activity. The pedagogy of illustration and activity can be related to the digital age shown in the table below.

	Pedagogy of knowledge transfer	Pedagogy of illustration	Pedagogy of action/activity
Era	**Till the end of the Middle Ages**	**17-19th century**	**20th century**
Source of knowledge	**Pre-processed knowledge, pedagogist, books**	**The objective reality**	**The objective reality**
Mediator of the knowledge	**The language**	**The stimuli**	**The action/activity**
Connection to the digital era	***Mainly exceeded: due to the pedagogical roles and the information sources***	***ICT devices as the devices of illustration; methodological issues***	***Simulations and virtual worlds; learning-methodological antecedents; learning environment as the field of action/activity***

Table: 2 The investigation of the learning methodology of the educational forms supported by the online learning environment [80].

In the second half of the 20th century, from the 1970s, the appearance of the effects of cognitivism on education starting from the scientific field of psychology can be observed.

First, the main characteristics of behaviourism. Behaviourism bases every human psychic function on the logics of the S-R relation where S is stimulus and R is response. In the conceptual system of behaviourism, learning is a result of gaining experience which is different from the creation of S-R relations, and the modification of the behaviour as an effect of stimuli because the relations of the stimuli results in the given behaviour rules out the mental processes between the input of the stimulus and the output of the response from the circle of psychological analysis. According to John B. Watson, considered to be the father of behaviourism, it is enough to create the necessary stimulus environment for learning, that is creating the S-R relations, and then learning will optimally occur. The concept of Learning Environment has become a basic concept of education theory [113]. Another prominent representative of behaviourism is Skinner, according to whom the basis of learning is the operant conditioning. In 1954 he writes in his work „The science of learning and the art of teaching" that the living being learns during its operant conditioning that a given behaviour has unique consequences. Confirmation has a key role in this because the activity which is confirmed will occur in the future much more than the one that is not followed by a confirmation. Based on this, he created the linear programming technique. According to this, for every student the same learning way is provided: that is, in this, the student – during

his/her independent, individual learning – proceeds along on the learning material divided into units so that at each step he/she has to answer a question posed which is followed by a feedback [108].

Congnitivism tries to understand the working of the brain. It puts information processing in the focus of the study. According to its most significant statement the working of the brain is the reception and sending, the processing, the interpretation, the storing and forgetting the sign, the information arriving from outside. According to cognitivism, learning is made up of these partial processes. To increase efficiency, it suggests the use of diverse techniques for directing and supporting the learning process (e.g. attention-focusing questions, highlighting, analogies, pictures, colours etc.)

To understand learning we have to understand the steps of this information processing in which the human brain – just like a computer – can be considered an information-processing structure. The early cognitivism compared the information processing process of the brain to the working of a computer. Ally drew up 9 more areas to define the connection between cognitivism and online learning as regards to the effects of cognitivism on online learning. These are the following:

1. It has to be ensured that the perception of the information could happen so that they could move to the work memory easily
2. It has to be supported that the information in the long-term memory could be recalled easily so the processing of the new information can be more efficient.
3. Information has to be cut in small units to avoid overloading the work memory.
4. Such strategies have to be applied which facilitate the deeper processing so that the information transfer could easily happen (in the long-term memory).
5. It has to be ensured that the education adjusts to the different individual learning styles in all areas.
6. Information has to be made accessible in different ways to support processing and the transfer to the long-term memory.
7. Students have to be motivated to learn.
8. Students have to be encouraged to use their metacognitive abilities because it helps the learning process.
9. The applied learning strategies also have to facilitate that the information could be applicable in different lifelike situations.

Benő Csapó writes in his work „School knowledge” (Iskolai tudás), that „the essence of human thinking is not performing operations, at least not in the sense as the computers perform operations. Its real strength does not lie in the computing and conclusion type of processes but in the knowledge applicable for a specific situation” [82].

According to the learning theory of constructivism, the learning process is an active process in which the student interprets and processes the new information with the help of his/her existing and systematized knowledge. According to this theory, the preliminary knowledge which exists in the form of schemes, scenarios, models etc. plays a fundamental role in the learning process. The deductive elements play a decisive role in the constructivist learning process, the new information is measured with the operation of a wider cognitive frame. The constructivist view is a student-focused view according to which the students have to be helped to construct knowledge themselves [42].

We can mostly support the process of knowledge construction in the online environment if we give the student opportunity for a lot of different interactions (interactions between student-student, teacher-student, student-learning environment, student-information), thus somehow forcing that the control of the entire learning process should be in the hands of the student [106]. The social constructivist theories emphasize that the individual knowledge construction is especially formed in processes mediated socially [144]. According to Vigotskij, the first stage of learning process happens in the interpersonal, social medium, then on the second stage the individual internalizes all that he/she has experienced in the social medium.

1.2.4 The effect of ICT on education

The widespread appearance of informatics-communicational technologies in the education can be traced back for more than a decade. The internet, the web2 applications, the virtual worlds, the simulations or each of the adaptive tutorial systems can strongly support the learning as long as we see them as a cognitive and/or metacognitive tool [64]. The earlier learning theoretical approaches give the basis of the model defined as the digital taxonomy of learning whose starting point is Benjamin Bloom’s 1956 model. Bloom’s taxonomy ranks the developmental levels of knowledge in three categories. These are the cognitive-intellectual, the affective-emotional, or volitional and the psychomotor-motional areas. From the methodological developmental perspective of the online learning, mobile-learning which increasingly spread due to the technological boom, the cognitive model is relevant.

Analyzing the aspect of learning supported by digital devices, [141] made the Bloom taxonomy applicable for the digital learning in the national academic literature which is shown in the table below:

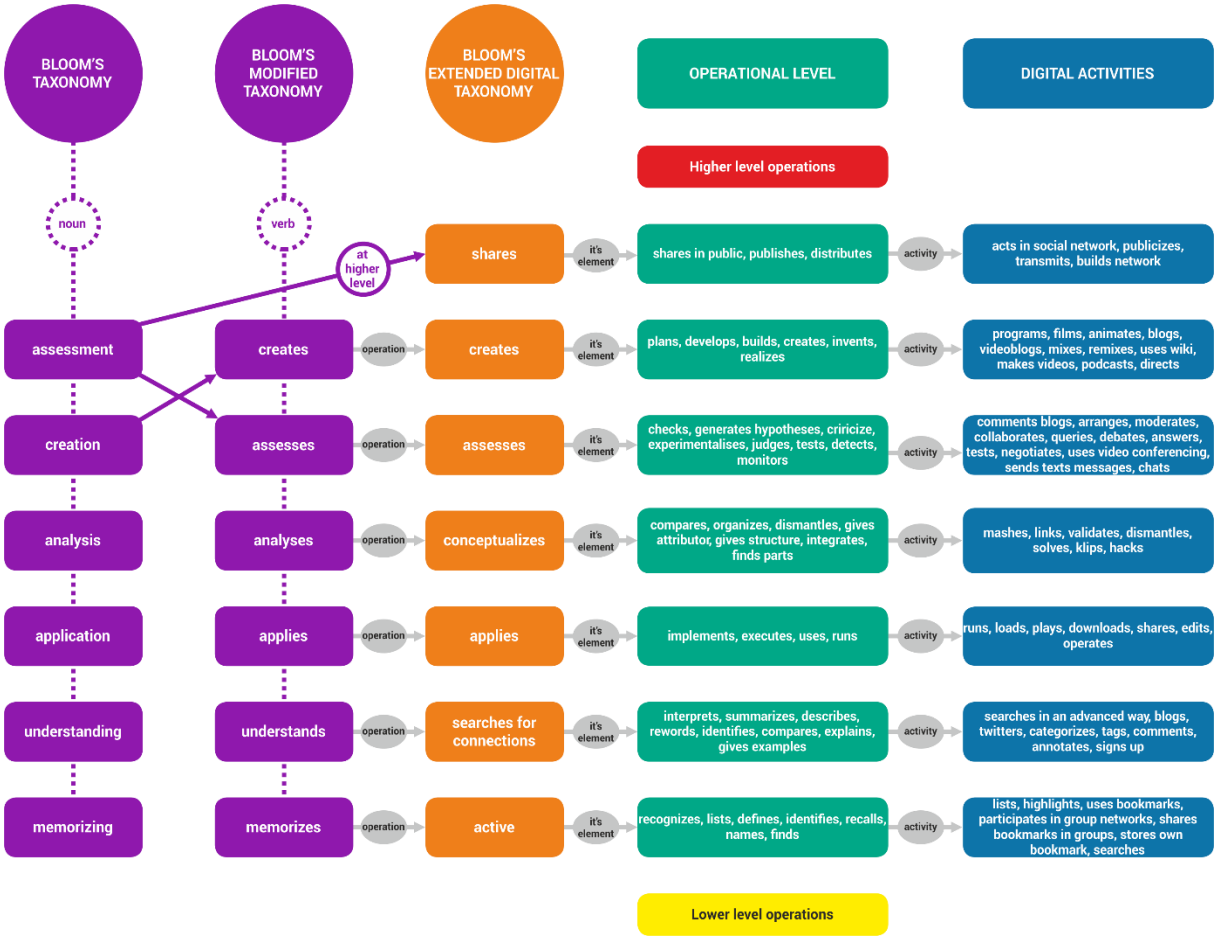


Figure 7: Digital Bloom taxonomy [83], [141].

As János Ollé writes: „Technology was present at the school earlier, it is present now, but its change, development visible during its every day use may have never been so fast. The school probably has to accept that the changes in its surroundings sooner or later appear in its internal world, in the every day practices. The only question is whether the application of technology in teaching-education is forced by the children, expected by the parents or started by the pedagogists." In the light of this idea, I will continue with presenting the research results in the next chapter of my study.

2 Theses, results

2.1 Thesis 1.

The appearance of the disruptive technologies in the learning material of the higher education

Thesis 1.: [RJ-1], [RC-1], [RC-2], [RC-5], [RC-6]

I proved that the disruptive technologies appear in the teaching material of the higher education with a delay. Engineering students often first meet new technologies at the end of the upward curve on the Gartner Hype Curve, after the Technology Trigger, after the Peak of Inflated Expectations, already in the Trough of Disillusionment.

In this chapter I am investigating the appearance of the disruptive technologies in the higher education in terms of the teaching material contents.
I made a questionnaire survey as the tool of the applied inductive research strategy.
The focus group research was the tool of the qualitative research chosen due to the relevance of my questionnaire survey focusing on the introduction of disruptive technologies.
The theory and the application of the qualitative methods show the approach of empiricism. This includes various research methods ranging from observing the participant, questionnaire surveys to interview methods and visual methods. The approach they have in common is that they attempt to investigate the phenomena in their natural environment, or in an artificial environment most similar to it. The aim of the researcher applying the qualitative methods is to understand activities and phenomena from the perspective of the actor, „from inside". With the qualitative methods, a deeper insight in the phenomena can be achieved, with the thorough investigation of few cases the real or false state of the hypotheses can be investigated.
Today qualitative methods are mostly applied in community research or in the investigation of the subcultures, in media or political impact assessments, but its application is recommended in each case when a problem, topic is in the phase of introduction, thus we, researchers are interested in the experimental level of the approach, and in producing the construction of these experiences, such as in case of the introduction of disruptive technologies in the higher education.
The specific research tools in the qualitative research are not fixed a priori, but the investigated question and the target group of the investigation determine what techniques are used ranging from interviews through questionnaires to observation, furthermore, it very often

happens that different methods are applied for investigating the different aspects of the problem in various parts of the research. It is specific of the qualitative research that it is a very personal undertaking, including the part of data collection and data analysis.

I composed my questionnaire concerning the appearance of the disruptive technologies in the teaching material of the higher education based on the questionnaire of the study titled „The future of higher education: How technology will shape learning" published in „The Economist Intelligence Unit" in 2008 supported by the New Media Consortium (Appendix 1.).

The objectives of the international questionnaire survey were the following:

- To determine whether the disruptive technologies appear in the teaching material of the higher education.
- How much later do the disruptive technologies after their appearance are integrated in the teaching material of the higher education?
- How much is the introduction of the disruptive technologies accepted by the lecturers of the institutes of the higher education?
- What educational methods and technologies do the institutes of the higher education which already have experience in the education of the disruptive technologies consider efficient for teaching the disruptive technologies?

In connection with the questionnaire survey I drew up the following hypotheses:

1. The disruptive technologies do not, or only a few appear in the teaching material of the higher education.
2. As long as a given disruptive technology is introduced in the teaching material of the higher education, then it happens with a significant delay, it happens after the Peak of Inflated Expectations of the Hype curve, in the phase of the Trough of Disillusionment.
3. The methods applied during the education of the disruptive technologies differ from the traditional „behind the desk" educational methods.

For the assessment and the statistical analysis of the responses I used the IBM SPSS Statistics 23 programme and the Microsoft Excel 2013 programme.

2.1.1 Disruptive technologies - Presenting the international questionnaire

The questions in the questionnaire can be categorized in six well distinguished groups:

1. Details of the institute of the higher education responding

2. Basic information concerning the colleague responding (gender, age, practice in the higher education)
3. Background information in terms of the educational techniques and methods used in the institutes of the higher education (Targeted questions with Yes-No options)
4. I required responses concerning the appearance of the disruptive technologies in the higher education by applying the 5-scale Likert scale
5. Collecting the specific information concerning the introduction of each disruptive technology where I asked about the year of introduction, the training level subject to the introduction, the scene of the education, the applied pedagogical methods and the achieved results was made in the forms of charts.
6. In the multiple choice questions I searched for the answers to the advantages and the challenges of the introduction of the disruptive technologies, to provide the most efficient methods.

In March 2015, I sent the representative questionnaire survey concerning the introduction of the disruptive technologies in the higher education to 30 universities having connections with the Faculty of Engineering and Information Technology of the University of Pécs, ranging from the USA to Europe and China covering a wide range of international institutes of higher education. By completing the study, 10 institutes of higher education sent back the filled out questionnaires.

I received the filled out questionnaires from the following institutes:

- Metropolitan State University of Denver, Colorado, USA
- Hochschule Heilbronn, Germany
- Hochschule für angewandte Wissenschaften Würzburg-Schweinfurt, Germany
- Johannes Kepler University Linz, Austria
- University Krok, the Ukraine
- Suleyman Demirel University, Kazakhstan
- Yanka Kupola State University of Grodno, Belorussia
- Nanjing University, China
- University of Engineering, Kolozsvár, Romania
- Faculty of Engineering and Information Technology of the University of Pécs, Hungary

The representatives of the institutes of higher education from 10 countries internationally responded to the questionnaire investigating the introduction of disruptive technologies in the

higher education, however, they summarized the experiences of the given university concerning the introduction of disruptive technologies. As 2-5 disruptive technologies were introduced in each university according to the responses, it was realized with the participation of 10-50 students and 2-3 lecturers at each premises, thus the underlying item number meets the focus group research requirements of DENZIN and Lincoln – 1994 most popular at the professional forums [40].

In case of my research field, several international examples justify the statement above, and I am highlighting two of these, both of which are connected to the introduction of a new educational method.

- The article, titled „A REVIEW OF RESEARCH ON PROJECT-BASED LEARNING" of John W. Thomas, a lecturer of the University of California, was published in 2000 in the 21st Century Learning, which investigated the project-based teaching, learning model in a 9-week experiment project merely in 1 institute with the participation of 20 people. Its results were accepted by the professional public opinion, and based on this, further projects were carried out. Its present citation number is: 1485 [140].

2.1.1.1 Assessment of the questionnaire

The proportion of the responses given to the questions is 93.5%. Most often there was no response in the topic of the results concerning the introduction of the disruptive technologies, but occasionally the efficient educational methods of the disruptive technologies were not determined either.

The average age of the respondents was 46 (dispersion: 5.44), their average experience in higher education was 19.5 years (dispersion: 6.5).

All the institutes of the higher education participating in filling out the questionnaire take part in international academic research programmes. 60% of them involves the business partners, mainly as guest lecturers. All of the respondents said that the student-centered educational methods can be found in their education. 80% of them apply cooperative learning techniques and 90% of the responding universities help their students' preparation with their own electronic teaching material. However, only 40% of them apply virtual educational environment.

The universities being interviewed integrated 2 to 5 disruptive technologies in the educational material, average: 3.4. Of the universities being interviewed, 70% embedded the introduction of the disruptive technologies in their BSc trainings and 30% in their MSc trainings.

We requested the respondents' opinion about the significance of the introduction of the disruptive technologies in the higher education by applying a 5-scale Likert scale which is shown in Figure 8.

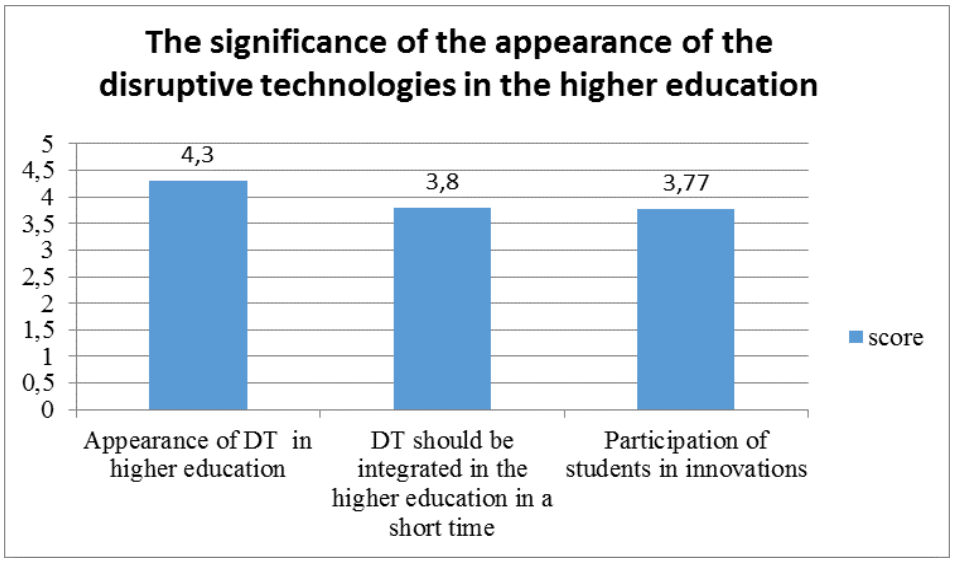


Figure 8: The significance of the appearance of the disruptive technologies in the higher education

We can say that the respondents clearly consider the integration of the new technologies in the education important, concerning the time of introduction the opinion is less concurrent. Some respondents did not consider this question significant at all.

A significant difference can be shown (p=0.00) at the universities where the technological innovations were placed in the MSc training, since they uniformly consider students' participation in the innovation maximally important.

According to the lecturers' opinion, the introduction of the disruptive technologies in the teaching material of the higher education increases the students' creativity, problem-solving way of thinking, job finding opportunities. Besides the beneficial effects it has on the students' preparation, it results a new way of thinking among the lecturers.

The proportion of the responses are shown in Figure 9.

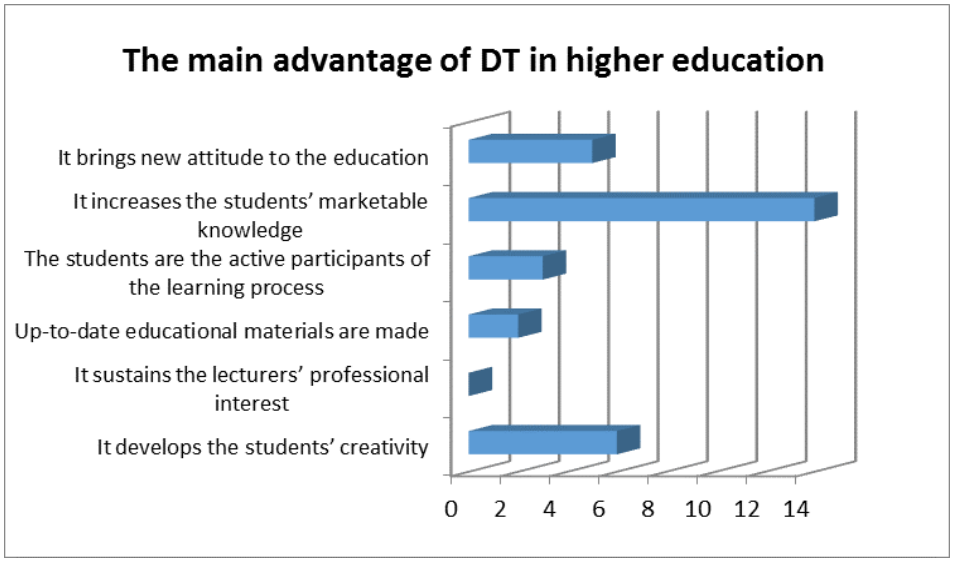


Figure 9: The main advantage of the disruptive technologies in higher education Source: personal editing [RC-1]

Time management meant the greatest challenge during the integration of the disruptive technologies in the education and during the education of the dynamically changing teaching material which is completely understandable as the recognition of the new technologies requires the existence of knowledge spanning through several scientific fields, occasionally also its supplement, thus it is very difficult to hold the transfer of knowledge where the items are closely-related to one another in the traditional 45 or 90-minute lessons. Finding the online internet contents is yet difficult especially in the period following the appearance of the technologies, but with the acceptance and the public awareness of the disruptive technology this obstacle is fended off. Occasionally the continuous updating of the teaching material besides the lecturers' workload appears among the challenges. (Figure 10.)

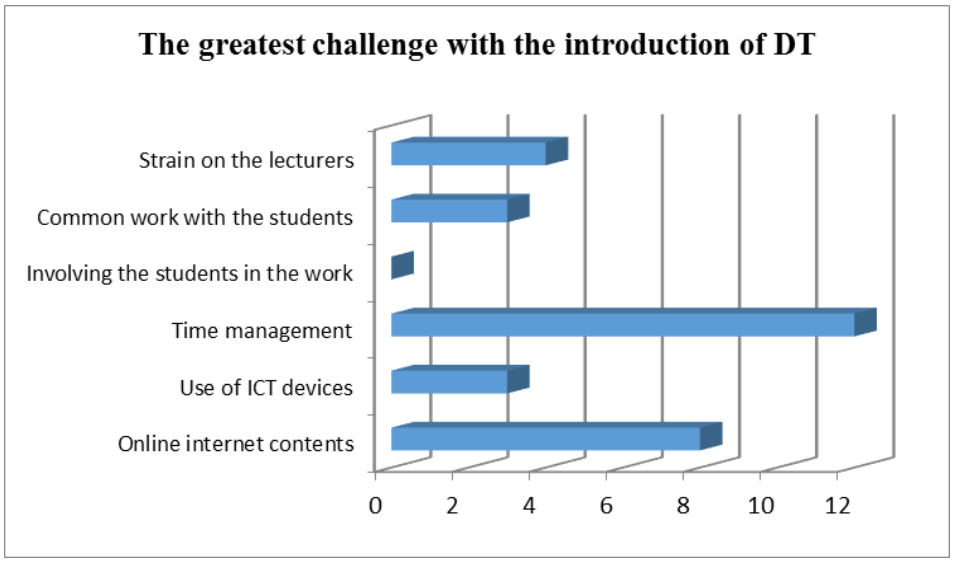


Figure 10: The challenges related to the introduction of the disruptive technologies Source: personal editing [RC-1]

The relatively high proportion of the response concerning finding online internet contents is confirmed by the fact that according to the responding colleagues' opinion the ICT preparedness of the lecturers not being trained for Information Technology and teaching in the higher education is mediocre.

The disruptive technologies most often introduced indicated with a year are the Big Data (2012, 2013), the Cloud Computing (2012, 2013, 2013), the Private Cloud Computing (2014, 2014), the Gamification (2014, 2015), HTML5 (2013, 2013), the Internet of Things (2014, 2014, 2015), 3D printing (2013, 2014), and the Virtualization (2010, 2011).

The Figure 11. shows the position of each technology on the Hype Graph at the first point of time when the institutes of higher education introduced them in the educational teaching material.

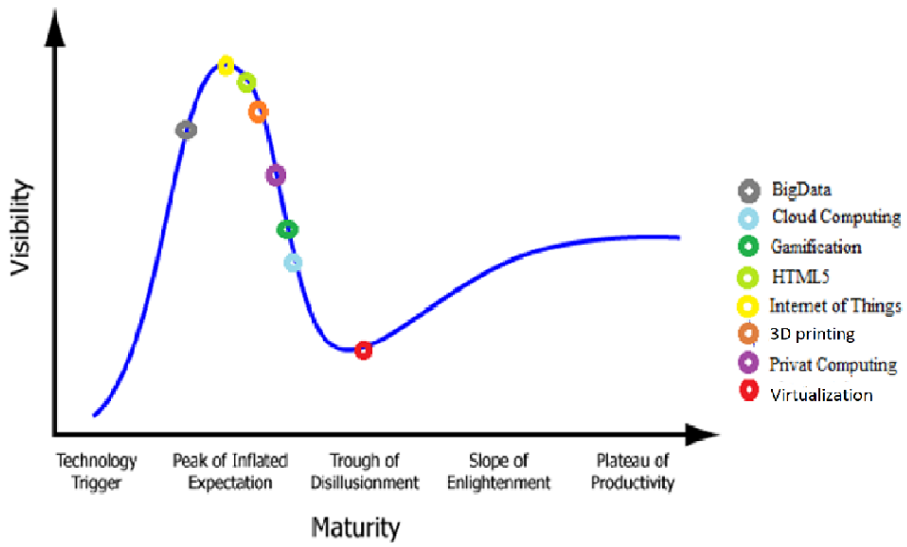


Figure 11: The position of the disruptive technologies on the Hype Graph at the time of the introduction
Source: personal editing [RC-1]

With a representative questionnaire survey I proved Thesis I. and showed that the disruptive technologies appear in the teaching material of the higher education with a delay. The engineer students often first meet the new technologies at the end of the upward curve following the Technology Trigger, after the Peak of Inflated Expectations, already in the Trough of Disillusionment, well-defined on the Hype Graph.

According to TAM's theory, the acception of new technologies, innovative pursuits are influenced by two factors. Utility and simple use. All the respondents agreed with the usefulness of integrating disruptive technologies in the educational teaching material and besides these the needs coming from the globalizing economy also confirm the agreement with usefulness. We can conclude from this that the causes of the late introduction have to be

investigated from the point of view of the simple use, even if here it is not actually about the use and distribution of a clearly technological innovation.
I drew up my Thesis 1.1 and 1.2. to explore the causes of the late introduction.

The ICT device supply of the generation Z students, their internet-usage habits

Thesis 1.1.

I found that there is a contradiction between technologies and techniques supporting learning available in the higher education and the online learning environment applied in the students' practices. I supported this statement with investigating generation Z students' attitude towards technological innovations, their information finding habits, their ICT device supply, their internet usage habits, their demands and requirements set against the learning environment and also the 2D scenes of information finding.

Thesis 1.2.
I showed that one of the causes of the delayed appearance of disruptive technologies lies in the contradiction of technologies in higher education and in students' practices.

To prove my theses 1.1. and 1.2. I applied the descriptive and the connection revealing strategies from the – descriptive, connection revealing, experimental [48] - research strategies. The realization was made by carrying out and assessing the questionnaire survey which was compiled to investigate generation Z students' ICT device supply, internet usage habits, information finding and learning habits, and their attitude towards technological innovations and towards the requirements of the labour market (Appendix 2.).

Antecedents
The University of Pécs searched for the answer about generation's Z science-communicational habits with a national investigation within the frameworks of the TÁMOP-4.2.3-12/1/KONV-2012-0016 project in 2012.
The main questions of the investigation were:

- the judgement of science, scientific results,
- the main peculiarities of the attractive science,
- science-communication – trends and devices,
- time utilization, free time activities,
- content consumption, - preferences,

- values, attitudes, lifestyles,
- media use.

A data base was created at the University of Pécs from the research results of the 2000 participants which supports the later research in connection with this topic.

2.1.2 The generation Z questionnaire survey

The generation Z questionnaire survey at the Faculty of Engineering and Information Technology of the University of Pécs

To compile my questionnaire, besides the research of the University of Pécs, the EU Kids online research carried out for the initiation of the European Union in 2011-2012 and the research questionnaires used by the American organization Common Sense served the bases.

In October 2015, in the survey carried out with the BSc engineer and electrical engineer students at the Faculty of Engineering and Information Technology of the University of Pécs, I asked 100 students aged 18-20 about the science-communication trends, their learning habits, the devices, the technologies applied by them, their time utilization and their media using, information finding and internet usage habits.

As a further methodological element, I carried out a detailed interview survey with university lecturers to find out about their applied devices, techniques and educational experiences gained in the circle of generation Z. I carried out 10 detailed interviews in the circle of the lecturers in connection with the data analysis.

The objectives of the questionnaire survey:

- To gain relevant information about generation Z students' digital life, their information finding habits, about their attitude towards the technological innovations and the research results.
- To reveal the effects generation Z students' digital life, the so-called cyber-life has on abilities.
- To determine whether generation Z students at the Faculty of Engineering and Information Technology of the University of Pécs create an online learning environment individually in connection with their preparation in the higher education.
- To determine how much the online educational scenes offered by the university are accepted in the circle of the students of the institute of the higher education.

– I am searching for the answer to the question what is the optimal learning environment – based on ICT devices and technologies - aimed at the education of generation Z students like?

Hypotheses:

1. The students' ICT device supply exceeds the devices available at the institute of the higher education.
2. The students follow the technical, technological innovations, they require their integration in the teaching material of the higher education.
3. The students' digital life has an effect on the students' abilities (multitasking, fast decision-making, highlighting, connection-finding abilities).
4. The students' time management abilities show a correlation with their different online activities.
5. The students themselves create learning teams and online learning environment in connection with their studies in which they apply the social network and other internet services.
6. There is a difference between generation Z students' digital life space and the ICT-based online educational abilities of the higher education.

Presenting the questionnaire

Our questionnaire contains 114 items connected to closed-ended questions and possible answers to 4 open-ended questions.

The questions asked in the questionnaire can be categorized in eight well-distinguished groups:

1. The demographic background of the person responding
2. Their status in the labour market, the question of employment
3. ICT device supply and internet accessibility
4. Questions aiming at being informed and at attitudes
5. Questions concerning the students' digital life
6. Information finding habits and knowledge
7. Time management and time spent on internet applications
8. The students' requirements concerning the educational environment

Presenting the sample

100 Hungarian citizens aged 18-20 participated (Figure 12.) in the research of the „generation Z"'s learning habits, technical and technological device use. Of them, 12 women and 88 men. The shift in the proportion of the genders suits to the proportion between the genders of the population participating in the higher education of engineering. The students being asked do their studies in the day courses.

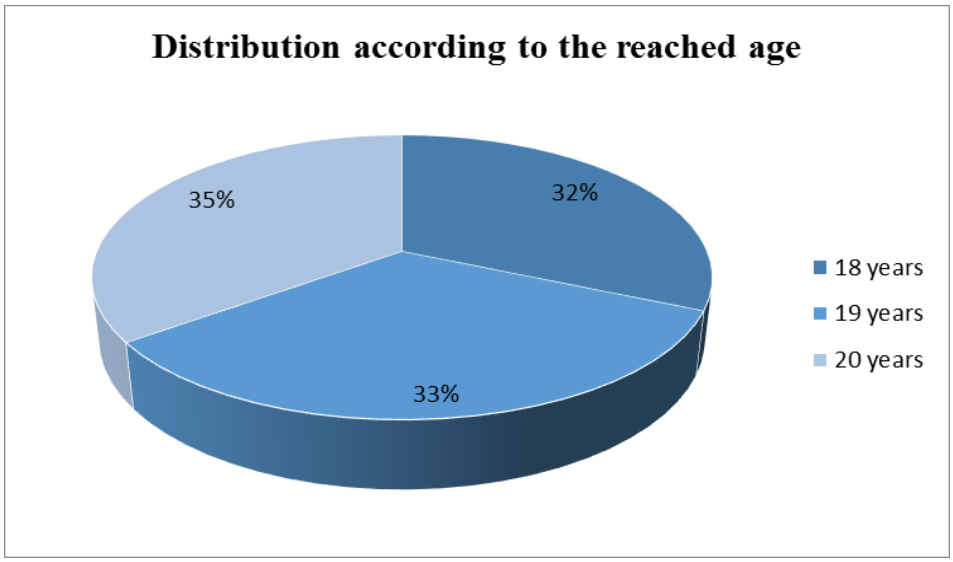


Figure 12: The distribution of the students participating in the survey according to age, Source: personal editing

Assessment of the questionnaire:

For the assessment and the statistical analysis of the responses I used the IBM SPSS Statistics 23 programme and the Microsoft Excel 2013.

During a questionnaire survey we are trying to be able to collect correct data without any measurement errors in connection with the issue. We can categorize the potential errors into four main groups:

- Sampling error: which derives from the fact that each sampling causes error as we will have more inaccurate information about the multitude than if we had asked the entire multitude. Although this kind of error cannot be avoided, but in our case we involved 55% of generation Z students studying in the courses (Computer Engineer BSc and Electrical Engineer BSc) at the Faculty of Engineering and Information Technology of the University of Pécs, so the number of the elements of the sampling facilitated to define the confidence interval at a level of 95% reliability.

- Coverage error: this error happens if the individuals potentially involved in the sample do not cover the entire multitude, we could eliminate this kind of error also by involving a great number of students belonging to the population.
- Nonresponse error: happens when the potential respondents are not willing to respond to the questions concerned in the survey. In our case we do not need to talk about this error as the students involved in the investigation responded to all the questions.
- Measurement error: means the difference between the respondent's real value belonging to the given variable and the value received with the help of the questionnaire. This is the most frequently occurring and at the same time the most difficultly recognizable source of error, thus the one that can be eliminated the least. The „socially acceptable response", the „agreeing response" or the „extreme response" (the respondent chooses the lowest or the highest value regardless of the question) can cause a systematic measurement error. In case of the population examined, the agreeing response gives the highest risk factor, so to filter this out I tried to investigate the respondents' values with more heterogeneous questions when compiling the questionnaire.

I measured the errors of the measurement, I investigated the values of the correlational coefficients and I made the statistical correction of the agreeing respondents' behaviour according to the following.

As the agreeing behaviour can be influenced by a lot of factors, it is a conventional statistical practice that we carry out the correction at the level of the individuals and not at the level of the particular groups. For this, I introduced the following notations:

x_{ij} – means the i-st respondent's real response for the j-st question where (i = 1, 2,…n and j = 1, 2 …J)

$\overline{x}_i = \sum_{j=1}^{J} x_{ij}$ means the i-st respondent's average of the responses given to the heterogeneous questions which is practically the estimated index-number of the agreeing response. If this value is high, then the agreeing response is specific.

After determining the phenomenon, the task is to reduce the effect. According to the frequently applied and at the same time the simplest supposition, the distortion of the agreeing response connects to the questions in an additive way and is regardless of that, which can be appropriate in most cases.

The reduction of the effect happens with creating the value cleaned x_{ij} from the distortion of the agreeing response according to the following:

$$\tilde{x}_{ij} = x_{ij} - \overline{x}_i$$

The check of the effect happens with the analysis of the correlational coefficients.

Descriptive statistics:

Demographic background: 5% of the students being interviewed come from the capital. This low rate is justified by the „draining" power of the capital concerning the enrolment in higher education. Very few students from Budapest apply for a place at the Faculty of Engineering and Information Technology at the University of Pécs. The students of the faculty are typically from the candidates living in less well-off financial circumstances in the Central and Southern Transdanubian regions. The Figure 13. shows the distribution of the students participating in the survey according to their permanent residence.

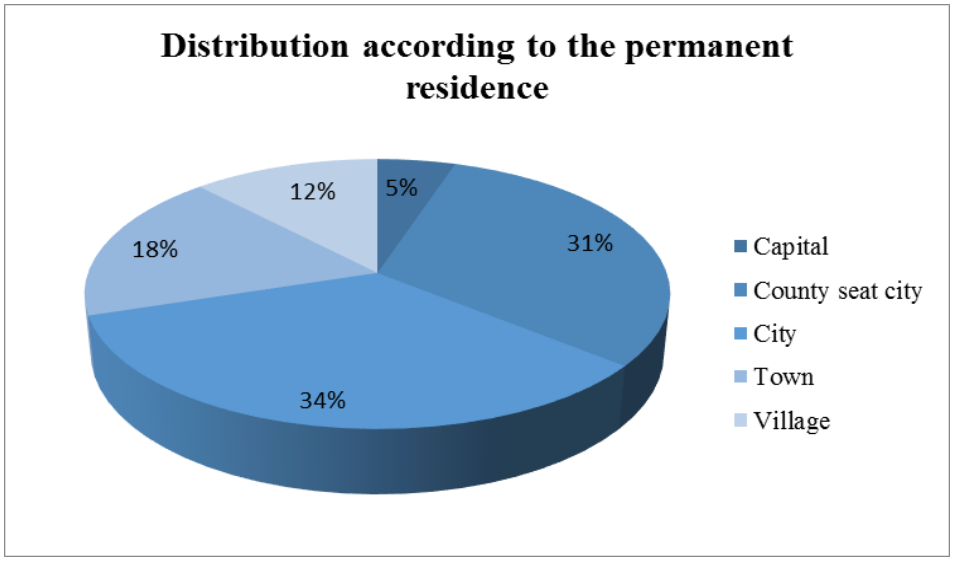


Figure 13: Distribution according to place of residence, Source: personal editing [RC-2]

Most of the students live in dormitories during their university studies, 27% of them live with their parents, 23% of them share lodgings with fellow students and 5 of them live in individual households. (Figure 14.)

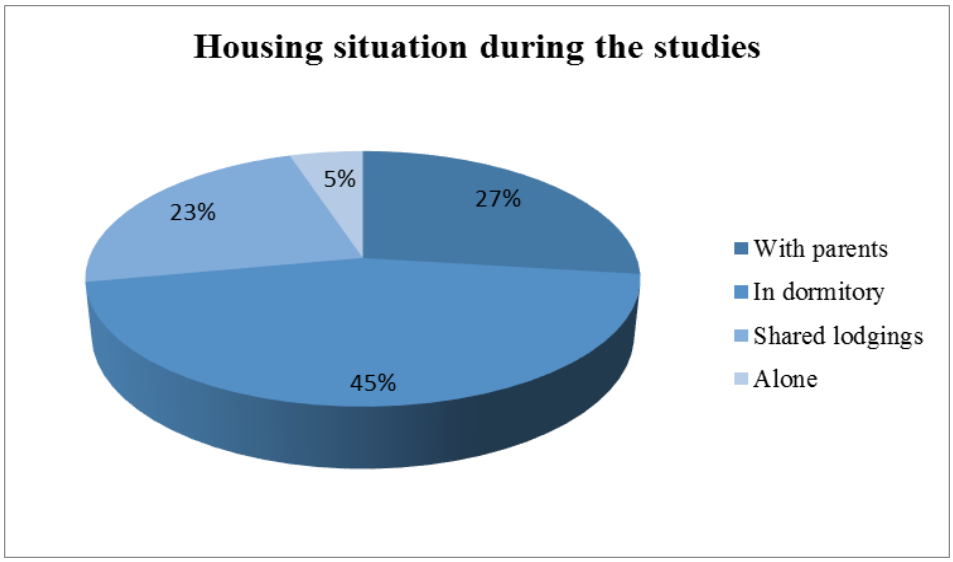


Figure 14: Housing situation during the studies, Source: personal editing [RC-2]

Labour market status, the issue of employment

A surprisingly high proportion of the students being interviewed, exactly 83% of them have a job besides being students on day courses, 44 people doing professional jobs. 16 of them, in the dual training, work in their profession with a student's contract, 10 work in the professional trainee programme, 18 work in profession fields temporarily.

ICT devices and their use

In terms of informatics device supply, we asked the students if they have desktop PCs, laptops, tablets, E-book readers, MP3/MP4 players, DVD/Bluray players or smart phones. The students' ICT device supply is especially good, in spite of the financial difficulties they spend significant sums to have modern ICT devices. Beyond the informatics „device dependence" characteristic of the generation, the existence of the devices available in a high number can also be explained by their professional interest.

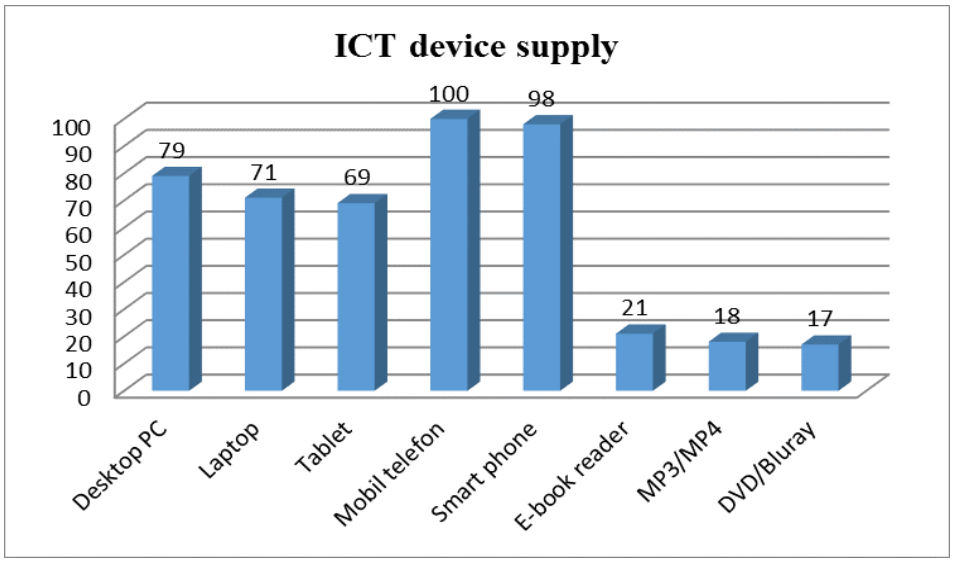


Figure 15: ICT device supply, Source: personal editing [RC-2]

It is clearly visible that, in accordance with other research results, the smart phones have become the primarily used devices for the students at the Faculty of Engineering and Information Technology of the University of Pécs, but the MP3, MP4, DVD and Bluray players have taken a back seat. (Figure 15.)

The students being interviewed have been using computers for 14 years on average. They have been using mobile phones from the age of 8-10, and smart phones since the appearance of the devices.

Being informed, attitude

We measured with a 5-scale Likert-scale how much the students are informed. It was named after Rensis Likert who first applied it. The aim of its creation was to investigate the given individual's attitude towards the given activities and concepts. Concerning its structure, we designate two extreme values at the two ends of the attitude scale which incorporates strong disagreement with the statement drawn up in the questionnaire (minimum value), and strong agreement (maximum value). The scale is measured so that in its middle (median value) the neutral feelings in connection with the statement are expressed. On the 5-scale scale applied in our case, value 1 incorporates disagreement meaning „not at all", value 5 incorporates agreement meaning „completely".

How much the students being interviewed are informed about the technological innovations:

– How much do you feel you are informed about the technical, technological innovations?

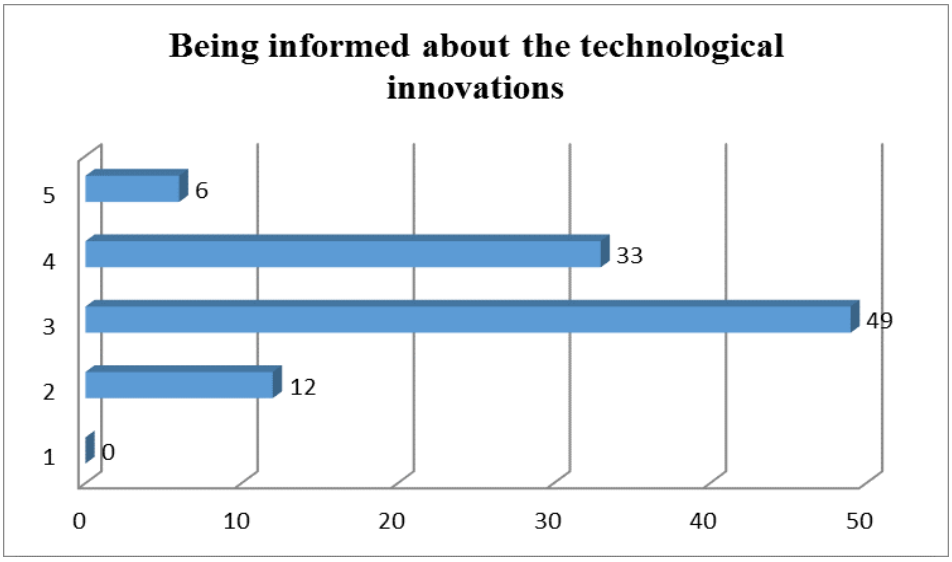


Figure 16: Being informed about technological innovations, Source: personal editing [RC-2]

– The frequency of orientation about the technical, technological innovations:

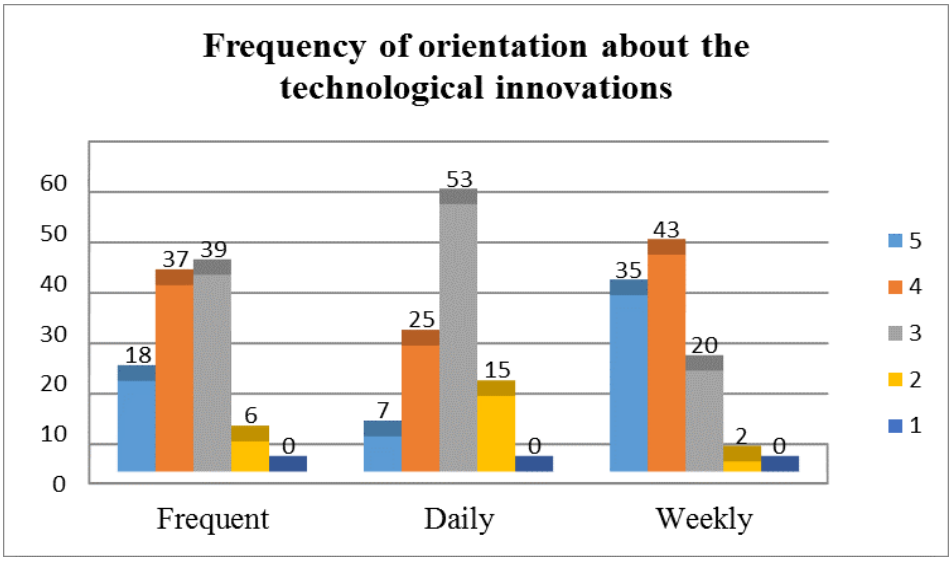


Figure 17: Frequency of orientation about the technological innovations, Source: personal editing [RC-2

Students are clearly interested in technological innovations. None of the students said that they would not orientate about technological innovations on a daily basis, 78% of the respondents surely checks weekly what technical, technological innovations have appeared in the world.

Based on the responses we can say that 87% of the students completely demand the integration of the technical, technological innovations in the teaching material in the higher education, possibly soon after their appearance.

Typically, the responding students check the appearing technological innovations on a weekly basis. 90% of the students being interviewed said that the scene of information finding is obviously connected to the internet sources.

Internet usage habits:

In terms of the internet usage habits, I first searched for the answer to the place of the internet use. 100% of the students have a home internet subscription, in the dormitories broadband internet access is available for the students. Besides these, 86% of the students also have a mobile internet subscription, they answered „everywhere" to the question of where you use the internet. The remaining 14% of the students reported internet use at the university, in the dormitory and at home. With respect to active internet use, a daily 5-7 hours activity is characteristic, noting „because I do not have more time for it".

In case of being informed about the legal, ethical issues the average score is: 3.3, dispersion: 1.2.

Multitasking is absolutely typical of the active activities, as the Figure 18. shows this, students claim about several activities that they deal with them in 100% of their time.

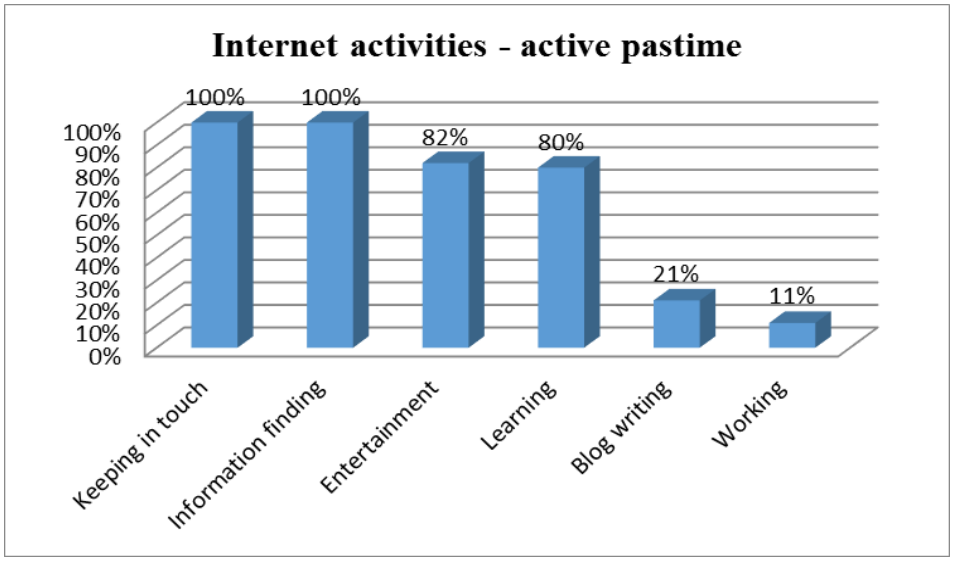


Figure 18: Internet-related active pastime, Source: personal editing [RC-2]

Concerning their other abilities, to the statement 'I can make decisions quickly", they gave an average score: 4.1, and to the question „I quickly find the significant knowledge from the available information" the average score given: 4.3, while to the question „I easily find the correlations between the information obtained in different places" they confirmed the positive judgement of their abilities with an average score of 4.5.

– How many people do you keep in touch with personally on a daily basis? average: 15

– How many people do you keep in touch with online on a daily basis? average: 37

The judgement of science

There is an explicit interest in the new technological results. 87% of the respondents are interested in technological novelties, discoveries, technological innovations. We can say that the scientific novelties are welcome in the social media, online appearances are uniformly judged more useful than the appearances in the printed press, professional journals. Only 17% of them read scientific informative papers regularly. 17% of them would willingly work as a researcher. As being students at the Faculty of Engineering and Information Technology, informatics is in the first place, engineering sciences in the second place engage their attention. It is an interesting phenomenon that the scientific field of mathematics ranked rather behind in the range (8th ouf of 10).

The connection between the time spent on the internet applications and time management

In connection with several online, internet activities, the students rated (on a 5-scale Likert-scale) how often they do the given online activity, and they also had the chance to determine the internet applications they mostly preferred by answering three open-ended questions. We required this partly in case of general purpose activities and partly in case of learning-related and learning supporting activities specifically.

We were searching for the answer to how the frequency of doing different online activities concerning learning, free time or entertainment is connected to their schedule and time management abilities.

According to the results of the correlational investigations, the time management shows a positive significant correlation ($r = 0.15$ - $r = 0.632$; $p < 0.01$ - $p < 0.05$), between the online learning activities (49-55;58;75. items) and the efficient time management (53, 57, 62, 69, 73, 106. items), at the same time a negative significant correlation can be shown in case of students giving high scores for the time management and for watching videos on video-sharing portals ($r = -0.24$; $p < 0.01$).

Learning environment, learning techniques, technologies

The students uniformly prefer common preparation and cooperative, collaborative work done on online spaces. The experience of learning together motivates them and beyond

successful individual performance they are willing to spend significantly more time on preparation, on preparing their peers than they would actually need individually in order to perform successfully.

100% of them said that they create their own, online social learning spaces as the scene of common work.

In case of team learning they claimed task sharing, time management, knowledge intensification after the individual elaboration of the parts of the process with knowledge sharing, motivation provided by the common success as an advantage. According to their accounts, in case of team learning each participant is forced to deal with the task. The effects of significantly fewer disturbing factors prevail.

Based on the responses of the students being interviewed, the following internet applications which they use to prepare for classroom tests and exams are the most popular:

The Skype and the TeamSpesk3 – programmes applied to communication, the Facebook which helps work going on in a closed community and keeping in touch, the TeamViewer – for sharing the screen (its main benefit is e.g. making graphs, explaining), the Google Drive – a programme applied for sharing content, for editing common documents/graphs. The use of google applications were given a score of 4.4 on average on the 5-scale Likert-scale which means that these are especially popular with the youngsters.

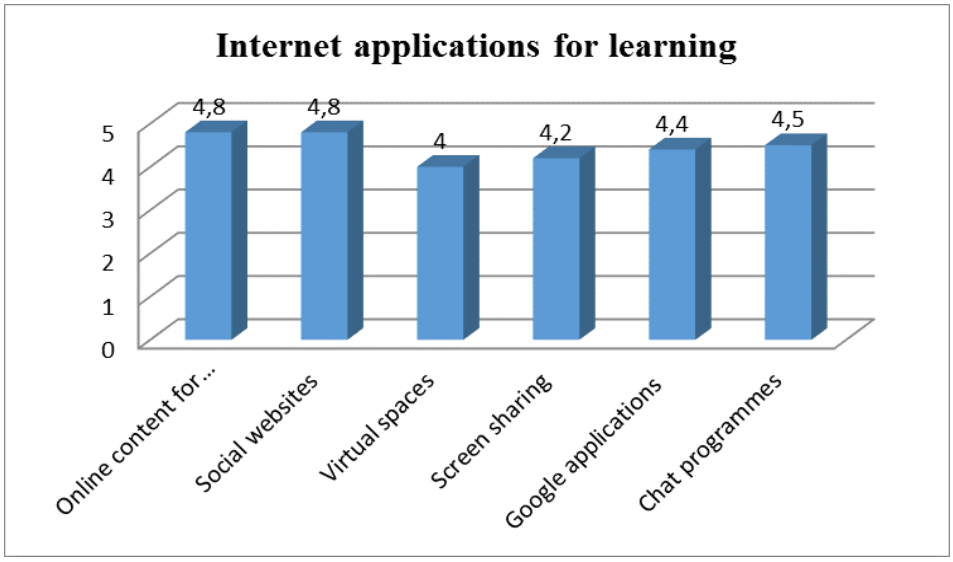


Figure 19: Internet applications applied in learning, Source: personal editing [RC-2]

Based on the answers given to the questions we can say that they do not use the surfaces, such as Coospace (average 3 points) or the Neptun main street (average point: 2.1) applications offered by the institutes of higher education as the scenes for common learning, or only if forced, and in this case for the shortest time necessary.

After measuring and recognizing the needs, the requirements can be well identified and by meeting them, the ideal educational environment can be realized for the generation of the present-day digital natives.

2.1.3 Lecturers' detailed interview

During the detailed interview carried out with the lecturers I asked the colleagues who teach generation Z students about their ICT device supply, internet and device usage habits and about their application in education.

The selected colleagues who teach both computer engineer and electrical engineer students belong to different generations concerning their age. Of the 10 colleagues 3 belong to the „Baby-boom" generation (1946-1964), 4 to the X generation (1965-1979) and 3 to the Y generation (1980-1995). Due to the salaries not being competitive so specific to the higher education of engineering, this distribution according to the age group is also characteristic of the teaching staff of the Faculty of Engineering and Information Technology of the University of Pécs.

The main characteristics of the above-mentioned three generations:

„Baby-boom" generation: 1946-1964

- they met the internet in their mid-lives
- they build the internet in their work and daily lives more and more intensively

X-generation: 1965-1979

- the messenger generation, the interim generation
- reliable, controlled, professionally demanding, highly motivated, cooperative, careerist

"Y-generation„: 1980-1995

- the first wave of the digital generation, internet is present in their lives day after day

Presenting the results of the interview:

All the colleagues belonging to the Baby-boom generation have been working in the higher education for more than 40 years.

They have a desktop PC at the workplace and also at home, but they do not have their own laptop, tablet.

2 of them have been using a computer for 25-35 years and a smart phone for about 3 years. They mainly use phoning, sms service and receiving emails from the telephone functions.

They spend 1-2 hours a day using the internet, mainly emailing, reading news, finding information and they use social applications in 15-20% of their time. They are members of

some social network applications, mainly Facebook, but they only use them to keep in touch privately. They do not like using the applications in the form of multitasking.

During their educational work they use presentations, videos to help teaching the material more efficiently. Only one of the colleagues supports the cooperative work, and even he uses it rarely. As a main reason, they mentioned the difficulty of assessing students' work.

They uniformly reject the application of students' own ICT devices in the classes. Arguing that „they distract the students' attention", „they disturb the classes with them".

They spend 4-5 hours a day at their workplace on average. Which is also due to the lower number of compulsory lessons. They moderately deal with talent care.

The colleagues belonging to the X generation did not start to work in the higher education. Some worked in the industry, some started their career in the public education. Their experience in the higher education is 20 years on average.

They are characterized by a significantly better ICT device supply. They have desktop PCs at their workplace, and two of them also at home, they all work with a laptop and 2 people also use a tablet for their work. 3 lecturers have an MP3/MP4 player and 1 has a DVD/Bluray player.

They have been using a computer for 25 years, thus from an earlier period of their life than the „Baby-boom" generation colleagues, they have had smart phones for 5 or more years. They use the functions of the smart phones, and happily download further applications. Multitasking application management is accepted by them.

During their educational work they willingly experiment with integrating internet applications in the education besides presentations. They only rarely create a separate facebook group in connection with teaching the given subject. Opinions differ about the application of cooperative work form. 2 people reject it – arguing that „it requires too much time, energy", and two try to apply it during work. In terms of virtual educational environment, the proportion is even worse. Only 1 person said to have already used such solution in the education.

They rejected the students' use of their own ICT devices with a proportion of 3-1. Also by reason of disturbing the course of the lesson.

The time spent at the workplace is 7-8 hours a day on average. In terms of talent care, they usually deal with one student a year.

The ICT device supply of the lecturers belonging to the Y generation is the best compared to their older colleagues, as expected.

Though they only have desktop PCs at the workplace, but due to the research work demanding more calculation, they are willing to spend a long time at their workplace if needed. They all have all the other devices listed.

They happily make their educational work more colourful with the opportunities provided by the internet, they often search and show videos from the youtube in connection with the topic, they know and apply the google services, the new presentational programmes, they practically select from them in terms of application. They willingly use modelling and simulation softwares for education. They do not reject cooperative work, but do not apply them every day either. However, they are interested in the VR environment, although its educational application has rarely happened so far.

Concerning the students' use of their own devices they are accepting, but they are not fond of smart phones being used in class.

Their time spent at the workplace is 7-8 hours a day on average.

Based on the results of the surveys, the table below shows the comparison characterizing the students' and the lecturers' digital life and competences by applying a 5-scale scale.

Summary of generation Z survey:

	Preferred by the students	**Preferred/expected by the lecturers**
Information	Image, sound video	Text information
	Fast, straightforward information finding	Gradual, limited number of „step-by-step" information transfer
	Relevant, promptly usable information	Information suitable for the curricular directives
	Information helps learning and is entertaining at the same time	Standardized information helping the education
	Random multidisciplinary information „accessible through hyperlinks"	Linear, logically constructed professional information
Working style	When „we feel like it", not time-bound working	Keeping the frames of the timetable
	Often „Just in time" performance	Preparation is pre-planned, ready for any eventuality, keeping the requirements in mind
	Team work, cooperative activity	Well distinguishable individual performance
	Real time online communication	Physical presence in class
Assessment	Prompt confirmation, stepping further	Deferred assessment
ICT device, software	Smart phone, tablet	Devices recommended by the lecturer
	Use of social media	Use of software strictly connected to the educational material

Table: 3: Summary of generation Z survey

As the result of my study we can say that there is a significant difference between the ICT device supply, the internet usage habits and the digital life of generation Z students and their lecturers being present in the higher education of engineering. The students use the smart phones as a primary device, while their lecturers reject the use of smart phones in class. While students are willing to use internet applications as a common learning scene where access can be limited, only their peers belonging to the community have a chance to access, provide real-time communication, at the same time the written comments, explanations do not get lost. For easier understanding further devices are available, e.g. with drawing, editing graphs illustration can be solved, the application gives an opportunity to share the screen.

While the students themselves create a VR learning environment, the lecturers partly know these applications and do not apply them in the educational practices.

Generation Z students' ICT device use is more certain than that of their lecturers belonging to the older generation. The students' cyber space life suited in the ICT has a developing effect on their practical information finding and processing abilities. They often meet the technological innovations earlier than the colleagues teaching them.

Based on the above-mentioned, Thesis I.1. and I.2. can be considered proven.

2.2 Thesis 2.

2.2.1 The disruptive effect of the disruptive technologies on higher education

In this chapter I am investigating the appearance of disruptive technologies in the higher education in terms of the changes of the educational strategies, of methods, and of the educational structure and quality.

Thesis 2: [RC-1], [RC-4], [RC-5], [RC-6], [RC-7], [RC-8], [RC-10], [RC-12]

I showed using Glenn's Futures Wheel that methodological, strategic, structural and quality improvements within education are in proportion with the speed of the introduction of disruptive technologies, witch significantly helps training and innovation in engineering. Furthermore, I showed that this interacting concatenation can become a self-inducing process.

Thesis 2.1.
I showed that the introduction of disruptive technologies induces the intensified application of internet-based learning environments and cooperative educational methodologies in the educational strategy.

Thesis 2.2.
I showed that the early introduction of disruptive technologies in the learning material induces the realization of the educational structures adjusting to the digital life of the new generations, particularly the CE generation.

Thesis 2.3.

I showed that technological innovations induce pedagogical developments, pedagogical innovations.

When justifying my Thesis 1. it was clearly found that from the two main factors – usefulness and simple use - drawn up in David's TAM theory, ensuring the simple use was mentioned as a required need by the respondents in terms of the early introduction of the disruptive technologies according to the international questionnaire survey. To ensure simple use pedagogical developments are needed. By pedagogical developments I mean the innovations, innovative activities which appear in the institutions of the higher educations and their aim is

to develop and implement the complex educational programme of the disruptive technologies, the rapidly appearing technological innovations. In this educational developmental concept, the scene of the developmental processes is the university, and the lecturers, researchers and the students of the institutions of the higher education accomplish them.

In my dissertation I drew up that ensuring the integration of the disruptive technologies in the learning material of the higher education for engineering as soon as possible after the appearance of the technology as a prior objective. To ensure this, I first investigated the effects the disruptive technologies have on the educational content, environment, methods and the model of the higher education, and the possible effects of the potential future events. I am investigating how the disruptive effect prevails in the higher educational environment. I am seeking answers to whether the new technologies will transform the present model of the higher education, if they replace the existing educational methods, scenes, the present educational strategy in the future.

To understand the trends, events and to consider the potential future events, besides the representative international questionnaire concerning the introduction of the disruptive technologies in the higher education presented at the justification of Thesis 1. I applied the „Futures Wheel method" [62]. When applying the method, we consider the historically influential factors, the present correlations and the future effects, consequences, thus the procedure facilitates it to think in three time dimensions The method stimulates the complex, evolutionary thinking, emphasizing that the consequences do not happen separately independent of one another, but they often appear creating an interactive sequence. The future wheel provides a clear visual map about the possible complexity of the interactions. It intensifies the future-oriented approach and the elaboration of the multi-concepts appearing in the alternative scenarios [68]. Although the futures wheel simplifies the representation of the future vision, but with the consideration of their complex character, it also makes it easy to comprehend and communicate. The time interval has to be specified at the futures wheel method. The implementation of the experimental education of the disruptive technologies in the early phase, thus the time of the launching event was realized between 2010-2015. The secondary effects start up continuously, their completion can be expected by 2015-2020. The complete realization of the tertiary effects can be expected by 2020-2030 according to the governmental strategy titled „Shifting in the higher education".

The goal was not to investigate all the effects, but to specify the most important effects which I separated to the different fields of education, such as the structure of the education, the educational strategy, educational process and the qualitative change of the education.

Prior to the exposition of the futures wheel presenting the effects of disruptive technologies in higher education, I would like to clarify the concepts in my thesis.

By **educational strategy** we mean the complex system of methods, tools, organizational methods and forms serving the achievement of specific goals which is based on coherent theoretical bases, it has a particular syntax (with the specification and the sequence of the steps to be taken) and it is realized in a typical learning environment [47].

We can categorize the educational strategies in two groups according to their central role:

- Target-oriented educational strategies
- Regulation theory- oriented strategies

Target-oriented strategies:

1. Teaching information with the help of presentation,
2. Teaching concepts with the help of explanation, discussion,
3. Teaching skills with the help of direct education,
4. Teaching social and learning skills with the help of cooperative learning,
5. Developing thinking with the help of exploratory learning.

We know from our didactic studies that the above-mentioned five strategies are different not only in terms of the central targets, but also concerning the applied educational methods, tools and processes. At the same time, we also know that the particular targets are dominant, but not exclusive targets during the educational process. When choosing the target, we must specify which one is the most important for us when teaching the disruptive technologies in the early phase after their appearance. At the same time, we must emphasize that during the education the application of the particular target-oriented strategies is needed at a different scale depending on the students' age, experiences and digital life as the particular target-oriented strategies influence one another conversely. For example, during teaching the information the thinking and the learning skills are developing, the students' concepts are expanding, but also in case of learning the concept we acquire new information, as a result of all these the thinking is developing.

Regulation-theoretical strategies:

1. Open education
2. Programmed education
3. Adaptive education
4. Optimal acquiring strategy

The common feature of the above-mentioned strategies is that they combine the methods, organizational methods, processes, the environment of the learning into an expedient system

in favour of successful education, learning. They usually serve to achieve different educational objectives successfully, are not bound to one single educational objective [47].

During teaching the disruptive technologies I tried to realize the optimal acquiring strategy. The optimal acquiring strategy is adaptive, needs the existence of individually processable teaching aids and thorough and regular feedback which I am presenting in details in connection with the pilot project accomplished to teach the memristor.

The **educational methods** are the continuous, recurrent components of the educational process, parts of the teacher's and student's activity which are applied by being organized in different strategies for diverse targets.

Educational methods frequently applied in the higher education: presentation, explanation, discussion, debate, demonstration, learning by doing method, project method, cooperative educational method, simulation, roleplay and game, study trips, home assignment.

To investigate the effects the disruptive technologies have on the educational methods, then to teach the technologies efficiently it is necessary to know a wide range of educational methods, and to know the „method-variations" developing in connection with the appearance of the disruptive technologies in the learning material of the higher education.

Many factors can influence the success of the educational process which have an effect often helping or hindering one another. For example, the educational environment, the educational tools, the educational organizational processes, the selected educational methods, but also the participants of the education and the content, subject of the education have influence on the success of the educational process.

I am summarizing the effects of disruptive technologies I have drawn up for higher education where the change and restructuring of the content of the learning material, the changes in the educational environment, the change of the educational strategies, the appearance of the new model of higher education were specified as the primary effect.

Naturally these appearing phenomena are also in a cause-effect correlation with one another, and the secondary, then tertiary future changes deriving from these will also be presented.

2.2.2 The effects of teaching the disruptive technologies – The Futures Wheel

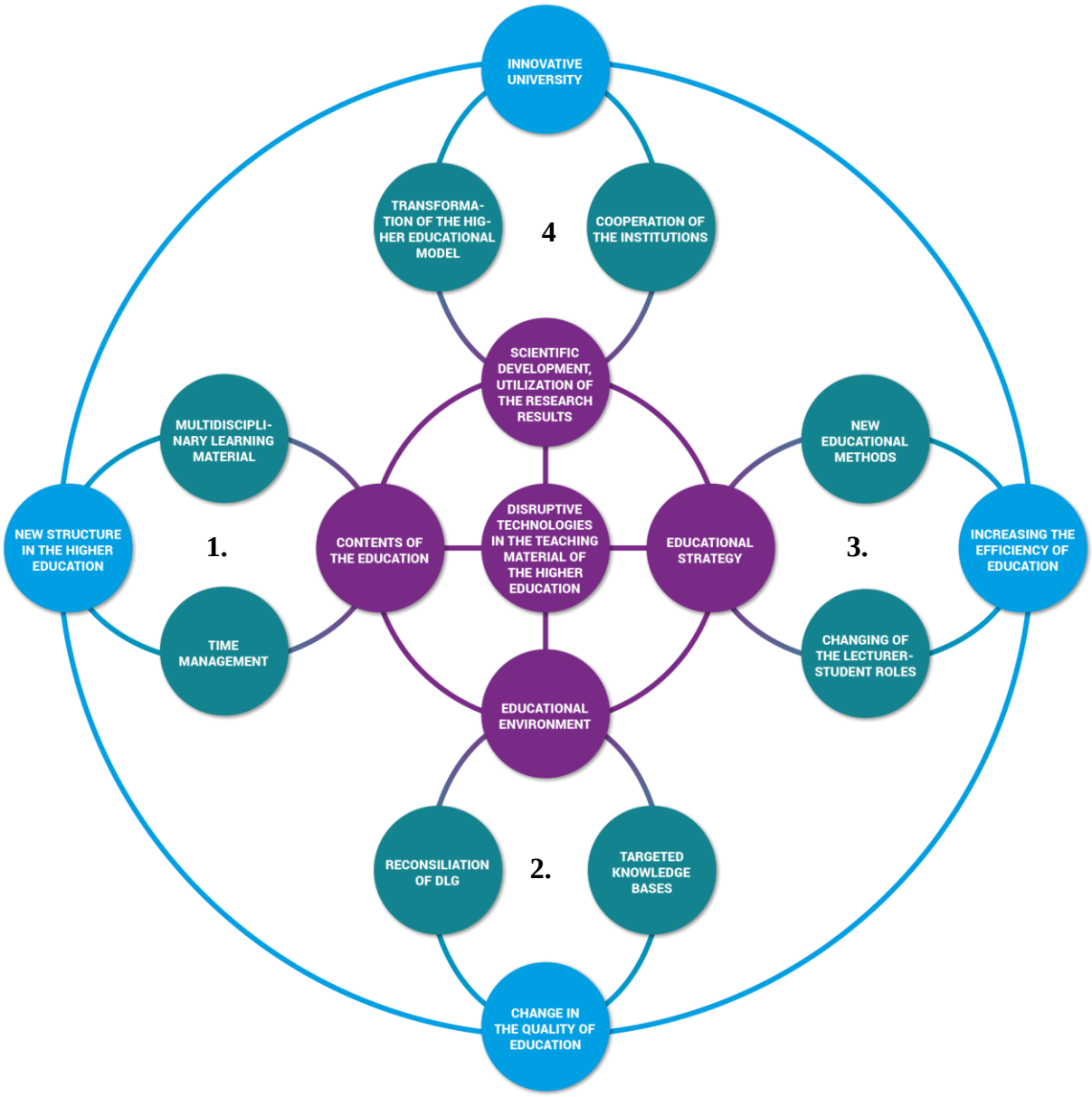


Figure 20: The effects of teaching the disruptive technologies – the Futures Wheel, Source: personal editing

1. Layer: Restructuring the educational contents:

A knowledge-based society has been in existence for a long time, at the same time with the appearance of the disruptive technologies in connection with the internet and the digital world completely new aspects have appeared by now. Leaders of famous universities negotiate that it is more and more difficult to compile a 5-year long educational programme because the change is simply too fast for the limited learning material contents of higher education to follow them. By the time the students graduate, their acquired knowledge becomes obsolete, thus the continuous appearance, updating, targeted categorization of the disruptive technologies in the learning material of the higher

education is more and more justifiable, particularly in the engineering training. The task of higher education for engineering is to prepare the future engineers for the challenges appearing in the world of technology. To this, the engineering, the technological, the technical innovations have to be integrated in the university learning material. As long as we integrate the disruptive technologies after their appearance at the launch of the technology in the learning material of the higher education, then it obviously entails the change of the learning material contents incorporated in the traditional subject frames. The main reason for this necessary change is that the specific product does not, or rarely exists in a feasible form following the launch of the disruptive technologies in the phase of the „Technological Trigger". It is often in a research phase, thus there are no pre-prepared compact learning contents which would help the lecturers' work and the students' preparation in the form of books or notes. This is one of the obstacles of the „simple use" specified in the TAM model, as the teaching of the disruptive technologies in the early phase puts extra tasks on the lecturers in many ways. The education can be started by assembling the theoretical background connected to the existing knowledge, by surveying it, by building the information new for the students logically on one another. The secondary effects derive from this directly:

1.1. **Large amounts of multidisciplinary type of learning contents are appearing,** as the techniques, technologies are still in their developing phase, the exploration of the opportunities for their multidirectional application is still in progress which requires knowledge spanning through several scientific fields. Several scientific fields are trying to utilize the bursting technology, thus the scientific research results also appear in several scientific fields. We can state that the sooner we integrate the „still developing" disruptive technologies in the educational learning material, the more extensive connections, knowledge is associated to their education which has an intense effect on developing the innovative educational tools, methods. The continuously expanding knowledge processing entails the development of the skills to structure, understand and highlight the essence which is in accordance with the competence requirements of the employers who today consider creativity, problem-solving, information finding and efficient application abilities more important than the existence of a large amount of lexical knowledge. With this we can confirm that the competitiveness of the higher education is greatly increased if, in spite of the difficulties, we try to start the integration of the disruptive technologies in the learning material of the higher education the sooner the better.

1.2. Teaching the large amount of learning material originating from several fields in the same time limit has also an effect on the structure of the learning material. **Time management** has a particularly important role in teaching, learning the disruptive technologies, the time balance analysis in the education of the technological innovations because in time balance analyses we often see that we spend much more time on certain activities than needed. We do not pay attention to the methodology of time management in the traditional educational system, so for the students this means the appearance of a new and useful element in the educational process. According to the results of the international questionnaire concerning the integration of disruptive technologies in the higher education presented in Thesis 1., the respondent colleagues' opinion is that the time management is one of the biggest problems and task to be solved in terms of the new bursting technologies which also decreased the chance of „simple use".

It is expedient to make a list of tasks as the realization of the optimal time management, then we can reduce the number of tasks ahead putting forward the tasks which can be carried out in a short time. The systematization, specification of the remaining tasks, revealing the necessity of the further ideas, then solving them by the specified deadline helps the efficient time management, the successful work. In teaching the disruptive technologies the time management comes into view which with the efficient work stimulate the creation of the new organizational methods and forms and the development of the new educational methods. In spite of the occasionally less thorough, deep acquiring of learning material due to lack of source and time, the students' knowledge, interest, motivation, global view must clearly be increased, with which we can meet the labour market requirements at a higher level.

In the long run, as a tertiary effect the structural change of higher education can be the next.

1.1.1. The structural change of the higher education

The restructuring of the learning materials, their multidisciplinary nature makes the chance of content regulation difficult. According to the field of the professional development it can be: vertical which is connected to one of the course subjects, out of class activity, such as the appearance of the disruptive technologies in the education. It can be horizontal when the professional development already affects the whole year's or even several year's work, - or complex, if a comprehensive development is realized which spans through the

whole institution of the higher education. The detailed curricula – which originally contain the subject and time schedule regulators - related to the specific courses transform and cease with the integration of the disruptive technologies, instead of them modular curricula spanning through several courses come into view, so the vertical development is surely realized. Teaching the developing disruptive technologies washes away the boundaries between the students participating in the bachelor and master training, or in the doctorate training, as getting to know the innovations successfully, the creative student ideas are accomplished depending primarily on the students' interest, motivation and diligence. The credits which justify acquiring the educational material of the disruptive technologies can be independent of the training levels based on the individual performance of the students. In the long run, we must think about ensuring the chance of easier permeability between the levels, and of credit acception. With the fading of the boundaries of the trainings not only the horizontal, but the complex professional development is also realized which leads to the transformation of the structure of the higher education.

2. **Layer: The change of the educational environment**

The development of the interdisciplinary learning material content appearing with the introduction of the disruptive technologies launches an intensified information hunger in the system of higher education for engineering. In favour of the fast and efficient information finding, - processing the need for the continuous presence in the communicational space is drawn up. Compiling and learning the new, developing learning material require the students' active learning participation. ***Knowledge is most rapidly accessible on the internet.*** The disruptive technologies can be taught by utilizing the opportunities provided by the internet, with up-to-date information, by forming continuously expanding, dynamically changing learning material contents in the upward curve of the Hype Graph, but according to the questionnaire survey carried out in the field of teaching the disruptive technologies the main information finding scene in the later phase is the internet.

As a result of this, the so-called multimodal teaching will spread more and more which can be traced in the dynamical change of the learning material content based on the online research because the hyper media line-up browsing on the internet has an effect on our senses, that is it facilitates the multimodal perception. By taking into consideration the learning-methodological fact that the learning process is the more efficient, the more

senses are involved in the process, it is an obvious conclusion that following the restructuring of the learning material content a new educational environment is formed. As technology is approaching the Peak of Inflated Expectations, media deals with it more and more, more and more scientific publications, debates, developments appear, thus the students can be participants of the innovation process. At the same time, the tool park of the institutes of the higher education is not ready for realizing the technological innovations bursting into the market, thus modelling and simulation has a bigger and bigger role in the higher education of engineering. ***As an effect of the appearance of disruptive technologies in the learning material of higher education the internet-related learning environment, the application of the education supported by the Web tools is intensifying, as the exploratory learning is the scene of the practices and the laboratory education.***

Besides the well-known media applications ***virtualization*** has an outstanding role which results in the radical change of the educational environment. The present ICT devices facilitate the visualization, cloud-based storing and forwarding of the text, image, voice and moving pictures, and other interactive media through networks regardless of space and time. These media can combine in an environment in which they cause the feeling of extended reality to the students in a specially developed VR (Virtual Reality) environment of the multimedia systems. According to the definition the virtual reality is a simulated environment which tries to describe, simulate the processes of the real world with the help of a computer model. We could only meet these at the popular products of the entertainment industry a few years ago, but today the creation of the educational scene of the disruptive technologies is unthinkable without the application of the VR space, particularly the 3D VR space.

2.1. The reconciliation of the Digital Life Gap.

The world of the cyber media develops the new tools, data managing, forwarding and recording technologies at a speed never seen before. The communicational technology of the information society has gained a priority for today's and the future CE generation students of the higher education, be it learning, work, entertainment or private life, that is the e-existence is the particularity of the students. The concept „hyper attention" defined by Hayles is characteristic of generation Z students which is defined with the following features: fast focus shift between the different tasks, the dominance of the multiple information stream, high stimulation threshold, low tolerance with boredom. This type of attention is really useful in situations

demanding rapid change of environment and fast reactions [65]. The communicational, learning, information finding habits of the CE, particularly generation Z students – whom the hyper attention is typical of – significantly differ in many aspects from the previous generations, thus from that of the lecturers teaching them. Efficient browsing, fast information transfer are typical of the students which is necessary as a prerequisite of the efficient learning concerning the disruptive technologies. ***The integration of the disruptive technologies in the learning material of the higher education makes it necessary also for the lecturers to intensely use the services, opportunities provided by the internet,*** the recognition and acceptance of the digital life of the students. The application of the social network - being an integral part of the digital life of the students - in the educational scene reduces the gap between the digital life of the lecturers and the students (DLG - Digital Life Gap). The communication made in the digital environment is natural for the students belonging to the generation called CE in CogInfoCom or the „digital natives" in other generation theories. The educational space integrated in this environment encourages the „digital native" lecturers to know and use the modern technologies as education itself goes on here. ***Thus, the preparation of the educational material, the up-to-date information finding, the visualization of the electronic learning material make the intense use of the ICT devices necessary which helps the approximation of the digital living space of the generations.***

2.2. ***Creating targeted knowledge bases.*** Besides the professional leading, supervision, control of the lecturers following the development of a disruptive technology a fairly big amount of targeted knowledge material is accumulated during the recognition of the disruptive technologies. If the institutes of the higher education store all the knowledge material in a given system similar to the practice, and apply the more and more widespread Web 2.0 approach, then the social feature is appearing more and more not only the informatics systems but also in the online educational space. ***The students*** can not only use the contents, but regardless of space and time ***they can comment the content, can upload new contents,*** can edit users, or in this context developer profiles. ***Through the developed cloud-based services the learning materials, the internet contents belonging to them will be available in a wider and wider circle.*** We can expect that learning in the e-Learnig and the VR environment will be the primary mode of education with the use of which by uploading the educational materials in a common system, the students can react faster and can

make their questions, comments, can share their ideas with their peers. With the more widespread sharing of the contents developed this way besides the online educational expertise the „common targeted knowledge base" can be efficiently developed. As a consequence of the development of the targeted knowledge bases the learning materials will be available regardless of space and time which strengthens the development of the individual Life Long Learning approach drawn up in the EU directives and also the telework opportunities, culture demanded by the market sector.

2.1.1. Change in the quality of higher education

We can achieve the development of the quality of the higher education with quality improvement. In terms of quality improvement, three factors have to be realized: it should be continuous, suppose an individual target and should be based on the needs and satisfaction of the partners. Due to the competitive situation today, the Hungarian institutions of higher education have become service providers, but the concept of an entrepreneur university and the naturalization of its characteristics in the higher education increasingly comes into view. As the higher education has become one of the determinative elements of the innovative system fundamentally influencing the competitiveness of the private sector with the growing role of knowledge, as a resource. The customers' demands have a bigger and bigger influence on the educational programmes, besides the traditional training forms the training programmes and courses - such as the more and more popular dual training form in which the practical professionals of the market sector participate as guest lecturers - demanded by the customers appear more and more often. The representative questionnaire survey also confirms this statement. The respondents rate the educational service activity of their university with an average score of 4.1 on a 5-scale Likert-scale. (dispersion: 0.737).

The companies increasingly demand the integration of the disruptive technologies in the learning material of the higher education, the creative solutions realized in education, newer innovations, also showing what soft-skills they require from the future employees beyond the professional preparation of the students.

After specifying the exact target, teaching the disruptive technology means a continuous work, the continuous reformation, development of the higher

educational system, which clearly meet the customers' demands. On the one hand, the customers of the higher education are the companies of the market whose needs are satisfied by the higher education more and more efficiently with the education of the disruptive technologies, with developing the students' cooperative, collaborative, problem-solving and creative thinking, foreign language knowledge, multidiscipline knowledge. At the same time the students are also customers. When justifying my Thesis 1. after evaluating the Z-generation questionnaire, I stated that they demand a marketable degree and knowledge, an educational space suiting to their digital life. The educational scene, method and strategy presented in the next chapter of my study also efficiently helps satisfying these demands in the education of the disruptive technologies. ***As a summary we can say that the integration of the disruptive technologies in the learning material of the higher education improves the quality of the higher education.***

3. **Layer: Educational strategy.** Probably the „Law of Accelerating Returns" by Kurzweil will prevail in the new educational strategies, that is the amount of the educational materials of higher education for engineering will be forced to follow an exponentially increasing curve so that we could transfer the exponentially increasing amount of information to the future engineers. This fact leads to the development, formation of the newer and newer strategies, such as the national educational strategy „The Digital Educational Strategy of Hungary" published in July, 2016. We choose the strategy from the existing offers in the given situation suiting the educational process based on the most important educational target, taking the circumstances (conditions, students' characteristics) into consideration. It must be considered that there is always a specific method group belonging to a chosen strategy. And specified processes, tricks are connected to the applied method. *In the light of this,* ***in the education of disruptive technologies in the early phase the primary target-oriented strategy is the „Development of the thinking with the help of exploratory learning".*** As according to the methodology of the Futures Wheel the consequences of the chosen event do not happen individually regardless of one another, but appear making up an interactive sequence, so the change of the learning environment, by choosing the methods given by ***the educational environment suitable for the efficient education of the disruptive technologies and the VR environment „Teaching social and learning skills with the help of cooperative learning" has also a central role in the educational practice.*** The structure of the education is

specified by the creation and realization of the ***optimal acquiring strategies*** from the regulation theoretical strategies. At the same time methods suited to the rapid and flexible operation of the business sector, but yet not applied in the higher education are also integrated during the realization of the strategies known from the academic literature, thus having an innovative effect on the traditional educational strategy.

3.1. The appearance of the new educational methods.

Factors determining the selection of the methods known form our didactical studies: the content of education (the nature of the subject, the topic), the peculiarities of the subjects, the educational – training target, the highlighted didactical task (the target of the lesson), the age of the students, the level and specialities of the students, the material, education-technological opportunities of the school, its facilities, the personality, the pedagogical qualification, methodological preparedness of the teacher. ***Nowadays the so-called disruptive educational methods,*** such as gamification, the flipped classroom, the mobile learning, the virtual environment (see Thesis III. (Antecedents) ***have appeared among the educational methods*** which also appear in greater and greater number and follow the Gartner's Hype cycle with the increase in the number of the new technologies.

Teaching the appearing disruptive educational methods and disruptive technologies demand the active student participation, thus looking on the categorization of the different educational methods, the following educational methods are preferred:

- According to the source of information the practical methods and the visualization,
- According to the cognitive activity carried out by the students: in the reproductive part exploratory, heuristic, and research type of methods,
- According to the logical direction of the education deductive and inductive type of methods to be applied in combination,
- According to the direction of the learning work the common lecturer and student dominated work-direction can be successfully applied,
- According to the didactical tasks of the educational process: the learning-teaching methods of the new knowledge, skills, the methods of the application, categorization and recording.

They contain methodological solutions collected in a targeted way from disruptive technologies. Such as the project method, as a method built on the common activity

of the lecturers and the students, the cooperative method in which, beyond the development of the knowledge and the intellectual skills, the evolving of the social skills and the cooperational abilities has an outstanding significance. Simulation, which will be useful in the process of the abstractions of the reality, the simplification during the education, but the homework also appears from the classical methods, as an educational method based on the students' individual activity between the classes, or the student presentation, the discussion and the debate method, as a dialogic oral communicational method, whose aim beyond acquiring the knowledge is to develop the logical thinking and the communicational skills. The target in case of the applied methods is the involvement of the CE generation students in the learning, to make the active participation, learning an experience. In my dissertation (Thesis III.) the edu-coaching method recommended for the education of the disruptive technologies in the upward curve is presented, which incorporates the basic principles of the efficient training process applied in the business sector in the higher educational environment.

3.2. Change in the Lecturer-Student roles

With the appearance of the disruptive technologies in the educational material in the early phase after their appearance the students can involuntarily become part of the developing process, the innovation. The paradigm shift will inevitably happen in the higher education of engineering. The student-centered, result-oriented education focuses on the creativity, active participation of the students in the innovations instead of the memorization of the learning material. The change of the lecturers and students roles, the transformation of the study groups spanning through the classical courses, the strengthening of the cooperation, the appearance of the training methods closer to the new market sector all strengthen the change of the classical lecturer and student roles.

Our classical teacher-pupil, or lecturer-student relation is based on the real situation that the teacher and the students are on two opposite sides of the professorship. Thus the relation of the lecturer and the student is characterized by a kind of opposition. The lecturer: presents, disciplines, gives orders, sets requirements, educates, and in an optimal case he also teaches. Using a simile, the lecturer is the „tool", the student is the „material".

In teaching the disruptive technologies in an early phase learning is a common work both for the lecturer and the student. Due to the deeper and more extensive

professional preparedness of the lecturer, naturally it is him who keeps track of the knowledge, ideas, thoughts gained from the internet. He can realize all this as a mentor during the education.

The students collect the resources to the solution of each problem, to the elaboration of the topics, to the realization of the project with the direction of the lecturer during the exploratory-research work. A similar situation is formed, as when we fix the target to be achieved, the tasks, the responsibilities and the deadlines in a cooperational, students contract. Thus, a work connection develops between the lecturer and the student which is characterized by a partner relation, similar to the training applied in the companies of the market between the trainer and the colleagues.

3.1.1. The increase of the efficiency in the education

We can define the efficiency of the education by comparing the invested resources and the indicators of the efficiency. To analyze the efficiency, we study which are the factors that facilitate and hinder the realization of the target. The aim of the service providing institutes of higher education is to satisfy the needs of the customers (companies and students). The companies, as employers want „ready engineers", the students expect a marketable knowledge, a valuable degree after finishing the training. First let us see in what ways we can give a successful answer to these challenges, if we integrate the disruptive technologies in the learning material.

In the education of the disruptive technologies in the early phase the applied diverse and innovative educational methods, the project approach becoming common in the higher education encourage the students to learn competences useful for the actors of the market, such as creativity, problem-solving thinking, innovative abilities, innovative approach, team work, the ability to think in projects, acquiring the communicational and presentational skills. Making the educational environment internet-based, the work in the 3D VR learning environment build on the use of the internet, on the rapid, target-oriented information-finding, categorization and processing, and the improvement of these skills also make the students valuable work force. The 3D visualization applied in the VR learning environment better suits to the cognitive processes of the human brain. The 3D visualization suits to the preferred scenes of the students' digital life (3D games), ensure a proper

feeling of comfort for work. We further enhance the student motivation by combining the cooperativity deriving from the team work, the research, -exploratory method, the project method and the Gamification. We utilize the opportunity of common work and learning from one another with cooperation, the integration of the practical application and the theoretical knowledge with the projects, the development of the competences essential for the information finding process, the practice of setting up and justifying, or disproving the hypotheses with the exploratory method, and making learning experience-based with gamification.

Active learning stimulates the cognitive processes, thus the students' performance improves. Information finding on the international sites stimulates the students' foreign language learning, particularly the knowledge and use of English considered to be the professional language of engineering. According to the principle of knowledge, the problem-solving ability do not depend on the applied formalism and the conclusion method, but how much and how highly qualified knowledge material is available in terms of the given field. Comprehension is realized with the arrangement of the thoughts, with the compilation of the thinking schema. A great amount of knowledge is needed even for the solution of the seemingly simple problems. With the integration of the disruptive technologies in the educational material, an increasing amount of knowledge material appears in the education, thus the necessity of training when starting a job significantly decreases. Meeting the above-mentioned facts, the training of the so-called „READY engineers" used by the employers is realized. This, at the same time meets the requirements drawn up by the companies and the students. ***All in all, we can state that the efficiency of the education is changing in the positive direction.*** Although it demands a rather high amount of working hours, creative solution from the lecturers, occasionally from the educational organizers to realize the teaching of the disruptive technologies in the early phase, but in return such „customer" demands are satisfied with which we can not cope in the framework of the traditional education, or only with a low efficiency.

4. Layer: Utilization of the research results, scientific development

In connection with the introduction of the disruptive technologies in the early phase in the higher education we must take into consideration the effect deriving from the development of the science which may result in the specialization appearing in an explicit form, breaking the frames of the traditional sciences, or perhaps the birth of new sciences. All this can result in research activities becoming diverse, and the transformation of the training programmes as we have seen. The students get involved in real practical projects or even in basic-research tasks during the recognition of the disruptive technologies. The scientific research, the creation of new knowledge, and the practice-oriented research, the follow-up of the industry-related developments appear in their work suiting to the concepts drawn up in the government strategy, these students will be the future innovators and entrepreneurs both with up-to-date engineering knowledge and business and analytical skills. The research results can appear in newer innovations, thus the basic research, and the applied research and innovation activity meaningfully improve the cooperation of the higher education and companies.

4.1. The cooperation of the institutions

Among the objectives of the European Union and the Hungarian government it has an outstanding role that at an institutional level the employer relations have to be strengthened, the training needs have to be integrated in the trainings in favour of reforming the content of the higher education training. The common research, development of the technological innovations carried out with the companies and the investors completely adjusts to this objective, during which the students can directly meet the knowledge of the skills and application opportunities, the research, planning, developing and prototype manufacturing processes required by the real economy. The extensive cooperation of the institutions is facilitated by the often strong interdisciplinary connection of the disruptive technologies. This can mean the cooperation of several institutions of higher education dealing with special research, but also the realization of the extensive R+D+I activity of the company and higher education partners. 90% of the representatives of the institutions of higher education asked in the representative survey declared the existence of living industrial relations, common research activities.

Shifting the education of the disruptive technologies to internet contents helps the information flow regardless of space and time which in the long run strengthens the development of the individual Life Long Learning approach, the adjustment to the

requirement of the compatibility of work and learning. Besides the introduction and expansion of the dual training, the institutional cooperation this way helps the creation of the distance learning and other flexible training forms satisfying the needs of the employers and employees, following the technological innovations.

4.2. The transformation of the higher education model

The values, expectations connected to the tasks of the higher education have expanded today. Efficiency in the economic sense, the direct utilization of the research results have also come into view which launched the thinking and practice on the scale of the business university – service providing university – entrepreneur university [72]. The relation of the market and the higher education has become tighter and more important which induces the transformation of the higher education models. Today the primary aim of the Hungarian institutions of the higher education is not to make profit, but the survival of the organization, to increase its reputation connected to professionalism, to develop its facilities and faculties, and to increase the number of students studying at the institution and to improve the talent care activities [149]. Due to the market-oriented feature of the higher education, more and more university leaders have business experience, thus the mentality specific to the successful companies of the private sector increasingly come into view in the management of the universities. Due to the fact that the institutions of the higher education are market-oriented, they try to improve the students' learning conditions, the satisfaction of the students and the future employers, with the improvement of the number and quality of the services, and also the cost management of the institution of the higher education which leads to the increase of the market share existing in the student markets. According to the practice, it has several modes of implementation. It can be implemented in the form of distance learning or by receiving foreign students. Among the priority objectives of the developing strategy of the University of Pécs are doubling the present number of students participating in the foreign language trainings up to 5000 students by 2020; creating a competitive training environment; increasing the research, developmental potentials of the University. The criterion of opening to the international student markets is the foreign language education, the existence of learning material suiting to the students needs in quality and form which is realized in a natural form during the education of the disruptive technologies thus helping the development of the service providing university model of the university

and the creation of the entrepreneur university model through company cooperations, market orders.

4.1.1. Innovative university

The appearance of the disruptive technologies in the higher education facilitates the creation and spread of the educational innovations which helps the formation of an innovative entrepreneur university model with a conscious higher educational strategy. The innovative university can be created along a well distinguishable competency-profile, thus the innovative university, as a new operational model of the higher education suppose an innovative educational programme, pedagogical innovation which is created with the cooperation of the industry and the higher education. Innovation is connected to the interactive learning process which combines many organizations and institutions in the research and educational process. The pedagogical innovations facilitate the more successful and efficient operation of the educational systems. As the industrial developers need the practical testing of the innovations, here we also have to ensure the possibility of practical testing so that the pedagogical innovations should not be separated from the reality and could really be feasible. Thus, it has a great significance how the implementation of the developed pedagogical innovations happen. All the help has to be provided for the innovative lecturers and the practicing professionals at the innovative university to carry the successful implementation process along. By the implementation of the pedagogical systems we mean the process in which the institutions, or the cooperating institutions recognize, test and incorporate the elements of the developed pedagogical system in their own pedagogical practice.

In my representative questionnaire the existence of the educational innovations received an average score of 4.6 on a 5-scale Likert-scale (dispersion: 0.51) which means that none of the respondents indicated a score less than 4. Thus, the institutions of the higher education dealing with the education of the disruptive technologies put an emphasis on the educational developments, innovations.

The education of the disruptive technologies strengthens the relationship of the education and the research, and creates a developed knowledge transfer structure. The multidisciplinary and applied research, developments, patents

spanning through the institutions can facilitate the development of the regional economy.

A strong change can be expected in the management solutions of the higher education, in the opportunities of involving the exterior resources, in the educational and research activity accomplished with the companies in the market.

In case of an innovative university the aim is to create an institution of higher education having an internationally recognized research culture and special educational model, creating pedagogical innovations based on technological innovations. This aim assumes a serious financial background which can be reduced with the opportunities provided by the internet, with the informatics innovations, with the application of the models and simulations feasible in the 3D VR learning environment.

The Hungarian Government accepted the document titled „Investment in the future: National research-development and innovation strategy 2020" in which it specified that operational programme. The aim is the knowledge transfer and technology transfer, and the closer cooperation of the companies utilizing the knowledge and the institutions of the higher education. According to the government strategy the task of the Hungarian system of higher education is to suit to this strategy in terms of ensuring the requirements out of the institutions (that is research background), and of activities in the institutions (real R+D+I). The innovative university model adjusts to the strategical objectives of the government. With the help of the futures wheel method the reconsideration of the thoroughly investigated and considered future consequences in connection with the rapid integration of the disruptive technologies in the educational material it intends for a forward development and adjustment to the international and national directives.

I carried out the justification of my Thesis II based on Glenn's Futures Wheel method. As I indicated at the presentation of the method, this method stimulates the complex thinking emphasizing that the consequences do not appear independently, separately from one another – but, often as in our case making up an interactive sequence (Table 4).

	Layer of the Futures Wheel			
	1. Content, structural layer	**2. Environmental, quality layer**	**3. Strategic, methodological layer**	**4. Research, social layer**
Hypotheses of Thesis 2. In proportion with the speed of the introduction of disruptive technologies, the -methodological	**x**		**x**	
-strategic	**x**		**x**	
-structural	**x**			
-quality change of education is enhanced.		**x**		**x**
-the interacting concatenation can become a self-inducing process				**x**
Hypotheses of Thesis 2.1. The introduction of disruptive technologies induces the enhanced application of: -internet-based learning environment	**x**	**x**		
- cooperative educational methodologies in the educational strategy			**x**	
Hypotheses of Thesis 2.2. The early introduction of disruptive technologies in the learning material induces: -the implementation of educational structures adjusting to the digital life of the new generations (CE)	**x**	**x**		
Hypothesis of Thesis 2.3. - Technological innovations induce pedagogical developments, innovations			**x**	**x**

Table 4: Justification for Thesis 2.

According to the facts written ***in point 1. of the futures wheel, the structural change of the education increases in proportion with the speed of the introduction of the disruptive technologies,*** as ***the appearance of the great amount of multidisciplinary learning material induces the development of the innovative educational tools and methods*** presented in point 1.1. ***The role of the time management in the focus of point 1.2. has a favourable effect on***

the creation of new educational forms which result in the change of the structures of the higher education presented in point 1.1.1.

Thus, the summary of the first branch of disruptive futures wheel confirms the statement of Thesis II. according to which the methodological, strategic, structural and quality change of the education is increasing in proportion with the speed of the introduction of disruptive technologies because the new technology, product is still in a research phase in the phase of the „Technological Trigger", thus their research can be carried out in several fields of science. As a consequence, the sooner we integrate them in the educational material, the more extensive knowledge material is associated to their education which leads to the transformation of the traditional educational frames, methods, strategies. As long as we introduce the educational introduction after the Peak of Inflated Expectations, perhaps in the phase of the „Trough of Disillusionment", then the appearance of a significantly less related knowledge is typical, thus the initially given changes induced by the great amount of multidisciplinary learning material also lag behind the ones presented previously, however, it puts back the efficient developing opportunities of the engineering students' creativity and innovative way of thinking. Confirming the complexity of the futures wheel, the justification of the quality change of the higher education is also justified by the facts described in point 2.2.1. appearing in the second branch of the futures wheel.

The second branch of the disruptive futures wheel (closely related to the first branch) confirms the change of the educational quality written in Thesis II. and also the statements of Thesis 2.1 and 2.2. because the early introduction of the disruptive technologies launches an „information hunger" in the system of the higher education for engineering. According to point 2. of the future wheel the internet gives the practical scene for following the research results, publications appearing in several scientific fields, for having access to the up-to-date information, which will also become a new learning environment for the students. **Thus, the statement in Thesis 2.1. that the introduction of the disruptive technologies induces the creation of the internet-related learning environment can also be considered as justified.**

Concerning point 1. of the future wheel, point 2.1. and 2.2. project the creation of the educational structure and educational environment approximating to the digital life of the CE generation students. I see the justification in the following: the great amount of multidisciplinary learning material and the internet-related learning environment demand the approximation of the digital life of the lecturers to the digital living space to which the CE generation is accustomed to. At the same time, it demands the existence, development of the „hyper attention" specific to the CE generation which is highly useful in case of the

dominance of a multiple information stream. **The communication made in the digital VR environment, the educational space integrated in it induce the creation of targeted knowledge bases and thus the statement drawn up in Thesis 2.2. that the early introduction of the disruptive technologies in the learning material induces the implementation of the educational structures adjusting to the new generations, particularly to the digital life of the CE generation.**

Thus, Thesis 2.2. has been justified according to the above-mentioned facts.

The third branch of the future wheel showed the change of the educational strategy in details. The educational strategy, resulting from its definition, includes the change of complex system of the educational methods, tools, organizational methods which is accomplished in an optimally created learning environment, thus increasing the efficiency of the education. Thus, as the summary of the third branch we can say that based on the target-oriented educational strategy called „Development of thinking with the help of exploratory learning" which besides a more indirect educational direction aims at making the students think by ensuring that the students construct their own thinking systems, they should pose questions concerning the new techniques and technologies, then find an answer to these in a target-oriented way. Finally, completing the usual strategy, we are trying to achieve that the students should draw up theories based on the responses, should make innovative recommendations concerning the application of the technologies. We are expanding it all with the development of the new, - innovative educational method and with the utilization of the opportunities provided by the VR educational environment based on the regulation theoretical strategy called the „Optimal acquiring strategy".

According to the third branch of the future wheel, the statement of Thesis 2.1. that is the introduction of the disruptive technologies induce the intense application of the cooperative educational methods, and the statement of Thesis 2.3., that is the technological innovations induce the pedagogical developments, pedagogical innovations can be considered justified.

The fourth branch of the future wheel indicates the changes in the scientific and economic fields of the institutions of higher education, and the development of the educational political objectives adjusting to the social changes, which are the direct consequences of the educational changes drawn up in Thesis 2. because the technological innovations put across the decisive role of the educational processes in the modern societies by expanding and ensuring the opportunities of the pedagogical development. **The efficient educational**

processes result in newer innovations. Thus, the statement of Thesis II that the interacting concatenation can become a self-inducing process is confirmed.

2.3 Thesis 3.

2.3.1 Introducing the concept of edu-coaching in the higher education of engineering

Thesis 3: [RB-1], [RC-3], [RC-4], [RC-8], [RC-10], [RC-11], [RC-12]

The introduction of disruptive technologies in the higher education can be accelerated compared to the current methodologies, to prove this, I developed the methodology of edu-coaching and introduced its concept in the academic literature of engineering.

The appearance of disruptive technologies in the teaching material of higher education requires a reformation from the university sphere clearly visibly according to the Futures Wheel explicated in Thesis II. Besides the structural and content transformations, it is necessary to create a new pedagogical culture which adapt to the changed social and student needs and demands, reacts flexibly to the expectations of the market and the needs of the job trainings and which applies the latest informatics and communicational techniques, particularly concerning the characteristics of the cognitive levels drawn up in the Bloom taxonomy and the CE generations students' behaviour. The educational methodology, the pedagogical views currently being applied and the specific student motivation, attitude and thinking patterns only incidentally ensure the training of engineers with innovative views. I see the greatest changing effect in the educational methodology and in the pedagogical practice applying it because the appearance of the disruptive technologies - still being formed – in the education stimulate to acclimatize a motivating method or methods in the higher education of engineering making the CE generation students more involved and requiring a much more active research and development activity from the students.

Teaching the disruptive technologies soon after their appearance obviously differ in several aspects from the routines of the traditional educational frames already when choosing the method in respect of the innovative contents of the education, of the multidisciplinary educational material spanning through several subjects, of the change in the roles of the lecturers and the students or of expanding the educational opportunities to a 3 dimensional VR space, which facilitates the expansion of the boundaries of the education technological opportunities. Choosing the appropriate method is not a simple task even for the experienced

teachers when teaching the traditional educational materials. It is important for the lecturer to know the complete scale of the applicable methods and to choose the most effective to teach the given learning material. Naturally the combined application of several methods during the education is expedient.

My tools to choose the optimal method group and to elaborate the edu-coaching method were the learning, teaching and training methods applied in the educational and market environment from which I selected the ones that consider the aspects specified by the Futures Wheel method suitable for the integration of the disruptive technologies in the educational material of the higher education.

First I surveyed the relevant educational methods created as a result of the international and domestic research of the 21st century, especially the „learning by doing" learning-centered methods brought to the fore by education history, particularly the constructivist pedagogy. I am investigating which methods suit to the assumptions specified in the education of the disruptive technologies in the „future educational practice". Following that I present the edu-coaching method I applied in the higher education of engineering which connects the teaching and developing methods applied in the educational and market environment.

The constructivist pedagogical method was especially highlighted from the pedagogical trends because according to the constructivist pedagogical approach the aim of teaching is not simply knowledge transfer but ensuring the conditions for creating the students' knowledge through personal constructions [111]. This, at the same time confirms the statement in Thesis 3. that it includes such methodological tools which facilitate the rapid introduction of the disruptive technologies such as the „Project method", the „Research-based educational method" or the „Project method", each of which well suits to the teaching of the disruptive technologies in an early phase, when the teaching material content together with the technology is sill in its dynamic phase. During the education of natural sciences and engineering, the knowledge must be incorporated in the base of critical thinking by the student being motivated in applying this knowledge. I followed the deductive way as a learning approach when elaborating the edu-coaching method because the recognition of the new technologies derives from the students' existing knowledge, and then with the help of generalizations and abstractions new, innovative solutions are born by the emergence of more and more complex knowledge systems.

The common feature of the learning by doing methodological trends is that the emphasis is put on facilitating self-reflection expanding to the students' activity, independent thinking and each element of the activity, and the learning process is based on the students' motivational

state besides the internalization of the experiences gained in reality. A knowledge building suiting to the students' character and knowledge level is intended in which the student is an active participant: looking for answers and solutions to a specific situation and phenomenon. This way suits to the pedagogical methods well applicable in teaching the disruptive technologies.

At the same time, the atypical learning methods gain more and more ground mainly in terms of the requirements of lifelong learning and to increase the adults' learning efficiency following the reform pedagogical endeavours in the modern educational practice. We must also consider the opportunities lying in the atypical learning methods when creating the educational method of the disruptive technologies because getting to know the new techniques, technologies extends beyond the frames of the formal education. The atypical learning is a form of lifelong learning which aims at developing the key competences necessary in the informatics society. The adults' learning besides working does not necessarily facilitate their participation in the formal education. Beyond the learning forms besides the formal education, - the informal learning, the atypical learning includes all the methods which have an effect on the individual's intellectual and physical development by the cognitive recognition. During teaching and learning the disruptive technologies, both formal and informal learning have a role in the process of information finding, filtering, processing and producing new information. so the application of these working forms well facilitates the elaboration of the edu-coaching method drawn up in Thesis 3.

The working forms of the atypical teaching-learning are group and team work, the peer learning, or the cooperative working form where the individual working forms can be the experimental learning, individual learning, practical learning, self-experienced, external learning, open learning, distance learning, media learning, flexible learning, digital learning, e-learning, blended learning, alternative education, or coaching widespread in sport and in the market sector.

These offer the opportunity of applying methods demanding a much greater independence than common in the traditional higher education for the actors of a wide variety of pedagogical situations, thus their overview and the adaptation of their best practice capital is justified to create the efficient educational method of the disruptive technologies.

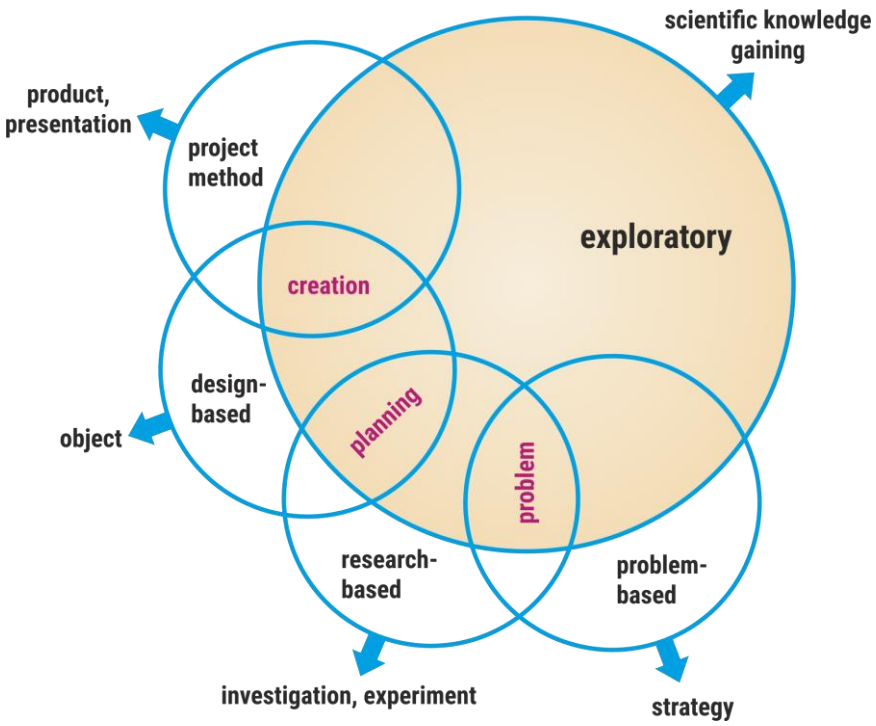


Figure 21: The methodological bases of the learning by doing methods [99].

In the following, I am surveying the education-organisational, strategic and methodological opportunities suiting to the education of the disruptive technologies. The common characteristics of the following methods are being student-centered, the change in the roles of the lecturers and the students, the similarity of the activities of the educational-learning process and the team work, each of which includes facilitating the integration of the disruptive technologies in the learning material of the higher education, in the phase right after the appearance of the technologies.

2.3.1.1 Cooperative learning

The more and more increasing need for the application of the cooperative learning forms nowadays can be traced back to the insufficiencies of the traditional pedagogy in the formal learning [110].

The cooperative learning includes such methods which can be both applied in learning and in the out of class activities. We mean cooperative team work if the team members carry out the tasks by contacting each other and to achieve a better common result sharing the work also appears in the team, thus it confirms the statement in Thesis III. according to which these methods help, facilitate the rapid introduction of the disruptive technologies in education. To justify this statement, I am summarizing the essence of the cooperative team work. Its main characteristic is the order, the meaningfulness and the expediency of the connections.

The ***cooperative learning-organization can be considered rather an education-organization***, whose principles are:

- simultaneous and comprehensive parallel interaction,
- constructive and encouraging interdependence,
- equal participation and access,
- individual responsibility and assessment/testing

Each member has an equal role in the cooperative team. The relationship between the roles is not hierarchical but cooperative in partnership. The members carry out both individual and team tasks.

The classical teacher's role changes and aims at three main activities:

- preparedness/readiness
- observation
- intervention.

Nowadays, the cooperative learning - with the help of the project method, the less well-known design method and the closely-related and much more widely known research-based learning strategy, and the problem-based learning method – is more and more popular in implementing the student-centered education.

2.3.1.2 The Project Method
(Project Based Education/Project Based Learning)

The project method was born at the beginning of the 20th century in the United States as the critique, alternative of the traditional school. It was experienced that the application of knowledge in the traditional school is separated from the knowledge itself, it is not clear what the knowledge learnt through the particular subjects can actually be used for. As during the recognition and learning the disruptive technologies, the new knowledge is closely related to its practical application, thus the essence of the project method clearly confirms the statement in Thesis III. that it is an educational method which facilitates the rapid teaching of the latest technologies, so it must be a part of the methodology to be developed. As an evidence for my statement I am summarizing the essence of the project method in the following.

The evolving of the project method was based on the principles of John Dewey (1859-1952), which primarily emphasized the following correlations.

- Learning must be based on personal experiences.
- Teaching must consider the students' developing needs and interests.

- The student has to participate actively in forming his own learning processes.
- The student has to be educated to actively take part in the affairs of the community, to become a citizen feeling responsible for the community.
- Shaping the whole personality, the close connection between the curriculum and the social reality are important.
- It demands the flexibility out of school.

According to the following characteristics, the project method adjusts to the characteristics specified in the early phase of the education of the disruptive technologies:

- The project can rarely be adjusted to the tight university schedule (2x45'), to the system of the classes.
- Due to its interdisciplinary character it breaks through the frames of the subjects.
- It often steps over the age frames set by the year.
- It demands a new type of teacher-student relationship (the teacher does not control from above, but is a member of the community accomplishing the project, helps the successful accomplishment of the project from inside).
- The project can hardly or not at all be assessed with the traditional grading.

Design based learning

The methodological logics of the design-based learning is that gaining knowledge is the most successful if the students do not learn about ready things (objects, environmental elements, processes), but when they have to design and create a specific thing (for example a model object or infographics). In case of the technological innovations in today's modern education, the model creation and the application of simulation programmes are ordinary tools in the higher education of engineering, their application has a role during the recognition of the disruptive technologies.

2.3.1.3 Research-based learning – Research-based strategy

The base of the research-based learning – which is actually a version of the design-based learning [3] – is a specific problem for which the students design an investigation, experiment to solve having their preliminary knowledge. Not what they learn or think is important but how they think, that is the emphasis is on the process of learning the things. During learning the students understand the concepts and the processes, their knowledge deepens by synthesizing the knowledge elements, their attitudes related to these become enriched and

they understand the essence of scientific recognition [94] interprets the research-based learning as a strategy which actively involves the students in the investigation of the content and the results. With this specific characteristic it clearly confirms the education, the recognition, the further research and revealing the fields of utilization of the still developing technological innovations. The research-based learning can lead to a usable knowledge, to the ability of sensible and lifelong learning, which closely suits the present international and domestic educational policy objectives.

2.3.1.4 Problem-based learning (PBL)

The academic literature often mentions the Problem-based learning, - teaching besides the Project-based education. The first version of the PBL method was elaborated by Barrows and Tamblyn [60]. It was successfully applied at the McMaster University in Canada in the 1960s [75].

The PBL is a teaching method – although according to certain researchers [146] it is rather a ***general educational strategy*** -, where the students work in a small group. They try to understand, solve and explain real-life problems. The Problem-based teaching, as an educational strategy confirms the statement drawn up in Thesis III. based on the following work forms: due to its PBL work form, it helps the students to evolve self-controlling learning, and to develop such competences which are not realized or are kept back during the traditional education. Meanwhile, the PBL improves the adaptability to changes, the acquirement of processes facilitating making decisions in unfamiliar situations, the assessment and acceptance abilities, the problem-solving ability, thus it improves the development of the critical and creative thinking abilities.

According to the study presented in the chapter Antecedents, titled „The future of higher education: How technology will shape learning" published in the Economist Intelligence Unit in October 2008, the technological innovations will have a significant influence on the methodology of the education. According to the research, significant changes in the future education: realization of learning in diverse places and time, the need for personalized learning, the strengthening of the students' opportunity for a free choice, the intensification of the short-term, project-based learning attitude, the integration of the personal experiences facilitated by the modern technologies in learning, the ability to successful learning, the change in the teacher's role. With keeping these characteristics listed here in view, I have integrated the benefits of the above-mentioned methods in the edu-coaching method that I

elaborated because the „formation” of the teaching material, the planning, the development get into the focus of the learning process during teaching the disruptive technologies, where the changing process appearing in the lecturers’ and students’ roles is well outlined.

2.3.2 Edu-coaching method

Here are some ideas about the emergence and spread of the coaching method as the introduction of the edu-coaching method - that I elaborated - well applicable in the higher education of engineering.

Tim Gallwey, a lecturer at Harvard and tennis expert, wrote in his books published since 1975 about the factors underlying the athletes’ performance enhancement and the change in the coaches’ roles. His „Inner Game” theory later spread to many fields of business life, as it is an advantage in the market competition to be rapidly adaptable, to have inner motivation, the ability to follow the fast changes and the commitment to conscious goals, so the organizations started to investigate those methods which are able to achieve really efficient changes and results at the level of the individuals. They gradually recognized the supporting and helping power which the coach provides in sports for his athlete, competitor.

The types of coaching are diverse, with many categorizations, such as life coaching – executive coaching. According to applied methodology: action-oriented coaching, NLP-based coaching, system-approach coaching. Categorization according to orientation: recognition-oriented coaching, achievement-oriented coaching, relation-oriented coaching, and besides these: preventive, strategic, stress, project, conflict, intercultural, team coaching, team case-processing coaching etc.

Presenting the edu-coaching[1] method [RC-12]

In most cases such clients contact the coaches who have bumped into a problem, a situation or a task which they cannot solve on their own. This basic situation is completely identical with the situation when students have to learn a topic for which they do not receive the pre-compiled, logically correlated learning material which is easy to learn, but they have to search for the necessary information and then get from the information to the knowledge own their

[1]The expression edu-coaching has spread in many fields nowadays. It appears e.g.: as an applied method in foreign language research, medical scientific field, or at the designation of the educational decision-makers, leaders’ coaching training. I first published its use in the higher education of engineering at the conference titled „Innovation and creativity in science”. The place, time of the conference: Kolozsvár, 6-7. December, 2013.

own. In order to integrate the information in the knowledge system, the students have to go through the process of information processing which cannot eliminate one or the other phase.

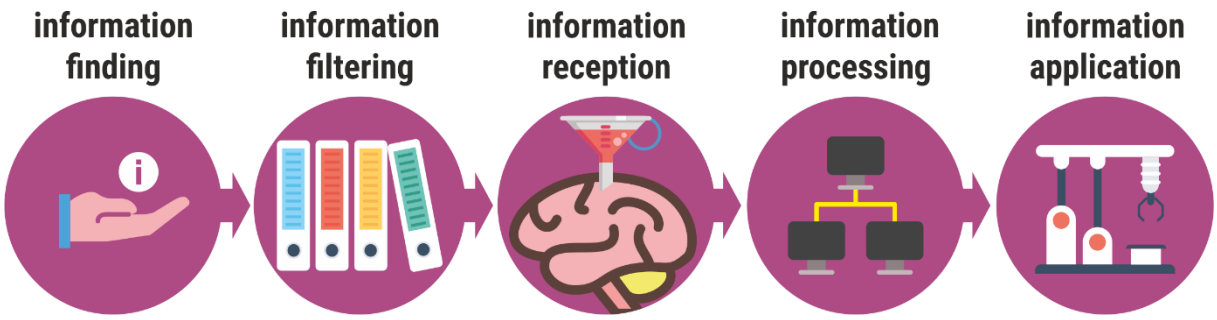


Figure 22: Processing the information, Source: personal editing

The method I elaborated is based on the short, solution-centered coaching technique, supplemented with the peculiarities of the higher education system, the science of engineering and the modern educational techniques.

The solution-centered procedure was formed at the beginning of the 1980s following the research of Insoo Kim Berg and Steve de Sharez. With their research, they wanted to find the answer to what questions and methods lead to a useful result in a client counsellor relation. Peter Szabó started to integrate the results in coaching in 1997, so the solution-centered coaching model developed which creates a simple and clear thinking frame for the „client" who draws up his goals, solutions and the steps leading to these in this framework. The coach edits the frame from targeted questions, confirming feedbacks and useful summaries. The „client" this way receives space and time to arrange his thoughts, to specify his goals, to make real his resources and to plan the next step.

The main tool of the coach is asking. The questions give the corner stones of the learning process. Children also always ask their peers and the adults. They get to know the world based on the answers they receive. In the present public educational system and higher education we experience that year after year the students ask less and less. The conversations are initiated not by them, but by their parents and teachers, that is the adults, but they also rather speak to the children than talk to them. Following the questions we get answers to our problems, get to know each others' thoughts, recognize our limits and ourselves. The better questions the participants – that is both the lecturers and the students - pose to each other, the more successful the teaching-learning process is. Composing the questions properly in terms of familiarization, deepening, resuscitation and application, and the acquirement of appropriately treating them is not an easy task, as the basic role of the questions is to actuate and to keep the thinking during the learning process in an active state.

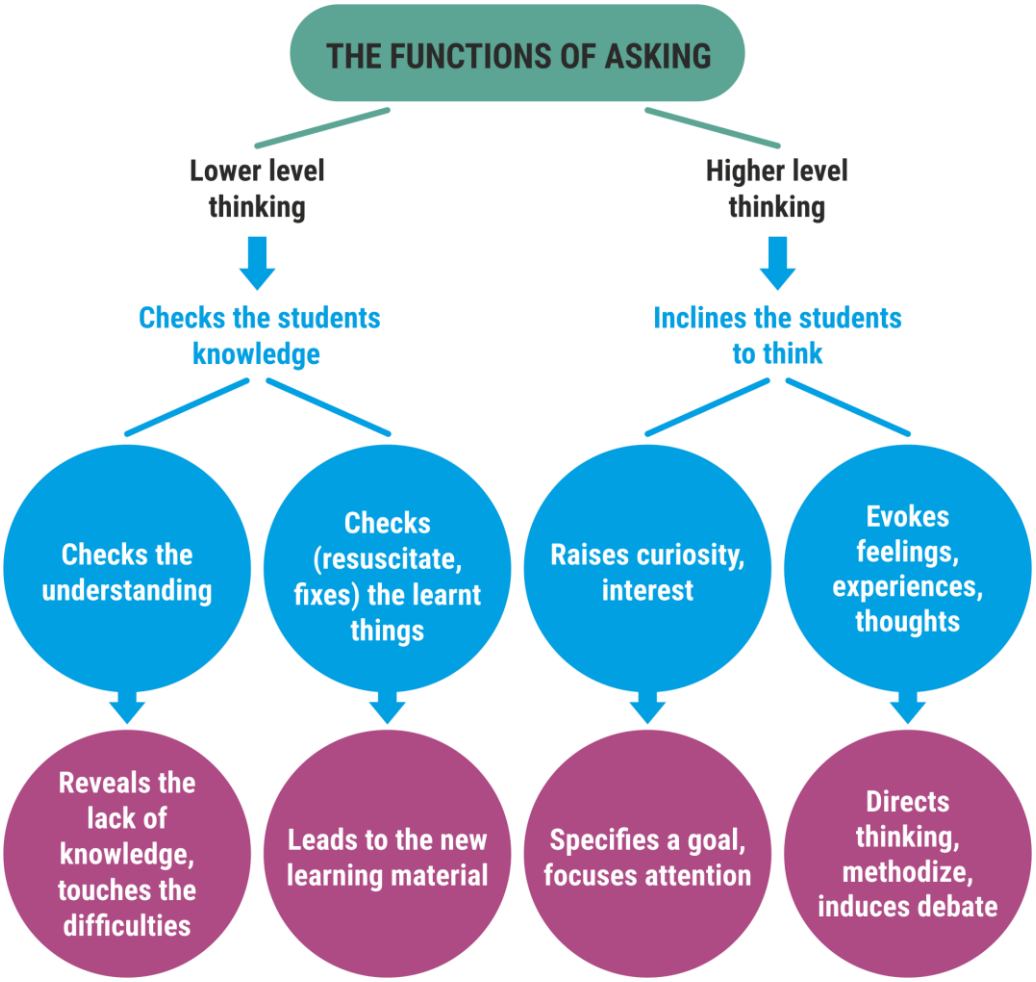


Figure 23: The functions of teacher interrogation in the teaching-learning process [100]

However, in reality often it is just the opposite that happens. The questions posed in the wrong way or at the wrong time can hinder the students' independent train of thought, and can cause content disturbance, can make them unsure. The lecturers might as well obstruct the thinking process by asking too much, they try to keep the learning process of the teaching material under control with many small questions and meanwhile they control the students' thinking. By this, not consciously, they absolve the students from the efforts of thinking, thus they slowly give up asking, and what is even a bigger problem, individual thinking. We often meet the phenomenon that the teachers, lecturers do not welcome students' questions, are less helpful to answer them watchfully, with sufficient details, encourage them less to participate in dialogues in connection with the learning material. Based on these, I particularly find it useful to introduce a method in the system of the higher education for engineering which is based on questions.

The work hypotheses of the edu-coaching method based on questions are the following:

1. Inventing the solutions
   The question „WHY" – to reveal the source of the problem - common in the classical education is replaced with such targeted questions and tools which focus the attention to the solution, so the conversation is raised from the level of the problem to the level of solution, thus the solution gets into the focus of the conversation. A question directed to the solution, for instance, is: „What would the solution facilitate?" or „If you could solve the problem, what would be different, what kind of operation could we accomplish?"
2. The experience of the solution already exists in the students
   „Which is the method/process/solution that worked earlier?" With this question we lead the students to what resources help them to solve the task. What they have to do for success, what brought a solution in a similar situation.
3. TRUST towards the students' resources, competences.
   The students specify what should be improved to reach the goal. They can work on what they consider important. This trust is a strong motivating factor on the way to reach the common goal as the students have to justify „their own truth" during the solution. Although the lecturer, as a coach can delicately coordinate the direction of the further progress with questions and summaries, but is primarily the observer of the process. If necessary, he „gives a safety net", helps the students if they have chosen the wrong direction, but he always has to keep in mind the freedom of choice.
4. The benefit of being an outsider, „not knowing"
   The lecturer, in the role of the coach, can enforce the unpretentiousness deriving from „not knowing" against the students' hypotheses, at the same time this „being an outsider" gives the freedom to pose „surprising" questions, with this he can delicately lead the course of learning in the right direction.

In terms of the working form, I consider the team work the most efficient to teach the disruptive technologies where the team members do both individual and common work. With this the supporting role of the cooperative education organization, the project-based educational method and the problem-based learning strategy. in the development of the method, based on which I considered the steps elaborated here as the basis of the edu-coaching method.

The actual tasks of the edu-coaching method:

1. Choosing the topic: Specifying the content of education
2. Preliminary planning
    a. Planning the optimal educational environment,
    b. Specifying the student target groups to be involve in the education (a target group spanning through courses, years or even training levels is also possible),
    c. Identifying special fields, project parts,
    d. Identifying the sources of information finding
3. Objective: Dual objective specification
    a. Specifying the external target which aims at a new product;
    b. Specifying the internal target: aims at learning targets
4. Organizing and planning tasks
    a. Making a schedule which includes the compilation of the progress plan and the schedule of the discussions.
    b. Specifying the number of people in the group
    c. Specifying the composition of the groups
    d. Considering the initial knowledge
    e. Specifying the initial tools necessary for the work
    f. Compiling thought provoking presentations, videos and other materials
    g. Forming the students' self-assessment system
    h. Compiling the question groups helping the work suiting the coaching method
5. Education with the edu-coaching method
    a. Coaching agreement – fixing the goal
    b. Fixing the time of meetings
    c. Making a list: „What do we already know?"
    d. Taking resources into account
    e. Specifying the steps of progress
    f. Making a mutual schedule
    g. Dividing the roles and the tasks, assigning deadlines to the tasks
6. Administering a project diary
7. Presenting the results
8. Closing, assessment

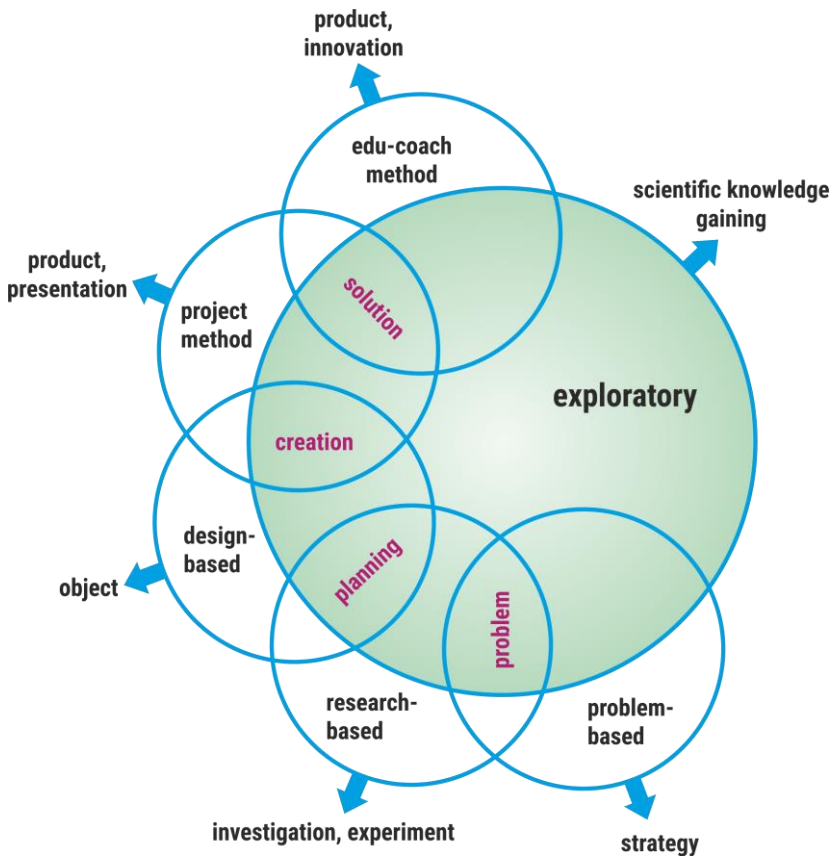


Figure 24: The position of edu-coaching in the methodological bases of the learning by doing method, Source: personal editing

As a summary, we can say that the presented edu-coaching method gives guidelines for creating such a work form which facilitates the rapid introduction of the disruptive technologies in the higher education of engineering. Due to its solution-centered educational approach, its application greatly contributes to the successful teaching of the disruptive technologies in the early phase, to the development of the engineering innovation. We can say that the presented educational methods supplemented with the edu-coaching method include such educational tools which facilitate the rapid introduction of the disruptive technologies, thus these confirm the statement in Thesis 3.

The efficiency of edu-coaching can be further increased with the educational application of modern IT devices. I am presenting a good practice for it in the next chapter.

2.4 Thesis 4.

2.4.1 Implementing the edu-coaching method in the 3D VR learning environments

In this chapter I am investigating the integration of the disruptive technologies in the learning material of the higher education in terms of specifying the optimal learning environment After the theoretical elaboration of the edu-coaching method presented in Thesis III. I have put the emphasis on the practical application of the method in the educational environment.

Thesis 4: [RJ-1], [RC-1], [RC-2], [RC-3], [RC-4], [RC-5], [RJ-3], [RJ-4]
I proved that VR educational environments can ensure the digital and cooperative tool demand of the edu-coaching method and is much better suited to the digital life of the generation Z students than the tools that are in current use. Therefore, I justified the claim that VR educational environments have an outstanding role in the structural development necessary for the education of disruptive technologies.

Thesis 4.1.
I showed that the cooperative VR learning environment efficiently moderates the contrast between the digital life of generation Z students and the ICT-based educational facilities of the higher education.

Thesis 4.2.
I proved that cooperative VR environments provide the digital tools necessary for project-based education, at the same time I justified that they ensure an efficient educational scene for the education of disruptive technologies and can integrate the digital life of generation Z students.

Thesis 4.3.
I have developed and implemented the cooperative VR pilot learning environment for teaching the memristor with the edu-coaching type of education to investigate and confirm the hypotheses in the thesis, and as a directive for planning this type of educational spaces.

The research results of „The Internet of the Future", the results connected to the fourth industrial revolution published as „Industry 4.0" increasingly tend to the direction of the 3D internet and the Internet of Things. Connected to this, the hypothesis that justified the induction of the internet-based learning environments and cooperative educational methods

by the disruptive technologies justified in Thesis 2. drew my attention to the internet-based educational environment, thus I decided to implement the edu-coaching method - presented in the previous chapter- in the 3D virtual educational environment.

To implement the actual tasks of the edu-coaching method, first I chose the educational topic which aimed at a technology from the wide range of the appearing disruptive technologies which suits both the computer science engineer and the electrical engineer students' educational material. The chosen disruptive technology is the Memristor, as the education of a new circuit element. As the complex solution of the steps listed at the preliminary planning, I decided to implement the education of the memristor in a virtual educational space. My decision was supported by connectivism, which is the learning theory of the digital era, recognized during my previous studies which interprets learning as a network building activity [138]. Connectivism does not consider people as isolated individuals, but as an individual situated in a network, as it is realized in the digital life of the students participating in the higher education today. The connectivist learning theory interprets learning as a process where the informal information exchange organized in a network supported by electronic tools has an increasing role. Learning is becoming more and more a continuous, life-long networked activity system embedded in other activities." [11] Besides the educational environment thoroughly chosen, the success of the learning process is influenced by the participants, - the motivation, the the commitment of the lecturer and the students, the applied methods, the learning organizational processes, even the structure of the educational content and the basic principles of selecting it, and many other factors. The educational technological and educational methodological conditions are completely provided in the VR space to organize courses based on the connectivist approach with which, combined with the edu-coaching method, we can implement the efficient education of the disruptive technologies in the early phase in a project- based cooperative and collaborative VR learning environment with the help of the solution-centered learning organization inherent in the edu-coaching method.

As a further support of my decision, I investigated the characteristics of the virtual environment which, based on their peculiarities, support the cooperation between several users. The CVE category, the collaborative virtual environment means a particularly important group in terms of education. The virtual worlds provide an opportunity to bridge the real distances in space, and the CVE facilitates the cooperation in the project, and the lecturer, as a coach according to the edu-coaching method which supplements it, helps to achieve the set targets.

2.4.2 Virtual reality

According to the definition, virtual reality is a simulated environment, which attempts to describe, simulate the processes of the real world with the help of a computer model. It is partly a common, shared space where several users are present at the same time. Thus, the event, the activity happens in real time facilitating direct communication, cooperative work with internet applications. The users develop, create contents, can work in common documents, can even change the VR environment, can supplement it with 3D models, process simulations. The main advantage of the VR environment is that it is accessible regardless of space and time, it is cost-efficient and simple to use.

In the online environment, many of the users, mainly the older generation, are present only passively, they obtain and use information as observers, they do not consider their own appearance important, or limit it consciously. On the contrary, in the virtual environment, according to the basic settings one cannot hide passively because it means quitting the process. This characteristic of the VR spaces also ensures the active participation of the students in the learning process and at the same time the activity of the older generation, the expansion of their ICT device using habits

2.4.3 The features of the VR space

The virtual spaces, to which we can connect from anywhere, operated by the servers are identical in the several basic characteristics listed below [14]:

- common, shared space in which several users can be present at the same time,
- being real time, that is the events and the activities happen in real time,
- directness, that is it facilitates the participants' direct communication,
- community characterizes it, that is the creation of the social groups is a supported activity,
- interactivity: the users can develop contents, can modify the environment, can create in the VR space,
- ensures a graphic user's access,
- permanency, the virtual environment remains, it preserves the status left behind at the last access when the user is not present.

All of the characteristics mentioned above well suit to the edu-coaching method, as the students do not have to carry out the accomplishment of the task in the shared space

individually. To find and share the information leading to the solution and integrating the information in a knowledge system are all helped by the social feature, the opportunity of interactivity, the access to information in the created environment regardless of space and time, thus we can state that the edu-coaching method can be well combined with VR educational environment.

The use of the VR space

The use of space in the virtual environment is significantly different from the space use common in online or real environment. For example, the avatar can get to any point of the space and can view any points from any points so that its position does not or hardly changes. This helps the development of the abstraction abilities of the participants, the foundation of the complex perspective and the development of the ability of spatial and time abstraction. One aim of the use of the virtual environment is the elimination of the spatial distance. Online communication solutions can bridge the spatial distances. Time distances in the VR space are bridged by keeping the communicated information, accessing it regardless of space and time.

The virtual environments in themselves, with ensuring the space independence and with the opportunity of integration with other systems, operate as developed communicational systems where we can work together so that there is an opportunity for both individual and team work. In the virtual space, similar to the real environment, we can specify who, where, when do what, and the results become accessible for the members of the team immediately. In the virtual environment, we might completely change our environment according to our technical knowledge with relatively little material and time input. The targeted equipments of the VR environment, the environment developing habits are a different research area.

We must not forget about the opportunities inherent in the development of the virtual space, such as editing common documents, creating, visualizing 3D objects, running simulations, as the further opportunities of knowledge gain which also help the cooperation, the implementation of the common project.

At the same time, the CogInfoCom research shows that the cooperation of the intelligent systems in the virtual digital space also efficiently facilitates finding, processing the information and the learning processes with the help of the extended reality. The cloud computing-technologies, the 3D internet and the creation of the technological innovation connected to the presently so widespread 3D VR tools today have facilitated to implement the education at the shared virtual spaces, thus the students can get and get to know the

professional information published about the future technologies as soon as possible, and even they can develop the techniques and technologies appearing in an increasing number. The above-mentioned facts confirm the hypothesis of Thesis 4, according to which the edu-coaching method can well be combined with the VR educational environment in favour of the structural development necessary for the efficient education of the disruptive technologies.

It is important to know to create the virtual educational scene that the CE generation students' personal ICT tools have the computing capacity and stability which facilitate that we could merge the real and virtual reality in the educational spaces – similar to the digital life of our students. This hypothesis was justified at a local level by the results of the questionnaire to survey the digital life of generation Z presented in chapter II. of this paper, thus the implementation of the pilot project is not hindered by the students' tool supply.

2.4.4 VR workspaces powered by MaxWhere

During my educational work carried out at the Faculty of Engineering and Information Technology I have developed and implemented a cooperative VR learning environment for the education of the disruptive technologies. Primarily, we applied the 3D visualization created in the VR learning environment with the use of VirCa platform [52, 53, 162, 154] developed by the Hungarian Academy of Sciences Institute for Computer Science and Control. Later the Széchenyi István University and the Mistems Ltd. developed new 3D VR spaces based on the MaxWhere engine. Today education is implemented in the MaxWhere virtual educational environment/framework system.

I chose the 3D visualization in the virtual space because it suits better to the natural cognitive processes of the human brain, and at the same time the 3D visualization also suits to the popular scenes of the students' digital life, (3D games), thus it provides a suitable comfortable feeling for work. This educational space helps to forget about the working and learning features of the activity carried out here. This is a virtual social world (VSW) and in this category the social space is the most significant aspect. We further increase the students' motivation with merging the cooperativity deriving from team work, the project method, the research, - exploratory method and the edu-coaching methods. We utilize the opportunity of learning from each other and common work with cooperation, the combination of theoretical knowledge and practical application with projects, the development of competences necessary for the process of knowledge gain and the practice of setting up, confirming or disproving the hypotheses with the exploratory method, taking responsibility and the power of inner

motivation with the help of edu-coaching. With this the education carried out in the VR environment completely suits to the standards developed for the learning and educational processes of the digital era by the international organization ISTE (International Society for Technology in Education) which the competence family called NETS (National Educational Technology Standards) contains presented in the chapter titled Antecedents.

The renowned pedagogist, Edgar Dale presents on the „Cone of Learning", a learning pyramid (Figure 26.) he created based on the experiences, that during learning the level of retaining information increases or decreases depending on each type of activity carried out. As we can see, active learning stimulates the cognitive processes.

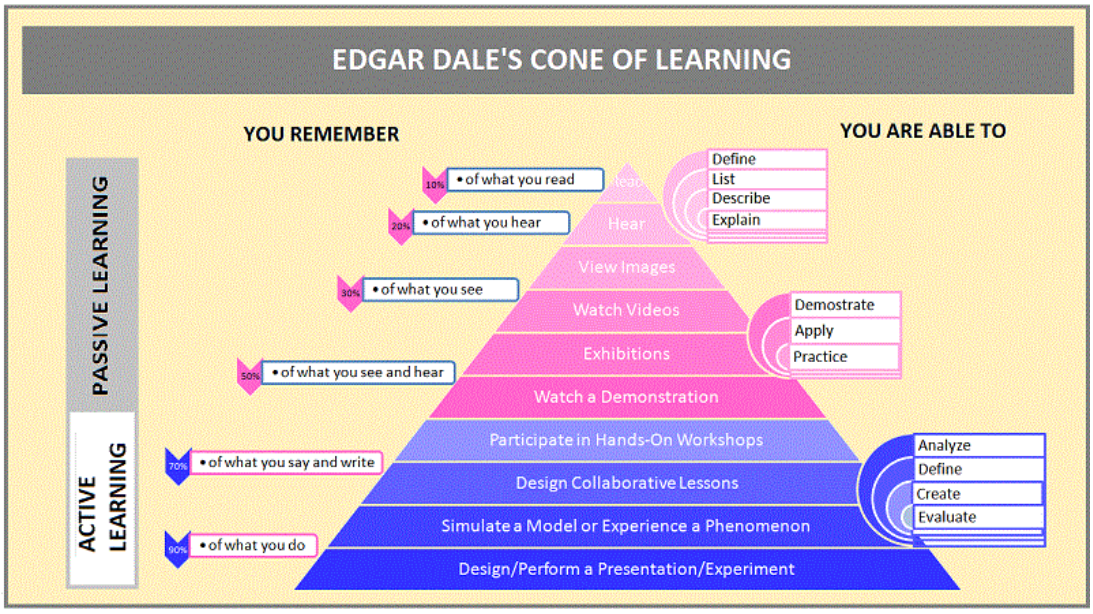


Figure 25: Edgar Dale's Cone of Learning [77].

The Cyber Learning solution enforces the activities shown in Edgar Dale's learning pyramid in the most optimal way. We must highlight as a further advantage that the previously made presentations, e-learning materials can be smoothly used both on the VirCa platform initially applied and in the MaxWhere environment already developed into a VR educational framework system. The presentations helping the previously prepared presentations can be inserted in the MaxWhere framework system just with a few clicks, but the opportunities provided by the google applications (Google Drive, Google Calendar, Translator, News etc.) can easily be integrated in the system, thus it is not necessarily needed to make a personal website or to share the individually developed contents necessary for the education. The applications embedded in the cloud, such as chat, video, or e.g. appear.in providing personal online appearance all ensure the opportunity of continuous contact, the real time

communication in the virtual space, thus they are completely suitable for the education of the still developing disruptive technologies.

VirCA – Virtual Collaboration Arena [52, 53, 153, 154, 159,160]

The Computing and Automation Research Institute of the Hungarian Academy of Science, the Széchenyi István University and the Budapest University of Technology and Economics jointly created the VirCa platform with the help of national and international projects. The Hungarian Academy of Sciences Institute for Computer Science and Control platform first appeared even internationally with grandiose VR abilities for which they were awarded the special prize at the IROS conference and exhibition in Taiwan (EU-FET'11 Award Cross Exhibit), then in 2013 they also won the TUV Rheiland innovation prize. The advantage of the VirCa is that it is a suitable platform for the visualization of the most diverse VR and AR projects which can visualize 3D, thus it is completely applicable for training the future engineers. To use it we do not need special visualization tools, it can run and be enjoyed on a PC or a laptop with an appropriate resource, thus it does not mean an extra investment for the students either.

MaxWhere [163, 164]

The development of the platform called MaxWhere, as a successor of VirCa, providing a professional user experience was carried out by the Széchenyi István University of Győr and the Mistems Ltd. MaxWhere is an innovative VR engine situated in a cloud, which integrates the opportunities provided by WEB technologies - HTML5, CSS, Javascript, etc. – and the 3D space, which is to replace the 2 dimensional graphic operating systems common at present, thus opening up a new dimension of the informatics applications.
MaxWhere radically transforms the experience of digital life, it realizes learning, information finding adjusted to the life situation through a common VR space realized with richer, more entertaining real interactions and expands the boundaries of the digital life.
It incredibly increases the opportunities of cooperative team work and learning independent of space and time so that it makes the Webtablen notes and chats set the URL of the discussions accessible in the browser of the mobile device, makes them manageable and adds them to the mobile starting screen so that they could be accessible by the users with one click. These only have to be uploaded on web tables, then share the site in a package, and the colleagues are able to connect to its work immediately.

The increased development of the immersive virtual environment keeps the ongoing processes within tighter frames, which is great help initially as when entering, all users will know what their task is, where to find their own materials during the total duration of the process, and they do not need to search for the information helping their work on the internet, or in their own printed or electronic materials either. Here the user is not sitting in front of the internet, as he did in the era of web 1.0, internet does not appear among users as an intermediary medium as in the era of web 2.0, but internet literally surrounds the user. MaxWhere is the realization of the expansion of opportunities provided by the web 3.0 virtual environments.

Its particular advantage is simple use which is not only realized in the field of transport in space, in content uploading and management, but it also concerns that there is no need for special investment in equipments. It can ensure the 3D experience so fashionable today without the application of VR oculus. The user does not need to be burdened with different sensors to follow the work processes.

When creating spaces, the developers paid attention to create landscape format webtables adjusting to the 4:3 proportion type of field of view of the human eyes easily interpretable for the human brain and to thoroughly designed working desks, thus helping rapid information finding and processing.

The 3D VR spaces are extremely powerful as they will give you a high-level overview of your teamwork. The arrangement inside them fulfils the dreams of Slack, Asana, Trello and Teamwork users and also integrates the benefits of Google Drive, Microsoft 365, Trello and other collaboration software through a single click.

Its development is continuous, adjusts to the users' requirements. It is a framework easily applicable, accessible for everybody, provided with Cognitive Informatics solutions.

2.4.5 Creating the VR learning environment for teaching the memristor

We created a VirCa and later a MaxWhere cooperative learning environment for the education of the memristor from the disruptive technologies in the framework of an educational pilot programme at the Faculty of Engineering and Information Technology at the University of Pécs (Appendix 4.). 3 computer science engineer and 3 electrical engineer students participated in the pilot project, thus these 6 people made up a learning team. Choosing the students from two different courses was justified by the content of the topic of the memristor – as a new circuit element whose application in the field of informatics can

strongly be expected. The primary aim was to achieve that with the integration of the applications suiting to the digital life of the CE generation students in the learning space, during work the students should not have to leave the learning environment, but - within that – they could use the social media applications, the browsing programme, could watch videos, could appear online, could communicate and prepare the solutions related to the given project. According to our supposition, with the fact that they can access everything in an environment well-known and preferred by them, the borderline between learning, work and free time activities fades, thus they spend exponentially more time, energy on carrying out their task. This hypothesis was completely justified by the records concerning the time spent on work in the project diaries applied in the edu-coaching method. To enhance the efficiency we replaced the role of the lecturer for the role of the coach suiting the coaching technique efficiently applied in the company trainings in the market sector, thus the lecturer appeared as an almost equal partner, as a „mentor", „helper" in the learning process. The steps of creating the course provided by the opportunities of the VirCa/MaxWhere platform have become significantly simpler as we could experience it in the case of „classical" connectivist courses.

2.4.5.1 The steps of creating the course

The steps of creating the course titled „Teaching the memristor in the VR space with the edu-coaching method":

1. Choosing the topic - Inventing the name, target of the course
2. Objectives
3. Preliminary planning – Planning the educational environment, assembling the initial „toolpark", editing the thematics, choosing the students, specifying the steps of progression
4. Assembling the „proposition" (related electronic materials, presentations, videos, learning materials, URL addresses) which continuously, dynamically „developed" compared to the initial status with the help of the students.
5. Defining the section-projects, tasks
6. Composing questions for each task, according to the coaching technique, editing a project diary (individual and common)
7. Content management
8. Presenting the results (per section projects and closing presentation)
9. Closing, assessment

The chosen topic is the memristor. The target is the extensive recognition of the memristor, as a new disruptive technology in the upward curve of the Hype Graph, revealing its developing, applicational opportunities, developing individual ideas.

Assembling the elements of the cooperative VR learning environment suiting to the topic

We created a futuristic „capsule" seemingly situated far from everything as the space of the cooperative research work in which the students can see at once on entering that with the help of the internet the digital world unfolds infinitely. The information – in connection with the topic in the focus of the education – arrive on loads of channels parallelly, thus ensuring to satisfy the CE generation students' information hunger and to maintain continuous interest.

When equipping the virtual room, we had to pay a special attention to choose the equipments and applications suitable for ensuring the most extensive cooperation possible. The students could naturally move freely in the room, they could look at each other's activity any time, could freely communicate with each other and also naturally with the lecturer helping as a coach.

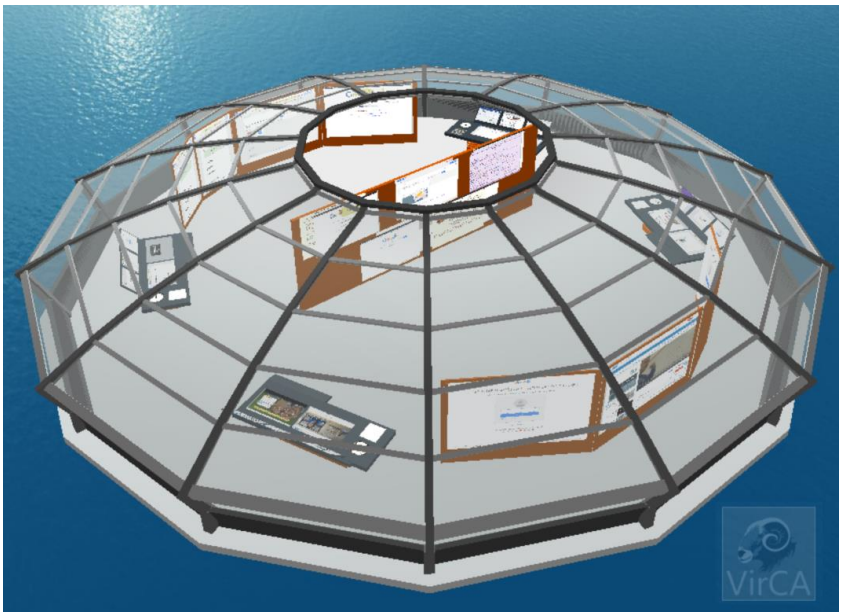


Figure 26: Cooperative VR space [RC-3]

A huge surface, so-called „messaging board" or „presentation space" was placed in the middle of the room which served to visualize the thoroughly considered, prepared information to be shared with the team members during the common project diary and brainstormings. As Figure 26. shows there are 5-5 freely alterable surfaces available on each side of the board for the team. They can place actually any kind of content, e.g. videos, presentations, plans, publications, even questions which help the successful accomplishment of the given project. A virtual (shared screened) presentational space was placed in units of four on the two

opposite side of the room on the right and left of the board. I uploaded them with initial information, one for the computer science engineer students and one for the electrical engineer students, which included a presentation of a lecture material I had made, a motivating professional video related to the given specialization to raise interest, a chat board and a browsing surface on both side.

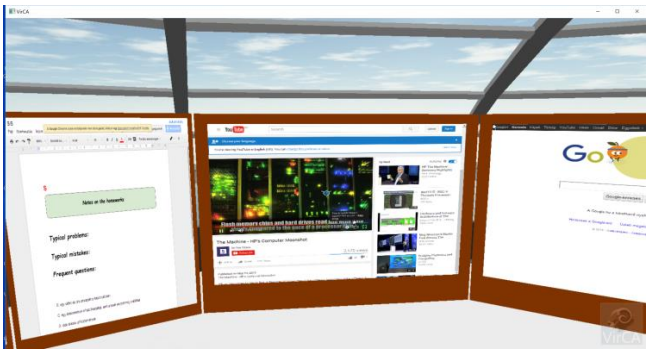


Figure 27: Presentation space for the computer science engineer students [RC-3]

Figure 28:: Presentation space for the electrical engineer students

Figure 27 shows a part of the initial surface made for the computer science engineer students in the middle of which the energetic presentation of „The Machine" project of HP welcomes them (The fourth screen missing from the picture includes the professional presentation.) On the surface for the electrical engineer students in Figure 28. Leon Chua, the inventor of the memristor talks about what the concept had been which made him think that a fourth basic circuit element also had to exist. Both the recording of the HP and Professor Leon Chua's presentation have the aim to get the students to first meet the technological innovation in the original environment related to their specialization enhancing the effect to raise interest even more. (The scraps surface helping the common thinking of the students is missing from this figure.)

Later both teams transformed these contents according to their project from time to time. We can say that the professional teams created the materials prepared for the „message board" here with the series of the cooperative and collaborative activities. Besides the online spaces, 2-2 working desks were also available for the members of both teams on which we placed a calculator helping to carry out the calculation tasks, and a clock to keep the set deadlines.

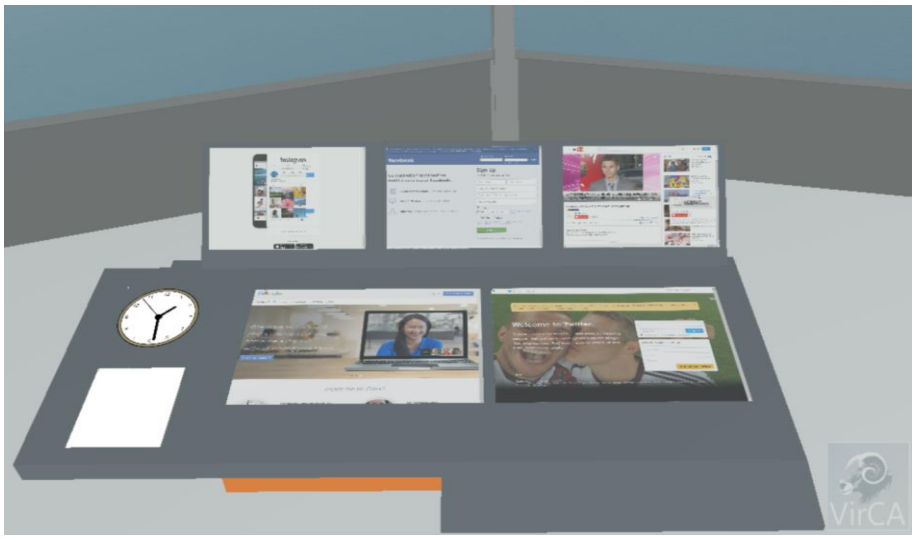


Figure 29: Working desk in the VR space [RC-3]

In the space equipped like this, according to the shared tasks everybody had the opportunity to create their own working environment. As a main rule, 1-1 student in every project of both team worked on the working desks equipped as seen above where the facebook, the chat, the mail programme, a browsing surface and a professional programme surface - as the most frequent content - generally accessible online helped the students' work, thus they did not have to „waste time" on selecting these applications either. The third member of the team, usually the leader of the actual project coordinated the four-unit presentational space mentioned above. The element of the psychology-focused learning definitions particularly correct in the everyday pedagogy that learning is not merely information finding, but also forming the attitude because the students in the VR space learnt how to behave during a project was implemented in the virtual space above. What factors they should consider in sorting out each role, how to behave in the role assigned to them. To take responsibility for their work, to learn the importance of time management and keeping the deadlines, to learn the competences, skills necessary during the team work, to keep the target to be achieved primarily in mind. They successfully developed their presentational skills required by the future employers, their communicational skills developed through presenting, defending their professional point of views. They experienced the necessity for the knowledge of English terminology which led to the development of their professional foreign language competences.

The educational environment created this way is completely in accordance with the results of generation Z questionnaire presented in Thesis I. We considered that according to the responses given to the questionnaire, the students uniformly prefer the cooperative, collaborative work implemented in the online spaces, they like working together with their

peers in online social learning spaces and they use the social media, the internet applications for their studies. In conclusion, we can say that the 3D VR learning environment efficiently moderates the contrast between the digital life of generation Z students and the educational facilities of the ICT-based higher education. The results of generation Z questionnaire presented in Thesis I. and the results of the interview carried out with the students participating in the pilot project justified this hypothesis. (The questions of the interview can be read in Appendix 3.)

All the students participating in the project stated in connection with the interview that in the 3D VR learning environment they had the chance to use, and they did use all the internet applications which they willingly use in their every day life.

The diagramme below shows the internet applications integrated in the VR environment categorized according to the number of the users.

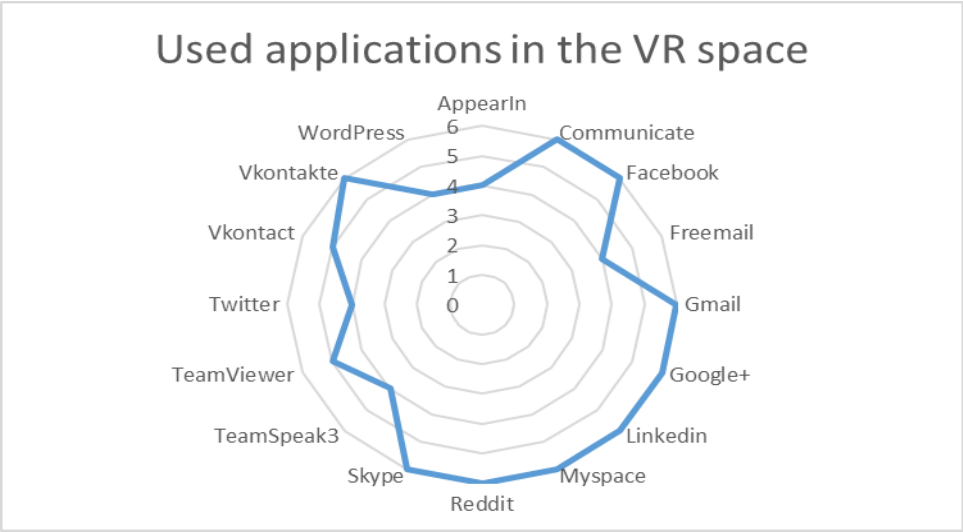


Figure 30: Internet applications the students use in the VR space, Source: personal editing

The VR learning environment suitable for the cooperative work created by considering the responses of generation Z questionnaire presented in Thesis I. can completely integrate the digital life of generation Z students, helping the efficient education of the disruptive technologies.

2.4.6 The application of the edu-coaching method in the 3D VR educational space

The 3D VR space in itself had an immensely motivating effect on the students, this effect was increased by the application of the edu-coaching method I had already tested in the traditional learning environment in the higher education of engineering which also incorporates

cooperativeness, the project method, the research, - exploratory method supplementing these with the techniques applied in coaching. By presenting the main phases of the application of the edu-coaching method in the VR space I want to justify the hypothesis of Thesis 4.3. according to which the cooperative VR learning environment facilitates the efficient implementation of the edu-coaching method. At the same time, I would like to show that students are granted trust deservedly in the education by the edu-coaching method because they carry out their tasks responsibly which they had undertook in the project.

At the first meeting, as the „astonishment" at the VR space immensely helped the intention to participate in the educational project which is very important because in the planning phase drawing up the target happens together, thus the students' activity, motivation are essentially needed. The main question is what is the needed knowledge in the future which we want to have when closing the project? In our case it was the exploration, invention of the fields of application of the memristor. The target carries in itself the „excitement of playing" with the activation of the creative, innovative spirit. According to the students' accounts it was immensely inspiring for them to test „whether I can create something new, a tool, development grounded in engineering?"

An important element of the preliminary planning phase following the creation of the optimal educational environment is defining the time of meetings when all the participants check in simultaneously in the virtual space and take part in the work. Predictability, time management and concentration on the task require the creation of this foreseeable system. These meeting times usually coincide with the time of a curricular class and with the closing time of one or the other sub-project.

The edu-coaching provides a conceptual framework for the students to have the opportunity to invent, develop new solutions, as a consequence they can consider the accomplished success as their own achievement. This conceptual framework practically means that the initial information has to be assembled after serious consideration, we must not specify a too extensive task unit. In most cases there is a contradiction between the existing knowledge system and the one to be processed. During the solution the existing knowledge has to be activated so that it leads to the needed result. During this process we create hypotheses, then we check them one after the other. The final goal is to place a given problem within the framework of a greater, more general concept system so that we could handle them securely also in new situations. The survey of the background information has to be formed so that the students themselves realize which knowledge they had gained earlier they can build on, what they have to review for stepping further. In connection with the knowledge gain concerning

the memristor the electrical engineer students claimed the basic circuit elements, the connections between them, the different switchings, electromagnetic knowledge etc. as necessary preliminary knowledge. The computer science engineer students highlighted and reviewed the hardware basic knowledge, the computer generations, their structure, operation, the types of memories, their working principles and the digital technological knowledge.

During the application of the edu-coaching method a significant element is the creation of the self-assessment system for the students which we carried out in each „meeting", as this helps to maintain the feeling of commitment, greatly contributes to develop responsibility and to target-oriented working. Usually a recurrent question is: how many points would you give to the present state in the working process on a 10-point scale where 10 means the maximal accomplishment of the task? „What should be done to achieve a value one point higher?" Thus, the students themselves draw up the next short-term target to the questions posed. As long as the student cannot tell what the next expedient step should be, then the members of the team draw up the course of stepping further together.

Besides defining the course of progress we paid a special attention to make a common schedule. We discussed the correlation between the tasks together. The most important of these was to specify those when the output of one task is necessary for starting the other task. The length of the project was defined by such task-series (critical way) because stepping further could only happen based on the results of the section tasks. The schedule, with the name of the responsible people indicated to each task had a central role in the VR space further increasing taking responsibility and student motivation. The students accounted about their time management in the individual project diary during their activity in the project. In the reflection, - and problem-solving phase which accompanies the learning process we concentrate on the solution and the way leading to the solution and not on the problems , thus if one of the students gets stuck with his task, then we did not look for the cause of the problem with targeted questions (as an experienced lecturer this is generally well-known for the teacher), but we tried to find the answer to how we could help stepping further so that primarily the students themselves could solve that. We applied these „clearing discussions" both in private conversations or also in teams which in many case helped the other members of the team in the process of solving the task individually.

Following the rules of the project management naturally the closing of the work could not be avoided. We discussed how much the target was accomplished, what worked, what did not work, what experiences can be carried on and what consequences can be drawn about the carried out process.

The students participating in the pilot project offered creative suggestions as solutions for the application of the memristor, as a new circuit element applicable in case of over-voltage and flash protection where they utilized the dissipative feature of the memristor when creating the theoretical models. These suggestions naturally cannot be considered as an implemented engineering development, prototypes were not made, but they served the process of acquiring the secure theoretical material. Last but not least, the common joy of well-done work serves as a positive confirmation for the cooperation in the further project.

The students said in the personal interview closing the project that they enjoyed the common work, the challenges, and they would willingly continue their studies in a similar 3D VR environment also in case of several topics.

The experiences of the pilot project summarized above, based on generation Z questionnaire presented in Thesis 1. and on the student interviews carried out at the closing of the project, the hypotheses of Thesis 4. were justified. With the implementation of the pilot project I showed that the edu-coaching method can well be combined with the VR educational environment in favour of the structural development necessary for the efficient teaching of the disruptive technologies. I justified in the VR learning environment which I developed and implemented that the VR space efficiently moderates the contrast between the digital life of generation Z students and the ICT-based educational facilities of the higher education. I proved that the cooperative VR learning environment due to its project-based opportunity provides an efficient educational scene for teaching the disruptive technologies and can integrate the digital life of generation Z students. At the same time, the education of the disruptive technologies is made efficient by applying the edu-coaching method in the VR educational space.

3 Summary of research achievements

In my thesis I presented the implementation of the pedagogical developments connected to the science of CogInfoCom.

In my summary, firstly, I described the research field of the thesis, then the theses and their benefits in education.

3.1 Research field of the thesis

First of all, let us recall the definition of coginfocom [7,8]:

"Cognitive infocommunications (CogInfoCom) investigates the link between the research areas of infocommunications and the cognitive sciences, as well as the various engineering applications which have emerged as the synergic combination of these sciences. The primary goal of CogInfoCom is to provide a systematic view of how cognitive processes can co-evolve with infocommunications devices so that the capabilities of the human brain may not only be extended through these devices, irrespective of geographical distance, but may also interact with the capabilities of any artificially cognitive system. This merging and extension of cognitive capabilities is targeted towards engineering applications in which artificial and/or natural cognitive systems are enabled to work together more effectively."

The first definition was finalised by a group of worldwide acclaimed professors dealing with different fields of informatics and cognitive sciences in 2010. This event in Tokyo was the first scientific conference on Cognitive Infocommunications. Cognitive infocommunications (CogInfoCom) is an interdisciplinary research field that has emerged as a synergy between infocommunications and the cognitive sciences. One of the key observations behind CogInfoCom is that through a convergence process between these fields, humans and ICT are becoming entangled at various levels, as a result of which new forms of cognitive capabilities are appearing. Crucially, these capabilities are neither purely natural (i.e., human), nor purely artificial; therefore, it is suggested that they should be treated in a way that unifies both engineering and human-oriented perspectives.

It can also be viewed as the next step of the scientific field termed as Human Computer Interaction. Since the border between human and ICT is disappearing - that means the border between natural and artificial cognitive system is getting fuzzy - we may have a higher level of discussion and consider this human ICT combo as one entity instead of two entities being in interaction and we may investigate new emerging cognitive capabilities of this combo.

Another important aspect is that the next generation grows up with ICT, its personal and social cognitive capabilities will be powered by ICT from very beginning that leads to the combo of artificial and natural cognitive systems that cannot be separated anymore on mental level even in case when the hardware components of the digital area is separated from that combo. This generation is the CE generation as was discussed in Thesis 1.in this dissertation.

VR and AR has a very strong relation and will emerge in combination in the near future as a largest boom in ICT. This will gain the emergence of the above mentioned human/ICT combo

and will strengthen the co-evolve life of VR, digital life and Human as never seen before. Therefore, various cognitive capabilities are emerging that are not really dedicated to any of human or VR/AI. Therefore, we may conclude that VR/AI + Human combo is one of the focus areas of Cognitive Infocommunication.

Education is one of the key components in growing and training – or say developing - the human cognitive system. If the VR/AI is applied in this „human cognitive system development„ then human will use VR/AI on various levels of his perception and information processes. As mentioned earlier, in this VR environment the social activity and experiencing of the 3D objects and their interactions (experiencing the VR world) trains various capabilities of human in a way never seen before and even triggers new cognitive capabilities. This is the point when we see various cognitive capabilities, born under the VR/AI powered education, that can never be separated on level of mental activities especially in case when this type of education is introduced to undergraduate students.

Based on the above, the scientific topic of the thesis belongs to education and VR in a narrow sense but in general it belongs to scientific discipline of Cognitive Infocommunications.

In my research I dealt with the investigation of the effects the disruptive technologies have on the higher education. My objective was to create the VR learning environment serving the needs of the CE generation students in the higher education of engineering suitable for the education of the disruptive technologies and also the method suitable for it. In my work I was looking for informatics solutions which can efficiently be applied for the problem of how we can place the knowledge of the disruptive technologies retaining the strictly limited field of engineering in the focus of the learning material combining the mainly project-based and multidisciplinary knowledge appearing in the market practices and the university environment in an enjoyable educational space and how the efficient knowledge transfer can be achieved. As an objective I drew up the shift of the frames of the present higher education of engineering to the Cyber educational space and the justification of the reason of existence of this VR environment.

To create the theoretical bases I studied the national and international academic literature. The theoretical background of the dissertation is based on several pillars. Besides surveying the disruptive innovation based on the disruptive technologies, the innovation-spread, the life-cycle analytical background of the technologies and the acceptance models my empiric research was based on national and international educational development research beyond studying the educational methods and strategies. By studying the academic literature I analyzed the effects the disruptive technologies applied in the higher education have on the

educational environment and methods and I also investigated how the disruptive effect prevails in the higher educational environment.

In my empiric research, starting from the reality along the inductive research strategy I studied the correlations between the data by analyzing the data collected with the help of questionnaire, by applying correlation-revealing research strategy, and then applying the experimental strategy I intervened in the traditional pedagogical processes.

I carried out two questionnaire surveys in connection with my first thesis from the exploratory methods. In the first questionnaire - with the participation of international institutions of higher education of engineering. - I tried to find the answers concerning the methods, circumstances, the time of integrating the disruptive technologies in the learning material of the higher education. I assembled my questionnaire based on the questionnaire of the study titled „The future of higher education: How technology will shape learning" published in The Economist Intelligence Unit in 2008 supported by the New Media Consortium By analyzing the data base created from the responses given to the questionnaire, by presenting descriptive statistics, then by the statistical investigation of the correlation between the data I justified my Thesis 1., that is the disruptive technologies appear in the learning material of the higher education with a delay, the engineering students often first meet the new technologies after the Peak of Inflated Expectations well defined on the Hype Curve, already in the Trough of Disillusionment. As according to David Tam's theory the acceptance of the new technologies, innovative pursuits is influenced by two factors, utility and simple use, thus in the light of the results of the international questionnaire I approached the cause of delayed introduction from the perspective of simple use. I applied the descriptive and correlation-revealing strategies from the research strategies. With the second questionnaire survey I wanted to gain relevant information about the digital life, the ICT-device supply, internet usage habits, the information finding and learning habits, and about the attitude towards the new technological innovations and labour market requirements of generation Z students currently studying at the Faculty of Engineering and Information Technology of the University of Pécs. I used both open-ended and closed-ended questions in the questionnaire. In case of questions serving the attitude investigations I applied a 5-scale Likert-scale. To assess the results I used the IBM SPSS Statistics 23 and the Microsoft Excel 2013 programmes. In favour of the reliability and consistency of generation Z questionnaire I tried to reduce the measurement error, to this I paid attention to filter out and correct the Sampling error, the Coverage error, the Nonresponse error and the Measurement error. I justified my hypotheses drawn up in Theses 1.1. and 1.2. with the investigation of the statistical correlations of the data. I stated that there

is a contradiction between the technologies - supporting studying- available in the higher education and the online educational environments applied in the digital life of the students. As a following methodological element I carried out a deep interview investigation with the lecturers teaching generation Z students in which I applied open-ended, closed-ended and 5-scaled Likert scale questions, as I tried to reveal the cause for the lack of the optimal learning environment with the investigation of the ICT-device supply and preparedness in informatics of the lecturers currently working in the higher education of engineering belonging to the older generation. In the deep interview carried out with the lecturers I asked the colleagues teaching generation Z students about their ICT supply, their internet-using and device-using habits, and about the application of these in education. As a result of my investigation I stated that there is a significant difference between the ICT device supply, internet usage habits and digital life of generation Z students and their lecturers currently present in the higher education of engineering. Thus, the cause for the delayed appearance of the disruptive technologies lies obviously in the contradiction of the technologies in the higher education and in the student practices.

As the next step of my study, I investigated the appearance of the disruptive technologies in the higher education from the perspective of the educational strategies (target-oriented and control theory- oriented strategies), methods and the structural and quality change of the education. By applying Glenn's Futures Wheel I showed that the methodological, strategical, structural and quality change of the education increases in proportion with the speed of the introduction of the disruptive technologies in the innovative engineering training which significantly helps engineering innovation. After their appearance, the disruptive technologies are still in their developing phase, thus extensive connection, knowledge material spanning through several scientific fields accompany their education which launches an enhanced information hunger in the higher education of engineering. This induces the application of internet-related learning environments and cooperative educational methodologies, thus it approximates the higher educational practices to the digital life of the CE generation students. The appearance of the still developing disruptive technologies in the education stimulated the introduction of method or methods motivating, engaging the CE generation students, requiring a much more active student research and development activity in the higher education of engineering, thus I introduced the concept of coach in the higher education of engineering and developed its method. The edu-coaching method presented in my dissertation tend to the product, the innovation among the methodological bases of the exploratory, learning by doing methods of the scientific learning and at the same time it gives the solution

to the problem raised in the learning process. Thus, the edu-coaching method provides guidelines for the creation of a working form which facilitates the fast introduction of the disruptive technologies in the learning material of the higher education for engineering according to the present technological development. The application of the method greatly contributes to the successful education of the disruptive technologies in the early phase, to understand and further develop the engineering innovations.

3.2 The benefits and implementation of the research results

I focused on the practical implementation as the closing of my research work.

Related to the pedagogical aspect of CogInfoCom, I shifted the frameworks of the traditional education to the cyber space. In the pilot project below, I showed that virtuality can replace particularly those deficiencies which cause certain difficulties in the open education or in the project in the real school environment.

As I stated in Thesis 2. the needs of educating disruptive technologies in their early phase are ensured by 3D VR spaces because space independence can very easily overcome the closed team organization of the frameworks of classes and years impeding projects. In the virtual environment, collaborators can not only come from different learning groups, but also from the school clientele and the business sector. Open virtual environment helps open education so that connection has no formal or hidden obstacles. Global cooperation becomes really global.

In the framework of the pilot project implemented at the University of Pécs at the Faculty of Engineering and Information Technology through the educational example of the memristor I showed that the edu-coaching method can well be combined with the VR educational environments in favour of the structural development necessary for the efficient education of the disruptive technologies. Based on the results of generation Z student questionnaire I showed a „good example” with which I justified in the cooperative VR educational space I developed and implemented that the VR space efficiently moderates the contrast between the digital life of generation Z students and the ICT-based educational abilites of the higher education. I proved that the cooperative VR learning environment due to its project-based educational opportunity ensures an efficient educational scene for the education of the disruptive technologies and can also integrate the digital life of generation Z.

Based on students' feedback we can state that the education of the disruptive technologies can be made efficient if the edu-coaching method is also applied in the VR educational space.

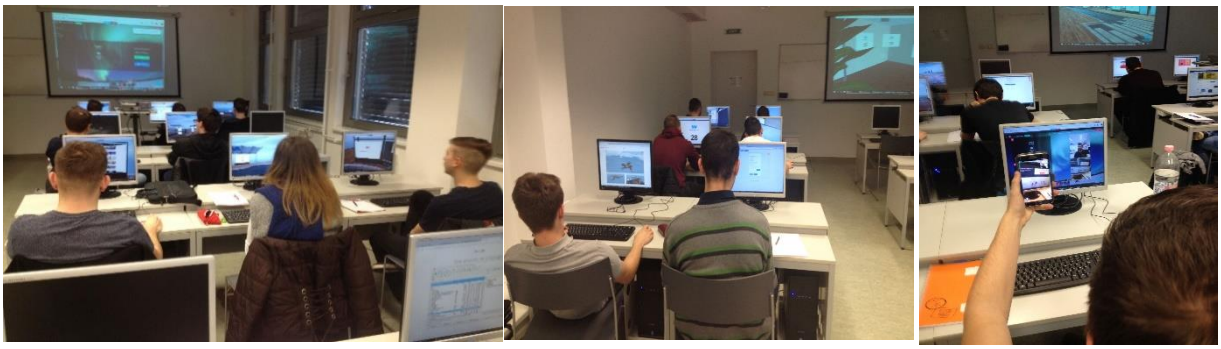


Figure 31: Work in the MaxWhere VR space

With my dissertation I proved that the cooperative VR environments ensure the tools necessary for the project-based education and can integrate the digital life of generation Z students further increasing the efficiency of the education (Figure 31.).

I conclude, that the 3D VR spaces of the MaxWhere [163] completely support the developing teaching-learning processes and the competence-based education, replacing the role of the teacher to a helper, as it provides an opportunity:

- To realize the series of activities gradually built on one another
- To common and differentiated work
- To establish, create a complex perspective
- To develop the ability to abstract in space and time
- To facilitate the understanding of processes, connections and laws
- To create hypotheses
- To continuous feedback, orientation (to carry out teacher's measurements, control)
- To continuous assessment and particularly self-reflection

3D VR spaces allow multiple parallel communication simultaneously.

The effect CogInfoCom has on modern informatics education is indisputable. The informatics educational significance of the 3 dimensional virtual spaces, like the recently emerging MaxWhere presented in this dissertation is, in my view, that it includes the aim of IoT, that is the physical objects with their unique abilities could appear on the Internet. 3D makes the contents placed in space, or the 3D contents appearing on the internet accessible in high resolution, in an immersive way.

The results of the research field of augmented cognition (AugCom) are integrated in the educational application designed for the MaxWhere platform presented in this paper, because

the 3D VR educational environment can extend students' abilities with the help of computer technologies, thus increasing the efficiency of learning.

As a continuation of the research I would like to investigate the opportunities for application of the edu-coaching method applied in the VR space in case of the traditional subjects successfully taught within the frames of the traditional subjects. In my opinion, the sustainability of the research presented in my dissertation, the opportunity of further studies is ensured by the education in the VR space itself because the investigation of the students' roles undertaken in the VR space is a promising, interesting research topic. This, supplemented with investigations measuring student creativity proves to be a further exciting research topic by revealing the correlations of the methods concerning the creativity. Education in the VR space and its pedagogical methods can mean the new branch of the Cognitive Informatics research because the investigation of the cognitive processes created by the close correlation of the human mind and the ICT devices can be ensured based on the investigation of the learning process, the development of student creativity, the development of common knowledge. Along with this, it can have a role in the research of the future internet.

4 Publications

4.1 The Author's Publications Relevant to this Dissertation

[RB-1] I.Horvath, The edu-coaching method in the service of efficient teaching of disruptive technologies, Springer book chapter, Cognitive Infocommunications and computing, in the Series of Topics in Inetelligent Engineering and informatics. Accepted

[RJ-1] Horváth Ildikó, (2016), The education of disruptive technologies in the innovative engineering training, Australian Journal of Intelligent Information Processing System, Vol.14, No.4.

[RJ-2] Horváth Ildikó (2016), Duális képzés a Pécsi Tudományegyetem Műszaki és Informatikai Karán, ELEKTROTECHNIKA 109; (4) pp.13-15.

[RJ-3] Horváth Ildikó: Simulation of a memristor Spark-Gap Model for lightning protection purposes, Technical Gazette 21, 5(2014), pp.1047-1050

[RJ-4] Horváth Ildikó, Elmer György (2014): Simulation of Memristor conducting alternating current, Pollack Periodica Volume 9, Number 3/December 2014 pp.71-78.

[RC-1] Horváth Ildikó, (2016), Disruptive technologies in higher education, 7th IEEE Conference on Cognitive Infocommunications (CogInfoCom 2016), 16-18 October, Wroclaw, Poland, pp. 000347-000352. doi: 10.1109/CogInfoCom.2016.7804574

[RC-2] Horváth Ildikó, (2016), Digital Life Gap between students and lecturers, 7th IEEE Conference on Cognitive Infocommunications (CogInfoCom 2016), 16-18 October, 2016, Wroclaw, Poland, pp. 000353 - 000358, doi: 10.1109/CogInfoCom.2016.7804575

[RC-3] Horváth Ildikó (2016), Innovative engineering education in the cooperative VR environment, 7th IEEE Conference on Cognitive Infocommunications (CogInfoCom 2016), 16-18 October, Wroclaw, Poland, pp. 000359 - 000364, doi: 10.1109/CogInfoCom.2016.7804576

[RC-4] Horváth Ildikó, Dr Kvasznicza Zoltán (2016), Innovative engineering training - Today's answer to the challenges of the future, Conference proceedings of the Clute Institute, 2016 International Education Conference Venice, Italy June 5-9. pp.466-472.

[RC-5] Horváth Ildikó (2016), Társadalmi elvárások és megoldások a műszaki felsőoktatásban, Horizontok és Dialógusok II. Neveléstudományi Konferencia, 2016. Május 4-6. Pécs, pp.41-42. ISBN:978-963-429-043-8

[RC-6] Horváth Ildikó (2015), Appearance of Disruptive Technology in Higher education of engineering, 11th International Miklós Iványi PhD&DLA Symposium 19-20 October, 2015. Pécs, Abstract Book. 128. p.

[RC-7] Horváth Ildikó, Kvasznicza Zoltán (2015), Educational methods assisting the improvement of the competitiveness of sotware engineering education 9th European Conference on Software Architecture (ECSA) 7-11 September 2015. Dubrovnik-Cavtat

[RC-8] Horváth Ildikó: A műszaki felsőoktatás versenyképességének javítását segítő oktatási módszerek, III. Interdiszciplináris Konferencia (IDK2014) Pécs, 2014.április 15-17. *pp. 119-121*.

[RC-9] Horváth Ildikó: Memrisztor-szikraköz működésének szimulációja, III. Interdiszciplináris Konferencia (IDK2014) Pécs, 2014.április 15-17.

pp. 265-266.
[RC-10] Horváth Ildikó: Konstruktív pedagógiai módszerek a műszaki felsőoktatásban, „Tavaszi Szél 2014" Nemzetközi Tudományos Konferencia, Debrecen, 2014. március 21-23.
[RC-11] Ildikó Horváth PBL in Modelling and simulation education, Fiatal Műszakiak Tudományos ülésszaka XIX., Kolozsvár, 2014. március 20-21. *pp.193-196.*
[RC-12] Horváth Ildikó: Konstruktív pedagógiai módszerek a minőségi műszaki felsőoktatás, a kreatív mérnökképzés szolgálatában, Innováció és kreativitás a tudományban, Kolozsvár, 2013. december 6-7. *pp.*
[RC-13] Horváth Ildikó and ELMER György: Simulation of membristor conducting alternating currents, 9th International PHD &DLA Symposium Architectural, Engeneering and Information Technology Sciences, Pécs, 2013. október 21-22 *pp.60.*
[RC-14] Horváth Ildikó (2012), Possible applications of Problem Based Learning in Engineering in Tertiary Education, Scince in Practice 2012, Scientific Electrotechnical Conference, Pécs 29-30. October, pp.29-30.
[RC-15] Horváth I: Teaching modelling and simulation in electrical engeneering at the BsC level. 9th International PHD &DLA Symposium Architectural, Engeneering and Information Technology Sciences, Pécs, 2013. október 21-22. *pp:60.*

4.2 The Author's Publications not Relevant to this Dissertation

[J-1] Gyula Kotek, Zoltán Berente, Attila Schwarcz, Zsolt Vajda1, Janaki Hadjiev, ***Ildikó Horvath***, Imre Repa, Attila Miseta, Peter Bogner: "Effects of intra- and extracellular space properties on diffusion and T2 relaxation in a tissue model" Magnetic Resonance Imaging (15 April 2008, 279-284) **(**IF:1,92**)**
[J-2] Paljunite A, Kriszbacher I, **Vránics I/Horváth I**., Kovács E, Szabados S, Boncz I,Hejjel L: Conformation of bleeding quantity measured after heart operations under the effects of certain harmful habits and operative data. Value Health 2009, 12(7):A318 (abstract**,** IF: 3.009)
[J-3] Paljunite A, Hejjel L, ***Vránics I/Horváth I.***, Kovács E, Szabados S, Boncz I, Kriszbacher I: Conformation of bleeding quantity measured after heart operations according to meteorological and astronomical factors. Value Health 2009, 12(7):A319 (abstract, **IF: 3.009)**
[J-4] Kriszbacher I, Bonc I, Gazdag L, Matyus A, ***Vranics I/Horváth I.,*** Csoboth I, De Blasio A, Zsigmond E, Betlehem J, Oláh A, Bodis J: Seasonal, Weekly and Daily Variation of Acute Myocardial Infarction and Transient Ishemic Attack in Hungary. Value Health, 2009, 12(3): A144 IF: 3,387**)**
[J-5] Gazdag L, Boncz I, Farkasne JE, Nemeth K, Kornya L, ***Vranics I/Horváth I***., Gabara K, Kriszbacher I: Time delay of Occurrence of Secondary Malignant Tumors after Primary Breast cancer in theFemale Population of Hungary Between 2003 and 2007. Value Health, 2009, 12(3):A36 **(**IF: 3,387**)**
[J-6] Gazdag L, Boncz I, Farkasne JE, Nemeth K, Kornya L, ***Vranics I/Horváth I.,*** Gabara K, Kriszbacher I: The Frequency of Occurrence of Secondary Malignant Tumors Evoling on the Field of Primary Breast Cancer in the Female Population of Hungary Between 2003 and 2007. Value Health, 2009, 12(3):A36**. (**IF: 3,387)
[J-7] Vigh terézia, Gazdag Levente, Vránics/Horváth Ildikó, Betlehem József, Oláh

András, Mátyus Anita: Szívinfarktus bekövetkezésének heti és évszakonkénti változásai kórházi felvételek tekintetében 2005-2207 év között, ÁpolásÜgy 2008. 22. évf.4. szám

[J-8] Pálfi Ferencné, Vránicsné Horváth Ildikó, Németh Katalin, Dr. Betlehem József: Az ápolók mentálhigiénés állapota, és a kiégési szindrómát provokáló faktorok előfordulása a vizsgált populációban, Nővér c. folyóirat 2007. 20. évfolyam 4. szám

[C-1] V.Horváth Ildikó, Liszt Ferenc, Boncz Imre, Kriszbacher Ildikó, Kovács L.Gábor: Financing of Medical Laboratory in Hungary 2008-2009, ISIRR 11th International Symposium Interdisciplinary Regional Research, Szeged, 2010. okt.13-15.

[C-2] V. Horváth Ildikó: Information Technology to Improve the Efficiency of the Diagnostic Imaging, Science in Practice 2009. International Conference- 2009 február 26-27. Pécs,*pp:85-90.*

[C-3] V. Horváth Ildikó, Dr. Bogner Péter: IT Applications for Processing of Maps in Diffusion MR Imaging, Miskolci Egyetem Innovation and Technology Transfer Centre kiadvány (2008)

[C-4] V. Horváth Ildikó, Dr. Bogner Péter, Kotek Gyula: Informatikai alkalmazások a diffúziós MR térképek feldolgozásában, A Dunaújvárosi Főiskola Közleményei XXIX/1. szám (2007)

[C-5] V. Horváth Ildikó, Csoboth Ildikó, Lászlóné Nagy Ilona: Társadalmi elvárások és lehetőségek az informatika oktatásban, Informatika a felsőoktatásban 2005. Debrecen

5 Figures

6 Tables

7 Bibliography

[1]. Academy of Marketing Studies Journal (2008), 12 (2), p. 19–34

[2]. Alvarez, C., Brown, C., Nussbau, M. (2011): Comparative study of netbooks and tablet PCs for fostering face-to-face collaborative learning. Computers in Human Behavior 27, 834–844.

[3]. Anderson R.D. (2006), Inquiryas an Organising Theme for Science Curricula. Abell,S.. . Lederman,N.. .szerk...Handbook on Research on Science Education. Erbaum. 807-830

[4]. Annual Reviews Sociology 21 eEurope Benchmarking Report

[5]. Arató F. (2010): Egy általános koopetarív modell lehetőségéről. Iskolakultúra,20.1.sz. 106-115.

[6]. Aronson, E. et al. (1978): The Jigsaw Classroom. Sage Publications, Beverly Hills, California.

[7]. Baranyi P. and Csapo A. (2012): Definition and Synergies of Cognitive Infocommunications, Acta Polytechnica Hungarica, Vol 9, No 1. pp.67-83. (ISSN 1785-8860)

[8]. Baranyi P. and Csapo A. and Sallai G. (2015): Cognitive Infocommunications (CogInfoCom), Springer International Publishing Switzerland, p.191. (978-3-319-19607-7, 978-3-319-19608-4 eBook, doi:10.1007/978-3-319-19608-4, http://www.springer.com/us/book/9783319196077#aboutBook

[9]. Baranyi P and Komlósi L. I. (2015), "Connected Cognitive Entity and the CE Generation: Emergent properties in the digital space"

[10]. Benda József (2002): A kooperatív pedagógia szocializációs sikerei és lehetőségei Magyarországon II. Új Pedagógiai Szemle, 10. sz.

[11]. Bessenyei I, (2007): Tanulás és tanítás az információs társadalomban. Az e-learning 2.0 és a konnektivizmus http://www.ittk.hu/netis/doc/ISCB_hun/12_Bessenyei_eOktatas.pdf lekérdezés időpontja: 2012.09.18. 18:40

[12]. Blin, F. & Munro, M. (2008) 'Why hasn't technology disrupted academics' teaching practices?

[13]. Bloom B. S. 1976. Human Characteristics and School Learning. New York: McGraw-Hill. (Read more: B. S. Bloom (1913–1999) - Educational, Learning, Benjamin, and Objectives - StateUniversity.com http://education.stateuniversity.com/pages/1791/Bloom-B-S-1913-1999.html#ixzz4ZnsebZoA)

[14]. Book2006, quoted by scopes2009 PDF]Learning Archetypes as tools of Cybergogy for a 3D. - ePrints Soton *eprints.soton.ac.uk/.../Learning_Archetypes_as_tools_of_Cybergogy_* - reproduced or *quoted* extensively from without first obtaining permission in writing from the copyright holder/s. ... learners alike. Carter & *Scopes (2009*). 78 . Virtual Worlds are defined by six prominent features (*Book, 2006*).

[15]. Brown, C. C., & Czerniewicz, L. L. (2010). Debunking the 'digital native': beyond digital apartheid, towards digital democracy. Journal of Computer Assisted Learning, 26(5),357-369. doi:10.1111/j.1365-2729.2010.00369.x

[16]. Carter, Vinson: A Comprehensive Review

[17]. Carvin, A(2002):Digital Divide Still Very Real, http://news.com.com/2010-1078-872138.htm

[18]. Castells, Manuel (2005 [1996]): Az információ kora: Gazdaság, társadalom és kultúra.I. kötet:A hálózati társadalom kialakulása (Gondolat–Infonia, Budapest)

[19]. Castells, Manuel (2006 [1997]):Az információ kora: Gazdaság, társadalom és kultúra.II. kötet: Az identitás hatalma (Gondolat–Infonia, Budapest)

[20]. Castells, Manuel (1998): The Information Age: Economy. Society and Culture. Vol. III:The End of the Millennium (Blackwell, Oxford)

[21]. Chikán Attila: Vállalatgazdaságtan, Közgazdasági és jogi könyvkiadó – AULA Kiadó, Budapest, 1994.

[22]. Christensen, C., Horn, M., & Johnson, C. (2008). Disrupting class: How disruptive innovation will change the way the world learns. New York: McGraw-Hill. ISBN: 0071749101

[23]. Christensen, C. M. (1997) The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business School Press, Boston, MA.

[24]. Christensen, C. M. & Eyring, H. J. (2011) The Innovative University: Changing the DNA of Higher Education from the Inside Out, Jossey-Bass, San Francisco.

[25]. Christensen, C. M., Horn, M. B. & Johnson, C. W. (2011) Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns , McGraw Hill, New York.

[26]. Christensen, C. M. & Raynor, M. E. (2003) The Innovator's Solution: Creating and Sustaining Successful Growth , Harvard University Press, Cambridge, MA.

[27]. Christensen C. and Colleagues: Disruptive Innovation in Technology and Engineering Education: A Review of the Three Works

[28]. Cisco – Intel – Microsoft (2009): Transforming Education: Assessment and Teaching 21st Century Skills. http://atc21s.org/

[29]. Clausen, C. – Hansen, A. (2002): The Role of TA in the Social Shaping of Technology. In Banse G. – Grunwald, A. – Rader, M. (eds.): Innovations for an e-Society, Challanges for Technology Assessment. Sigma, Berlin, 91-99. o.

[30]. Coombs,P. H., Prosser, C. and Ahmed, M. (1973).New Paths to Learning for Rural Children and Youth, New York: International Council for Educational Development.

[31]. Combos P.H., Ahmed M., (1974): Attacking Rural Poverty How nonformal Education can help, Baltimore, The John Hopkins University Press, 292 pp.

[32]. Conole, G., et al . (2008) 'Disruptive technologies', 'pedagogical innovation': what's new?

[33]. Couch, A., Keniston, K. (1960): Yeasayers and naysayers: Agreeing response set as apersonality variable, Journal of Abnormal and Social Psychology, 60 (2), 151-172

[34]. Csapo, A. and Baranyi, P. “CogInfoCom channels and related definitions revisited,” in Intelligent Systems and Informatics (SISY), 2012 IEEE 10th Jubilee International Symposium on,Subotica, Serbia, 2012, pp. 73–78.

[35]. Csépe V, Győri M, Ragó A (szerk) (2007): Általános pszichológia 2. Tanulás, emlékezés, tudás. Budapest, Osiris Kiadó pp.402.

[36]. Dani E. (2016): E-létezés és „hiperfigyelem” http://folyoiratok.ofi.hu/konyv-es-neveles/e-letezes-es-hiperfigyelem, (Date of download 22. 07. 2016.)

[37]. Davis, F.D, Bagozzi, P R ,Warshaw P “User acceptance of computer technology: A comparison of two theoretical models, Management Science, 1989, 35 982-1003.

[38]. Davis, F. D. “Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology,” MIS Quarterly (13:3), 1989, pp. 319-339

[39]. Dessewffy T. – Rét Zs. (2004): Az info-kommunikációs technológiák terjedése – objektív és szubjektív gátak. in: Társadalmi riport 2004, (Szerk., Kolosi T., Tóth I. Gy., Vukovich Gy.), Budapest, pp. 332–342.

[40]. Denzin N. K., Lincoln Y. S. (1994). Handbook of Quaalitative Research. Newbury Park: Sage

[41]. DiMaggio, Paul-Hargittai Eszter-Neuman,W.Russel-Robinson, John P. 2001): Social Implications of the Internet.

[42]. Duffy T.M., Cunningham D.J. (1996): Connectivism: Implication for the design and delivery of instruction. In D.H. Jonassen (Ed.) Handbook of research on educational communications and technology (pp.17-198) NewYork Scholastic

[43]. Duma László, Erdős Szilveszter (2008): A jövő intelligens technológiai és menedzsmentkérdései, Vezetéstudomány XXXIX. EVF.2008. 12. szám

[44]. e-Inclusion-The Information Society's potential fot social inclusion in Europe.Commission of the European Communities. Brussels, 5.2.2002.

[45]. EU Kids Online II (2011): A magyarországi kutatás eredményei. Nemzeti Média és Hírközlési Hatóság, Budapest

[46]. European Commission : GPP – Green Public Procurement – A collection of good practices, Luxembourg: Publications Office of the European Union, 2012, ISBN: 978-92-79-26276-0

[47]. Falus I., (2003), Didaktika, Digitális Tankönyvtár, http://www.tankonyvtar.hu/hu/tartalom/tamop425/2011_0001_519_42498_2/index.html

[48]. Falus I., (2010), A pedagógusképzés korszerűsítése – európai tendenciák, Pedagógusképzés, Pedagógusképzők és továbbképzők folyóirata, 2010/1. Budapest.

[49]. http://fircc.unideb.hu/content/FIRCC_eredmeny.pdf, Bakonyi P, Sallai Gy., A Jövő Internet Nemzeti Kutatási Program eredményei 2014, Debrecen

[50]. Findings from an in-depth study of students’ use and perception of technology’, Computers and Education (2008), vol. 50, pp. 511-524

[51]. Future Management Group AG. (2011): http://www.futuremanagementgroup.com/en/your-future-management/the-eltville-model.html (Date of download: 10. 12. 2011.)

[52]. P. Galambos, I. Fülöp and P. Baranyi: "Virtual Collaboration Arena, Platform for Research, Development and Education" in Acta Technica Jaurinensis, Vol. 4, No. 1, 2011, pp. 145-155. (ISSN 1789-6932)

[53]. P. Galambos, C. Weidig, P. Baranyi, J. C. Aurich, B. Hamann and O. Kreylos: „VirCA NET: A Case Study for Collaboration in Shared Virtual Space" in Proc. of. 3rd IEEE Int. Conf. on Cognitive Infocommunications (CogInfoCom 2012), Kosice, Slovakia, December 2-5, 2012, pp. 273-277. (978-1-4673-5188-1)

[54]. Gartner, Inc. : Hype cycle, www.gartner.com , 2012, 2013, 2014, 2015, 2016, (Date of download: 15.05.2016.)

[55]. Gay, G., Stefanone, M., Grace-Martin, M., Hembrooke, H. (2001): The effects of wireless computing in collaborative learning environments. International Journal of Human–Computer Interactions 13. 257–275.

[56]. Gere, C.: Digital Culture. Reaktion Book, London, 2002. 11

[57]. Gere, C.: (2002): Digital Culture, ISBN 1-86189-1431 www.reactionbooks.co.uk

[58]. Gibbs, J. (1987): A Process for Social Development and Cooperative Learning. Center Source Publ., Santa Rosa.

[59]. Giesecke, H. (1996): Wozu ist die Schule da? Die neue Rolle von Eltern und Lehrern. Klett-Cotta Verlag, Stuttgart.

[60]. Gijbels, D., Dochy, F., Bossche, P. V. d., 1980; quotes: Arts, Gijbels and Segers, 2003 Review of Educational Research Spring 2005, Vol. 75, No. 1, pp. 27-61 Effects of Problem-Based Learning: A Meta-Analysis From the Angle of Assessment

[61]. Glenn, Jerome C. Participatory methods, In: AC/UNU Millennium Project, Futures Research Methodology, 1994, 3.

[62]. Glenn, Jerome C.: The Futures wheel, In: AC/UNU Millennium Project, Futures Research Methodology, 1994

[63]. Glenn, J. C. (2003): Futures Research Methodology. American Council for the UNU; Cdr edition (2003. 08. 01.), 700.

[64]. Greene J. A.,Muis K. R. , PIESCHL S. (2010): The Role of Epistemic Beliefs in Students' Self-Regulated Learning With Computer-Based Learning Environments: Conceptual and Methodological Issues. Educational Psychologist, 45 (4), 245 — 257

[65]. Hayles K. (2009), Hyper and Deep Attention: The Generational Divide in Cognitive Modes, http://engl449_spring2010_01.commons.yale.edu/files/2009/11/hayles.pdf, pp.187-188. (Download: 2015.11.05)

[66]. Hargittai, Eszter(2002): Second-Level Digital Divide. First Monday volume 7, number 4

[67]. Hideg É., Nováky E. (1998): Egyének, társadalmi intézmények jövőorientáltsága, Jövőelméletek 2. Budapesti Közgazdaságtudományi Egyetem Jövőkutatás Tanszék, Budapest 1998/b

[68]. Hideg É., Nováky Erzsébet: JÖVŐKUTATÁS – INTERAKTÍVAN, AULA Kiadó Kft, Budapest 2012. ISBN 978-963-339-038-2, pp.53.

[69]. Hideg, Éva, Nováky, Erzsébet: Changing attitudes to the future in Hungary. Futures, April 2010

[70]. Hronszky I., Várkonyi L.: Innovációmenedzsment tanulmány radikális innovációk kihívásairól és menedzselési lehetőségeiről

[71]. Hrubos I. (2006): A 21. század egyeteme – Egy új társadalmi szerződés felé. Educatio, 15. évf. 4. pp. 665-68

[72]. Hrubos I. (2012): ELEFÁNTCSONTTORONYBÓL VILÁGÍTÓTORONY A felsőoktatási intézmények misszióinak bővülése, átalakulása, AULA Kiadó Kft Budapest, 2012.

[73]. Hrubos I. (2004): Gazdálkodó egyetem – Szolgáltató egyetem – Vállalkozó egyetem. In: Hrubos I. (szerk.): A gazdálkodó egyetem. Felsőoktatási kutatóintézet – Új Mandátum Könyvkiadó, Budapest

[74]. http://abonyita.inf.elte.hu/digkomp20100225.pdf

[75]. http://www.edb.u-texas.edu/mmresearch/Students97/Hemstreet/pbl2.htm

[76]. http://elte.prompt.hu/sites/default/files/tananyagok/TanulasiTanitasiTechnikakAFoldrajztanitasban/ch05.html

[77]. http://unilrn.com/learning-vs-education/ (Date of download: 17.06.2016)

[78]. http://flippedlearning.org/wp-content/uploads/2016/07/HigherEdWhitePaper-FINAL.pdf

[79]. http://goliat.eik.bme.hu/~hronszky/varkonyi/Innovaciomendzsment-Radikalis.pdf

[80]. http://kommon-szakkollegium.hu/online-oktatas-konferencia/155/tanulmanyok/papp-danka-adrienn-az-online-tanulasi-kornyezet-fogalmanak-ertelmezesi-lehetosegei/

[81]. http://mccrindle.com.au/print-infographics/generation-z-and-generation-alpha-infographic

[82]. http://www.tankonyvtar.hu/hu/tartalom/tkt/iskolai-tudas-eloszo/adatok.html (Date of download: 10. 05. 2016.)

[83]. http://www.tankonyvtar.hu/hu/tartalom/tamop412A/2011-0021_24_az_oktatastervezes_es_technologia_aktualis_kerdesei_es_trendjei/323_tuds_kpessg_kompetencia_pedaggiai_taxonmik.html (Date of download: 10. 05. 2016.)

[84]. http://www.cmo.com/features/articles/2015/6/11/15-mind-blowing-stats-about-generation-z.html#gs.6xtpVwU (Date of download: 12. 07. 2016.)

[85]. http://www.itu.int/itu-t/recommendations/index.aspx?ser=Y (Date of download: 01. 11. 2016.)

[86]. Hüsing, T.,Selhofer,H.(2002): The Digital Divide Index- A measure of social inequalities in the adoption of ICT. empirica GmbH, Bonn

[87]. Infocommunications," Acta Polytechnica Hungarica, vol. 9, pp. 67–83, 2012.

[88]. ISTE NETS: https://www.iste.org/my-profile/standards-download

[89]. Jones, C. & Healing, G. (2010) 'Net generation students: agency and choice and the new technologies', Journal of Computer Assisted Learning, vol. 26, pp. 344-356.

[90]. Journal of Technology Education Vol. 24 No. 2, Spring 2013 pp:96-103

[91]. Klein, H. K., Kleinman, D. (2002): Science, Technology & Human Values 27, 1. sz., Winter 28–52. The Social Construction of Technology: Structural Considerations. http://www.prism.gatech.edu/~hk28/Klein02-SciTechHumanVal.pdf (Date of download: 21. 10. 2015.)

[92]. KLINE, S. J. – ROSENBERG, N. (1986): An overview of innovation. In R. Landau & N. Rosenberg (ed.), The Positive Sum Strategy: Harnessing Technology for Economic Growth. Washington D.C. National Academy Press, pp. 275-305.

[93]. Kristiansen, R. (2011): Digital natives - Thinking map. http://roarkristiansensblogg.blogspot.hu/2011/03/digital-natives-mindmap.html (Date of download: 12. 03. 2013.)

[94]. Lane, J. L. (2007): PDF]Inquiry-based Learning - Schreyer Institute for Teaching Excellence

https://www.schreyerinstitute.psu.edu/pdf/ibl.pdf *Jill L. Lane*. Schreyer Institute for ... 7-15-*2007*. Inquiry-*based Learning* ... Inquiry-*based learning* is a *research*-based *strategy* that actively involves students in.

[95]. Linden, A., Fenn, J. (2003): Understanding Gartner's Hype Cycles. http://www.ask-force.org/web/Discourse/Linden-HypeCycle-2003.pdf (Date of download: 30. 05.2015.)

[96]. Lovelles B. (2002), The 2002 Brown Center Report on American EducationHOW WELL ARE AMERICAN STUDENTS LEARNING? With sections on arithmetic, high school culture, and charter school, https://www.brookings.edu/wp-content/uploads/2016/06/09education-2.pdf (Download: 2016. 02.10)

[97]. Lowther, D., Ross, S., Morrison, G. (2003): When each one has one: The influences on teaching strategies and student achievement of using laptops in the classroom. Educational Technology Research and Development 51(3), 23–44

[98]. Margaryan, A., Littlejohn, A. & Vojt, G. (2011) 'Are digital natives a myth or reality? University students' use of digital technologies', Computers and Education, vol. 56, pp.429-440.

[99]. Makádi M. (2012), A térbeli intelligencia fejlesztése a földrajztanítás-tanulás folyamatban, Doktori értekezés, ELTE TTK, Budapest

[100]. Makádi M. (2005), A természetismeret tanulása. A földrajz tanulása. Katona A. Ládi L. Victor A. szerk.Tanuljunk, de hogyan!? . Nemzeti Tankönyvkiadó, Budapest. 170-222

[101]. Markides, C. (2006) 'Disruptive innovation: in need of better theory', The Journal of Product Innovation Management, vol. 23, no. 1, pp. 19-25.

[102]. Marton Á. (2005): A mintavételi hiba kiszámítása és felhasználása a hivatalos statisztikában. Statisztikai Szemle. 83. évf. 7. sz. pp. 613-627.

[103]. Meyer, H. (2003): Zehn Merkmale guten Unterrichts. Empirische Befunde und didaktische Ratschläge. In Pädagogik, 10/2003, 37–43.

[104]. Mitra, A., Steffensmeier, T. (2000): Changes in student attitudes and student computer use in a computer-enriched environment. Journal of Research on Computing in Education, 32, 417–433.

[105]. Moberg, Ĺ., Johansson, M., Fi, G. (2010): Printed and tablet e-paper newspaper from an environmental perspective – A screening life cycle assessment. Environmental Impact Assessment Review 30, 177–191.

[106]. Murphy, K. L., & Cifuentes, L. (2001). Using Web tools, collaborating, and learning online. Distance Education, 22(2), 285-305.

[107]. Murano P (2006), 'Why anthropomorphic user interface feedback can be effective and preferred by users' , in: Enterprise information systems VII , Human-computer interaction (5) , Springer Netherlands, pp. 241-248.

[108]. Nádasi A. (2012): Oktatáselmélet és technológia. http://bit.ly/1bNKNqM (Download: 2015. 07. 19)

[109]. Nádasi M.,(2003): Projektoktatás. Oktatás-módszertani Kiskönyvtár V. Budapest, Gondolat Kiadói Kör − ELTE BTK Neveléstudományi Intézet, 92 p.

[110]. Nagy József: A hagyományos pedagógiai kultúra csődje Iskolakultúra 2005. június-július - EPA

epa.oszk.hu/00000/00011/00094/.../iskolakultura_EPA00011_2005_06_07_III-XI. p.2005/6–7 melléklete.

[111]. Nahalka I. (1998), A magyar iskolarendszer átalakulása befejeződött, Új Pedagógiai Szemle, 48. évf. 5. sz. 1998. május, Budapest

[112]. Nahalka I. (2002): Hogyan alakul ki a tudás a gyermekben? Konstruktivizmus és pedagógia. Nemzeti Tankönyvkiadó, Budapest.

[113]. Nahalka, 2003 -- NAHALKA István (2003): A tanulás. In: Falus Iván (szerk.): Didaktika. Nemzeti Tankönyvkiadó, Budapest.

[114]. National Geographic Magyarország: Hogyan élünk majd 2020-ban? http://www.geographic.hu/indexphp?act=napi&id=4010

[115]. Nishinaga, N.(2010): NICT New-Generation Network Vision and Five Network Targets. IEICE Trans. on Communications, Vol. E93-B, No.3. pp. 446-449. March 2010. Online ISSN: 1745-1345, Print ISSN: 0916-8516

[116]. Nováky E (1997). : Jövőkutatás, AULA Kiadó, Budapest

[117]. Nováky E. (1998): Módszertani megújulás az előrejelzés-készítésben, In: Posztmodern és evolúció a jövőkutatásban (szerk. Hideg Éva) Budapesti Közgazdaságtudományi Egyetem Jövőkutatás Tanszék, Budapest 1998/b

[118]. Nyíri Kristóf (2006): Virtuális pedagógia – a 21. század tanulási környezete (in:Új Pedagógiai Szemle 2006/07-08. http://www.oki.hu/oldal.php?tipus=cikk&kod=2001-07-it-Nyiri-Virtualis (Date of download: 01.03.2007.)

[119]. OAS. (2011): Organization of American States. Forrás: Knowledge-based Society. http://www.oas.org/en/topics/knowledge_society.asp (Date of download: 25. 10. 2011.)

[120]. Olson M.S. – Bever D. – Verry S. (2008): Növekedésből mélyrepülés, Harvard Business Review, 2008. 6. szám

[121]. Ortelt, S. (2011):. Infoblog. Forrás: From Textbooks to Tablets: South Korea's Education System Goes Digital by 2015: http://blog.infotrends.com/?p=4646 (Date of download: 06. 07. 2011.)

[122]. Pais E. R.(2013).: Alapvetések a Z generáció tudománykommunikációjához, Pécs, Hungary

[123]. Pataki B.(2005): A technológia menedzselése, Typotex, Budapest

[124]. Prensky M. (2001): Digital Natives, Digital Immigrants. On the Horizon. MCB University Press, Vol. 9 No. 5, October 2001

[125]. Rab Árpád (2007): Digitális kultúra – A digitalizált és a digitális platformon létrejött kultúra. In: Az információs társadalom. Tankönyv. Gondolat–Új Mandátum 2007, pp. 182–201. http://vigzoltan.hu/x_bit/netis/11_Rab_digikult.pdf (Date of download: 18. 10. 2012.)

[126]. Rich, R. F. (1990): Knowledge Creation, Diffusion, and Utilization: Perspectives of the Founding Editor of Knowledge. Science Communication , 12(3), p. 319–337.

[127]. Riva G.and Davide F.. Communications Through Virtual Technologies. In Identity, Community and Technology in the Communication Age, pages 124–154. IOS Press, 2001

[128]. Rogers, A. 2004. Non-formal education: flexible schooling or participatory education? (CERC Studies in Comparative Education 15). Comparative Education Research Centre, The University of Hong Kong.

[129]. Rogers, E.M. (1983): Diffusion of Innovations. 3rd ed. New York,The Free Press.

[130]. Rogers E. M., 1995, Diffusion of innovations, The Free Press, NewYork

[131]. Rushkoff, D. (2012): Technologies have biases in EDGE: This Will Make You Smarter. New Scientific Concepts to Improve Your Thinking, Edge Foundation, New York, 41.

[132]. Sallai, Gy.: Chapters of Future Research. CogInfoCom 2013 - 4th IEEE International Conference on Cognitive Infocommunications, ISBN 978-1-4799-1-1543-9, Paper 27, pp.161-166. Track on Chapters of the Future Internet Science and Engineering. Plenary talk. Dec 2-6, 2013, Budapest

[133]. Sallai Gy(2007).: Converging Information, Communication and Media Technologies. In G. Banse, editor, Assessing Societal Implications of Converging Technological Development, pages 25–43. Edition Sigma, Berlin, 2007.

[134]. Sams, A., Jon Bergmann, Kristin Daniels, Brian Bennett, Helaine W. Marshall, Kari M. Arfstrom (2014): Flipped Learning Network. The four Pillars of F-L-I-P. Definition of Flipped Learning. URL: http://bit.ly/1kQYCfn (Date of download: 24. 04. 2014.)

[135]. Schumpeter, J.A. (1939): Business Cycles, McGraw-Hill, NewYork

[136]. Selwyn, N. (2007) 'The use of computer technology in university learning and teaching: a critical perspective', Journal of Computer Assisted Learning, vol. 23, no. 2, pp. 83-94.

[137]. Sharples, M. (2003) 'Disruptive devices: mobile technology for conversational learning', International Journal of Continuing Engineering Education and Lifelong Learning, vol. 12,no. 5-6, pp. 504-520.

[138]. Siemens G., 2005., Knowing Knowledge. E-book: http://www.elearnspace.org/KnovingKnowledge_LoeRes.pdf

[139]. Steinmetz, A. (2013): Lecture is dead in the 21st century. Ohio Social Studies Review, Fall 2013, Volume 50, Issue 2. URL: http://bit.ly/1niPGAy (Date of download: 07. 05. 2014.)

[140]. Thomas John W. (2000) A review of research of project-based learning, 21st Century Learning, San Rafael, California, http://www.bie.org/research/study/review_of_project_based_learning_2000, (Date of download: 25.05.2017.)

[141]. Turcsányi-Szabó, - TURCSÁNYI-SZABÓ Márta (2011): Fenntartható innováció a tanárképzésben – az elmélettől a gyakorlatig. Oktatás-informatika, 3-4. http://bit.ly/MvaVME (Download: 2015.05.02)

[142]. Ujhelyi A. (2013):Digitális nemzedék –szociálpszichológiai szempontból. Konferenciakötet: Digitális Nemzedék 2013 Konferencia, Budapest http://digitalisnemzedek.hu/wp-content/uploads/2013/03/digitalisnemzedek-konferencia-2013.pdf(9-14.oldal) Download 2015.02.08.

[143]. Understanding resistance to change through the lens of activity theory',Computers and Education , vol. 50, pp. 475-490.

[144]. Vigotskij, 2000 - VIGOTSZKIJ, L. SZ. (2000): Gondolkodás és beszéd. Trezor Kiadó, Budapest

[145]. Waldbuesser P, Komlósi L.I. (2015): Empirical findings in cognitive entity management: A challenge in the digital era, http://ieeexplore.ieee.org/document/7390632/authors

[146]. Walton, H. J., Matthews, M. B., (1989): Essentials of problem-based learning

[147]. Webster, Frank (1995): Theories of the Information Society (Routledge, London – New York)

[148]. Webster, F.E., Jr. (1988): Rediscovering the Marketing Concept. Business Horizons, 31. p. 2939.

[149]. Webster, R.L. –Hammond, K.L. (2008): Does a market orientation strategy exist toward business school students? A view from three levels of academic administrators.

[150]. Wiener, Y. – Vardi, Y. (1980): Relationships between job, organization, and career commitments and work outcomes –an integrative approach. Organizational Behavior and Human Performance , 26 (1), p. 8196.

[151]. Wissema, J. G. (2009): Towards the third generation university: managing the university in transition . Cheltenham, Edward Elgar.

[152]. http://hypecycle.umn.edu/

[153]. D. Vincze, Sz. Kovács, M. Gácsi, P. Korondi, Á. Miklósi and P. Baranyi: „A novel application of the 3D VirCA Environment: Modeling a standard ethological test of dog-human interactions" in Acta Polytechnica Hungarica, Special Issue on Cognitive Infocommunications, Vol. 9. No. 1, 2012, pp. 107-120. (ISSN 1785-8860) IF: 0.588

[154]. VirCA: http://virca.hu

[155]. Gy. Persa, Á. Csapó and P. Baranyi: „CogInfoCom Systems from an Interaction Perspective – A Pilot Application for EtoCom –„ in Journal of Advanced Computational Intelligence and Intelligent Informatics, Special Issue on Cognitive Infocommunications, Vol. 16, No. 2, March 2012, pp. 297-304. (ISSN 1343-0130)

[156]. Á. Csapó and P. Baranyi: „The Spiral Discovery Method: An Interpretable Tuning Model for CogInfoCom Channels„ in Journal of Advanced Computational Intelligence and Intelligent Informatics, Special Issue on Cognitive Infocommunications, Vol. 16, No. 2, March 2012, pp. 358-367. (ISSN 1343-0130)

[157]. Á. Csapó and P. Baranyi: „A Unified Terminology for Structure and Semantics of CogInfoCom Channels" in Acta Polytechnica Hungarica, Special Issue on Cognitive Infocommunications, Vol. 9. No. 1, 2012, pp. 85-105. (ISSN 1785-8860)

[158]. P. Baranyi, Gy. Persa and A. Csapo: „Definition of Cognitive Infocommunications and an Architectural Implementation of Cognitive Infocommunicationy Systems" in World Academy of Science, Engineering and Technology, An Int. Journal of Science, Engineering and Technology, (Cemal ARDIL, EiC, Bali) Issue 58, October 2011. pp. 501-505. (pISSN 2010-376x, eISSN 2010-3778)

[159]. P. Galambos, C. Weidig, P. Zentay, Á. Csapó, P. Baranyi, J. C. Aurich, B. Hamann and O. Kreylos: „VirCA NET: A Collaborative Use Case Scenario on Factory Layout Planning" in Proc. of 3rd IEEE Int. Conf. on Cognitive Infocommunications (CogInfoCom 2012), Kosice, Slovakia, December 2-5, 2012, pp. 467-468. (978-1-4673-5188-1) (abstract for plenary demonstration)

[160]. [C_1] P. Galambos, P. Baranyi, and I. J. Rudas: "Merged Physical and Virtual Reality in Collaborative Virtual Workspaces: the VirCA Approach," in The 40th Annual Conference of the IEEE Industrial Electronics Society, (IECON'14) Dallas, TX-USA, October 29 - November 1, 2014, pp. 2585–2590.

[161]. P. Galambos and P. Baranyi: „VirCA as Virtual Intelligent Space for RT-Middleware" IEEE/ASME Int. Conf. on Advanced Intelligent Mechatronics (AIM 2011), Budapest, Hungary, July 3-7, 2011, pp. 140-145. (978-1-4577-0837-4)

[162]. P. Galambos, B. Reskó and P. Baranyi: "Introduction of Virtual Collaboration Arena (VirCA)," in The 7th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2010), November 24-27, 2010, Bexco, Busan, Korea, pp. 575-576.

[163]. seminar.maxwhere.com/

[164]. www.mistems.hu/maxwhere/

8 Appendices

Appendix 1.: Disruptive Technology

With the questionnaire below we are trying to find the answer to the question when and in what educational form the disruptive technologies , after their appearance, are introduced in the higher education of engineering and computer science.

Please help our research by filling in the following form.

Your gender: male – female Age: …… How long have you been teaching in the higher education? ……..

Does your institute involve the business partners in the IT manager training?	☐ YES	☐ NO
Does your university participate in international academic programmes?	☐ YES	☐ NO
Do you apply student-based pedagogical methods in the education?	☐ YES	☐ NO
Do you apply cooperative learning methods in the IT training?	☐ YES	☐ NO
Are electronic learning materials used for education in your institute?	☐ YES	☐ NO
Do you apply virtual learning environment in the education?	☐ YES	☐ NO

If YES, in which subject(s)?.....

Answer the next questions by using a scale of 1-5 where 1 – very important, … 5 – not important at all

How important do you consider the appearance of disruptive technologies in the educational material in the higher education? …….

How important do you consider the disruptive technologies to be integrated in the educational material in the higher education after their appearance? ……..

How important do you consider it that the students should recommend new solutions and fields for the specific disruptive technologies? ……..

What do you think the greatest advantage of integrating scientific technology in the educational material in the higher education is? (Underline where applicable)

- it develops the students' creativity, problem-solving skills
- it maintains the lecturers' interest
- up-to-date educational materials are made
- the students become active participants of the learning process
- it increases the students' marketable knowledge, their job opportunities improve
- other: …….

What causes the greatest challenge in the integration of disruptive technologies in the educational material in the higher education? (Underline where applicable)

- finding online internet contents
- use of ICT devices
- appearance of new reference literature in a foreign language
- involving students in work
- the common work with students changes the traditional student-teacher relation
- other: …….

With which educational methods do you consider it feasible to integrate the disruptive technologies in the educational material in the higher education? (Underline where applicable)

- with traditional classroom education
- with guest lectures of the business partners
- with the students' individual process of source material
- with project-based education
- with applying the cooperative method
- with applying the cooperative/collaborative method in the virtual educational environment
- other: ……

How efficient do you consider the methods below for teaching the disruptive technologies ?

1 – most efficient, 5 – not efficient at all

- with traditional classroom education
- with guest lectures of the business partners
- with online, distance learning
- with applying the cooperative/collaborative method in the virtual educational environment
- with the students' individual process of source material
- with project-based education
- with applying the cooperative method
- a method recommended by you: ……

Name of disruptive technology	The year when it was introduced in the education	How it appears in education? (in BSc and MSc education: lecture, laboratory, practice, introduction in research team, topic in Scientific Student Circle, or if in any other forms, Please name it)	Pedagogical methods applied in education	Results achieved in this topic in your institute
Quantum Computing				
3D Bioprinting				
3D Scanners				

3D Printing				
Automatic Content Recognition				
Autonomous Vehicles				
Mobile Robots				
Audio Mining/Speech Analytics				

Name of disruptive technology	The year when it was introduced in the education	How it appears in education? (in BSc and MSc education: lecture, laboratory, practice, introduction in research team, topic in Scientific Student Circle, or if in any other forms, Please name it)	Pedagogical methods applied in education	Results achieved in this topic in your institute
Big Data				
Cloud Computing				
Private Cloud Computing				

dbSaaS				
Memristor				
In-Memory Database Management System				
Gesture Control				
Speech Recognition				

Name of disruptive technology	The year when it was introduced in the education	How it appears in education? (in BSc and MSc education: lecture, laboratory, practice, introduction in research team, topic in Scientific Student Circle, or if in any other forms, Please name it)	Pedagogical methods applied in education	Results achieved in this topic in your institute
Mesh Network Sensors				
Biometric Authentication Methods				
Gamification				

HTML 5				
Other:……				
……..				

Thank you for your co-operation.

Appendix 2.: The internet-usage habits of the generation Z

With this questionnaire I would like to get a picture about the ICT device using habits of students studying in the higher education for engineering, how much they are informed and their social media usage applied for learning.

Please help our work by filling in this questionnaire.

Gender of respondent: male – female Date of birth: …….....

Permanent place of residence (please underline): capital city (county seat) town village

Housing situation during university studies?
I live with my parents dormitory sharing a lodgings with students I live alone

Do you have a students' working contract besides your day course studies? ☐ YES ☐ NO

Do you participate in professional trainee programmes? ☐ YES ☐ NO

Do you participate in dual training? ☐ YES ☐ NO

Do you work in your future profession as a casual worker? ☐ YES ☐ NO

If you work in your profession, are you involved in carrying out engineering tasks? ☐ YES ☐ NO

Have you ever done tasks carried out in distance work? ☐ YES ☐ NO

Do you think companies follow technological innovations? ☐ YES ☐ NO

Do you have a language exam or a good command of English? ☐ YES ☐ NO

Do you have internet access at home? ☐ YES ☐ NO

Do you use mobile internet on your phone? ☐ YES ☐ NO

Please underline the devices below which you have.

Desktop PC Laptop Tablet Smart phone E-book reader

MP3/MP4- player DVD/Bluray-player

Please answer the questions below by using a 5-scale scale. 1 – not at all… 5 - totally

1. How much do you feel you are informed about daily home news? .....
2. How much do you feel you are informed about daily international news? .....
3. How important do you consider it to be informed about daily news? ..…….....
4. How much do you think you are informed about labour market requirements? ……..
5. How much do you think you are informed about technical, technological innovations? .....
6. How important do you consider it to be informed about technological innovations? ……
7. How typical are the following statements for you?
   - I watch at least one news programme on TV every day …….....
   - I listen to news on the radio every day …….....
   - I read news websites on the internet every day…….....
   - I read daily papers every day (of printed press) ……...
   - I regularly get informed about technological innovations…….....
   - I get informed about technological innovations every day……
   - I check out on technological innovations at least once a week …….....
   - I get informed about technological innovations on the internet …….....
   - I get information about technological innovations from TV, radio …….....
   - I am only interested in professional innovations …….
   - I am interested in new technological achievements …….....
   - I particularly demand to be able to learn about technological innovations at university …….

8. How typical are the following statements for you (1- not at all, …. 5- totally)
   - I gladly watch professional videos on video-sharing portals ……
   - I gladly keep in touch with my friends on social network applications (e.g.: facebook) …….....

- I often share my opinion with others on social sites ……
- I am a member of a Facebook group related to specific subjects …….....
- I also gladly see the lecturer of the subject in the facebook group created for studying …….
- I prefer online solutions when preparing for exams, classroom tests ……...
- I regularly use social sites with my peers to learn...……..
- We often share learning tasks with my peers……
- We often use virtual spaces with my peers to study…….....
- Virtual spaces greatly help successful preparation ……...
- We use screen sharing services during preparation …….....
- I gladly use google applications (drive, calendar, news, etc.) …….
- I can successfully deal with several things at the same time ……...
- I regularly use several applications parallelly ……..
- I am glad if I can access the learning material anytime, anywhere ……...
- I regularly use the environment recommended by the university for cooperative work …….....
- I only use Coospace/Neptun main street etc. programmes in the most necessary case..……..
- I consider online educational environment offered by the university sufficient for preparation ……...
- I often face the problem of time management ……..
- I am afraid of not finding work in my profession after receiving my degree ……
- If I am in a new situation, I am regularly insecure…….
- I like new life situations, I feel excited about whether I can solve the problem ….....
- Being successful and recognition are important for me……..
- It is important for me to get a high salary for my work……...
- It is important for me to invent new things, creativity is important …….

- Daily time management does not mean a problem for me at all …….
- The security of the workplace is more important than a high salary …….
- It is important for me to do useful work for the society…….....
- The benefit of my work is not important, only the salary received for it……
- I am consciously preparing for my future……...
- I consciously schedule my time, I am ready with everything on time……..
- I understand the effects that move economy…….....

When I need information:

- I primarily rely on online sources ……...
- I turn to my friends, acquaintances ……
- I turn to my parents ……
- I use social media (TV, radio) ……
- I use offline sources (books, newspapers) ……

9. On average, how many hours a day do you spend on:

- Finding internet-related information……
- Internet games……..
- Finding online information……..
- Social network applications…….
- Reading……
- Watching films/videos/series ……..
- Online learning……

10. Where do you use internet? (Please underline.)
    - everywhere
    - at home
    - in the dormitory
    - at friends' home
    - in internet cafes

11. What do you use internet for?
    (You can underline several responds.)
    - Information collection
    - Keeping in touch
    - Learning
    - Entertainment
    - Writing a blog
    - Work

    Rate the scientific fields below according to your interest (the rates show the place)

    - mathematics …….
    - natural sciences …….
    - informatics …….
    - engineering sciences …….
    - economics …….
    - literature …….
    - history …….
    - innovation …….

12. What problems do you most often face in everyday life? (1- not at all, 5- regularly)

- time management ……
- career ……
- searching for new life situations ……
- adequacy in learning ……
- relationship ……
- friends, community ……
- relationship with parents ……
- relationship with lecturers ……
- not appropriate learning environment……

13. Please list which are the 5 most popular online internet applications which are useful for learning and help students preparing for exams and classroom tests:

1. ……
2. ……
3. ……
4. ……
5. ……

15. Please list the internet applications on which you spend most time.

16. Please write down what the learning environment is like in which you would gladly learn? Please also specify what you expect from lecturers for successful preparation?

17. According to you opinion, what needs to be changed on the appearance of the surfaces helping learning which the university offers to efficiently help your preparation, to suit to your expectations? Please specify your opinion in details.

Thank you for your cooperation.

Appendix 3: Student Interview

Please answer the questions below by using a 5-scale scale. 1 – not at all… 5 - totally

1. How much did you like the VR space used for teaching the memristor?.....
2. To what extent do you agree with the statement that in the VR space you had the opportunity to use all the internet applications which you gladly use in your private life?.....
3. How important do you consider to be informed about daily news? ..……..
4. How useful did you consider the application of the VR space? ……...
5. How much could you accomplish cooperation with your peers? .....
6. How suitable do you consider the VR learning environment to carry out the tasks of the project?
   .....
7. How much did you like edu-coaching method during the education?
   ……...
8. How much did you enjoy common work in the VR space?……..
9. What was your favourite application during work? …….
10. How much did you think you could efficiently work together with your peers? …….
11. How annoying was it if your peers did not finish their tasks by the deadline? …….....
12. Did you spend more time with the learning material than you usually do during the traditional education?
    .....
13. How successful did you consider your work during the project? …….....

In your opinion, how much more time did you spend on gaining knowledge related to the memristor than to other learning materials? (Please rate in %) .....……

Please list the internet applications which you used in the VR space?

…….
…….
……
……
……....
……
……

What was the greatest sense of achievement in your work?

……
……
……

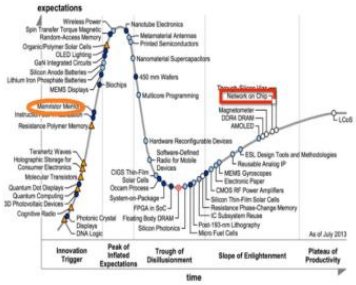
Thank you for your cooperation!

Appendix 4.: Memristor Training study-guidelines

Memristor
Training study-guidelines

Contents

- Introduction
- History
- Definition
- Theory
- Analogy of memristor
- Construction
- Working
- Applications
- Summary
- References

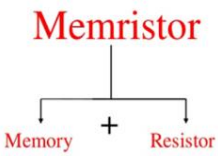


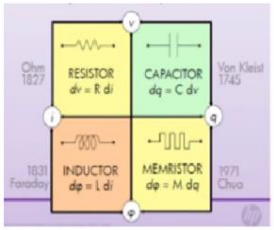
Generations of computers

- Zero generation computers – mechanical machines (John Atanastof's machine –**captors**, DRAM, MARK I. – **relay**)
- The first computers used vacuum tubes for circuitry and magnetic drums for memory. (ENIAC-Elektronic Numerical Integrator And Computer)
- Second generation computers - **Transistors** (1961 - PDP-1,)
- Third generation computers – Integrated circuit (1965-1980 –Transistors were miniaturized and placed on siliconchips, called semiconductors.)
- Fourth generation computers – The microprocessor brought the fourth generation of computers, as thousands of integrated circuits were built onto a single silicon chip, from the central processing unit and memory to I/O controls—on a single chip.
- Fifth generation computers– AI -**Memristors**

What is MEMRISTOR?

- Fourth fundamental circuit element
- Passive element
- Two terminal device





History

1971: Leon Chua*, From University of California Berkeley

- He mathematically postulated that based on the relations between the four fundamental circuit variables and the symmetry, there should exist another circuit element that relates the charge and flux

2008: HP – memristor: 3nm

2014: „The Machine project"

Év, Szerző	
1990 S. Thakoor, A. Moopenn, T. Daud & A. P. Thakoor	"Solid-state thin film memistor for electronic neural networks"
1994 F. A. Buot & A. K. Rajagopal	"Binary information storage at zero bias in quantum-well diodes„ and described current-voltage characteristics which was similar the memristor I-V curves in AlAs/GaAs/AlAs quantum well diodes.
1998. James Heath, Philip Kuekes, Gregory Snider, & Stan Williams *(From HP Labs)*	"A Defect-Tolerant Computer Architecture: Opportunities for Nanotechnology"
2000 A. Beck, J. G. Bednorz, Ch. Gerber & C. Rossel, *(From IBM Research Lab in Zurich)*	"Reproducible switching effect in thin oxide films for memory applications"
2001 Shangqing Liu, NaiJuan Wu, Xin Chen & Alex Ignatiev *(From University of Houston)*	"A New Concept for Non-Volatile Memory: The Electric Pulse Induced Resistive Change Effect in Colossal Magnetoresistive Thin Films"

Év, Szerző k	
1960 Bernard Widrow *(From Stanford University)*	ADALINE (ADAptive LInear NEuron)
1967 J. G. Simmons & R. R. Verderber	"New conduction and reversible memory phenomena in thin insulating films"
1968 F. Argall	"Switching phenomena in titanium oxide thin films" ⟶ HP memristor
1971 Leon Chua *(From University of California Berkeley)*	**"Memristor - the missing circuit element" in IEEE Transactions on Circuit Theory**
1976 Leon Chua & Sung Mo Kang	"Memristive devices and systems" published in IEEE Proceedings.

Év, Szerző	
2008!!! Dmitri Strukov, Gregory Snider, Duncan Stewart & Stan Williams	"The missing memristor found„ – HP Labs, Nature.
Blaise Mouttet	"Logicless Computational Architectures with Nanoscale Crossbar Arrays„ – Nanotechnology Conference , Boston
Victor Erokhin & M. P. Fontana	"Electrochemically controlled polymeric device: a memristor"
J. Joshua Yang, Matthew D. Pickett, Xuema Li, A. Douglas A. Ohlberg, Duncan R. Stewart & R. Stanley Williams	"Memristive switching mechanism for metal/oxide/metal nanodevices„ - Nature
Blaise Mouttet	„Proposal for Memristors in Signal Processing"
2009 N. Gergel-Hackett, B. Hamadani, B. unlap, J. Suehle, C. Richter, C. Hacker & D. Gundlach	 to create a flexible and low power memory, NIST
2010 H. J. Koo, J. H. So, M. D. Dickey & O. D. Velev	 The physical built device at NCSU

4 basic passive circuit elements

Nonlinear	Linear	Local value
Resistor	$v = f(i) \Rightarrow v = Ri \Rightarrow dv = R\,di$	R
Capacitor	$q = f(v) \Rightarrow q = Cv \Rightarrow dq = C\,dv$	C
Inductor	$\phi = f(i) \Rightarrow \phi = Li \Rightarrow d\phi = L\,di$	L
Memristor	$\phi = f(q) \Rightarrow \phi = Mq \Rightarrow d\phi = M\,dq$	M

Definition of Memristor

- **MEMRISZTOR is a semiconductor whose resistance varies as a function of flux and charge. This allows it to remember what has passed through the circuit.**
- Memristor is a portmanteau of "memory resistor". It is a passive device with two terminals, where the magnetic flux is related to the amount of passed electric charge through the device.
- Symbol of a memristor: M
- Characterised by MEMRISTANCE: $M(q) = \frac{d\varphi}{dq}$
- Unit: Ω (ohm)

Memristor definition

For a charge-controlled memristor,

$$\phi = f(q)$$

differentiating yields: $\frac{d\varphi}{dt} = \frac{df(q)}{dq} \cdot \frac{dq}{dt}$

having the voltage as $v(t) = \frac{d\varphi}{dt}$ and the current as $i(t) = \frac{dq}{dt}$ can be rewritten as:

$v(t) = M(q)\,i(t)$ where $M(q) = \frac{df(q)}{dq}$.

Flux controlled memristor

Similar to the equations above we can write for a flux controlled memristor,

$q = f(\phi)$, differentiating yields: $\frac{dq}{dt} = \frac{df(\varphi)}{d\varphi} \cdot \frac{d\varphi}{dt}$

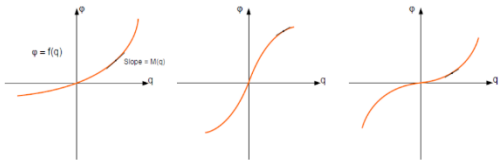
Having the current as $i(t) = \frac{dq}{dt}$ and the voltage as $v(t) = \frac{d\varphi}{dt}$ can be written as: $i(t) = W(q)\,v(t)$,

where $W(\varphi) = \frac{df(\varphi)}{d\varphi}$

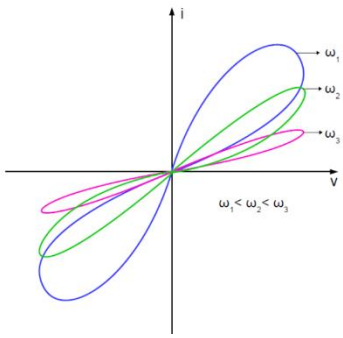
W(φ) is called the MEMDUCTANCE, and similar to conductance, it has the units of Siemens.

Memristor properties- Flux-charge relation

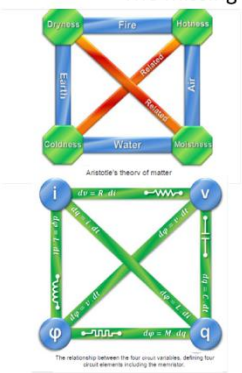
The q-ϕ curve, has a monotonically increasing characteristic. The slope of this curve is the memristance M(q). Hence, the memristance is always positive M(q)≥0. Based on the passivity condition, a memristor is a passive element if and only if the memristance has a non-negative value. The instantaneous power dissipated by the memristor is given by: **P(i)= M(q)i(t)²** and since M(q)≥0, the dissipated power is always positive as well. Therefore, memristor is a passive device.

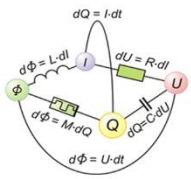


Memristor properties-Current-voltage relation



The missing circuit element

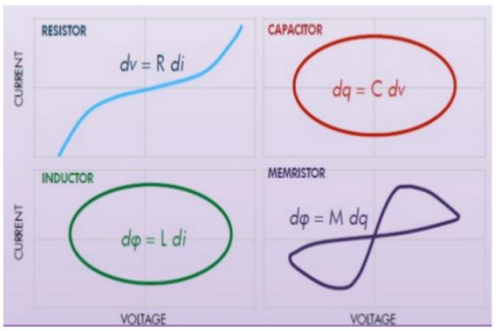




$q(t) = \int i(t)dt + q_0$

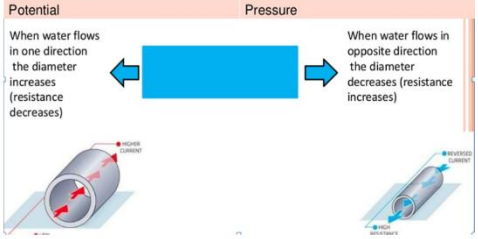
$\varphi(t) = \int u(t)dt + \varphi_0$

I-V characteristic:



Memristor analogy

Memristor	Pipe
Charge	Water
Conductance	Cross sectional area
Potential	Pressure



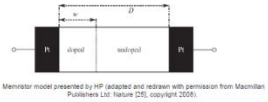
Memristor models

- Can be used in extensive range of applications.
  In each application, different characteristics are expected from memristor.
  - logic and memory applications
  - an element that has the ability to compute
  - control and store the data

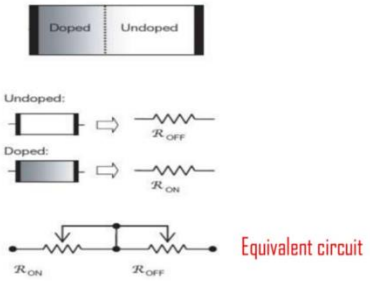
They need to have fast read and write times!

The difference between stored data should be large enough to avoid bad noise margins and have better sensitivity. Also for storing Boolean data in a memristor, the ratio between Ron and Roff resistances should be high enough. There are other characteristics that are important for memristor applications, such as good scalability, low power consumption and compatibility with conventional CMOS.

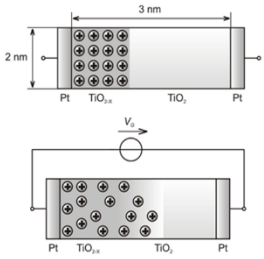
Linear Ion Drift model



Memristor model presented by HP (adapted and redrawn with permission from Macmillan Publishers Ltd: Nature [25], copyright 2008).



Working



- Permanent shift between the layers
- It exists even after the voltage has been removed
- Causes the permanent change in resistance

Basic Operation

- When the charge flows in one direction through a circuit – the resistance of memristor increases
- When the charge flows in the opposite direction in the circuit – the resistance of memristor decreases

$$q = \int_{-\infty}^{t} i(t)dt = q(t_0) + \int_{t_0}^{t} i(t)dt$$

- Thus, we can say that the memristor „remembers" the history of the applied voltage on it.

Why the MEMRISTOR?

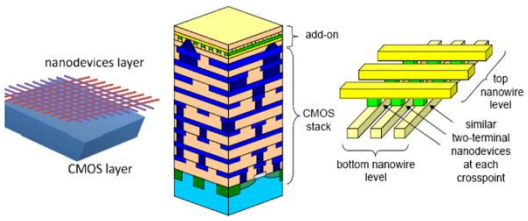
Advantages of memristors:

- Has properties which can not be duplicated by the other circuit elements (resistors, capacitors, and inductors)
- Capable of replacing both DRAM and hard drives
- Smaller than transistors while generating less heat
- Works better as it gets smaller which is the opposite of transistors
- Ability of combining logic operation with memory cells on the same chip and in diferent places through the chip.
- It can act as a configurable switch in FPGA chips
- Quicker boot-ups
- Requires less voltage (and thus less overall power required)

Why the MEMRISTOR?

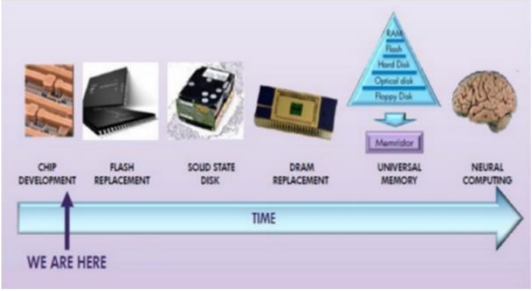
- Can work both as memory and logic function
- Higher data density due to nano-scale size
- FLASH scalability is approaching its limits
- DRAM is fast approaching their limit
  - DRAM architectures and circuitry are adapted to 25fF cell capacitance
  - Taller cell capacitor – Thinner cell dielectric <32nm
- Requires less energy and dissipates less heat
- Provides greater reliability when power is interrupted in data centers
- Can use anything between 0 and 1
- Compatible with CMOS process and provides innovating nanotechnology due to the fact that it performs better the smaller it becomes.

3D Hybrid - CMOS/NANO

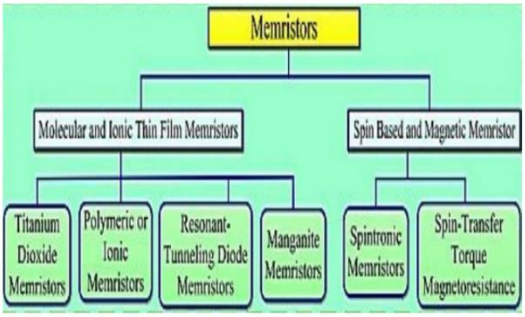


- CMOS stack + nano add-on
- nanowire crossbar of two-terminal devices (memristors)

Memristor opportunities

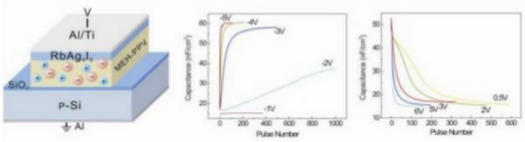


Memristor Fabrication



Molecular and Ionic Thin Film Memristors

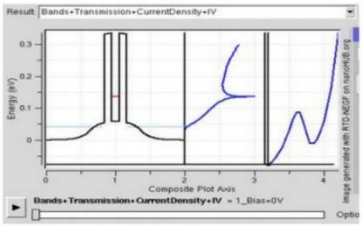
- Polymetric memristors



In 2004, Juri H. Krieger and Stuart M. Spitzer published a paper "Non-traditional, Non-volatile Memory Based on Switching and Retention Phenomena in Polymeric Thin Films" at the IEEE Non-Volatile Memory Technology Symposium, describing the process of dynamic doping of polymer and inorganic dielectric-like materials in order to improve the switching characteristics and retention required to create functioning nonvolatile memory cells. Described is the use of a special passive layer between electrode and active thin films, which enhances the extraction of ions from the electrode.

Molecular and Ionic Thin Film Memristors

- Resonant tunneling dioda memristor

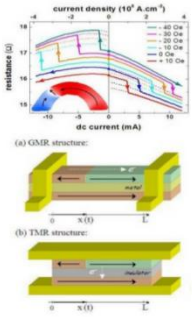


In 1994, F. A. Buot and A. K. Rajagopal of the U.S. Naval Research Laboratory demonstrated that a 'bow-tie' current-voltage (I-V) characteristics occurs in AlAs/GaAs/AlAs quantum-well diodes containing special doping design of the spacer layers in the source and drain regions, in agreement with the published experimental results. This 'bow-tie' current-voltage (I-V) characteristic is characteristic of a memristor although the term memristor was not explicitly used in their papers. No magnetic interaction is involved in the analysis of the 'bow-tie' I-V characteristics.

Spin based and Magnetic Memristors

- Spin memristive systems – Spintronic memristor

Yiran Chen and Xiaobin Wang, researchers at disk-drive manufacturer Seagate Technology, in Bloomington, Minnesota, described three examples of possible magnetic memristors in March, 2009 in IEEE Electron Device Letters. In one of the three, resistance is caused by the spin of electrons in one section of the device pointing in a different direction than those in another section, creating a "domain wall", a boundary between the two states. Electrons flowing into the device have a certain spin, which alters the magnetization state of the device. Changing the magnetization, in turn, moves the domain wall and changes the device's resistance.

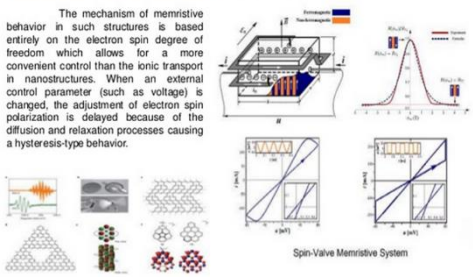


Spin based and Magnetic Memristors

- Spin memristive systems – Spintronic memristor

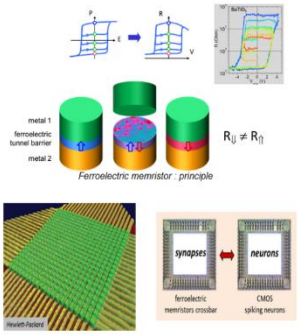
A fundamentally different mechanism for memristive behavior has been proposed by Yuriy V. Pershin and Massimiliano Di Ventra in their paper "Spin memristive systems".

The mechanism of memristive behavior in such structures is based entirely on the electron spin degree of freedom which allows for a more convenient control than the ionic transport in nanostructures. When an external control parameter (such as voltage) is changed, the adjustment of electron spin polarization is delayed because of the diffusion and relaxation processes causing a hysteresis-type behavior.



Ferroelectric Memristors

- The ferroelectric memristors is based on a thin ferroelectric barrier sandwiched between two metallic electrodes.
- Switching the polarization of the ferroelectric material by applying a positive or negative voltage across the junction can lead to a two order of magnitude resistance variation: $R_{ON} << R_{OF}$ (an effect called Tunnel Electo- Resistance)
- In general, the polarisation does not switch abruptly



Do you have any ideas for memristor application? Think about it!!!

- Check its operational principles
- Observe its characteristics
- Revise its fields of applications
- Why choose the memristor in certain fields of engineering?
- Consider which of its characteristics can be used in new areas?
- Justify and give professional reasons to your ideas.
- Use the available internet-based learning materials