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E-LEARNING EVALUATION METHODS

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E-learning evaluation methods

Doctoral thesis

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Budapest, 2020

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1 INTRODUCTION

Contemporary research subjects and related studies cover a variety of interesting topics, that stem from everyday issues and dilemmas. In past centuries researchers and scientists searched for answers to many theoretical, abstract and general questions, that would describe the world around us (be it the laws of physics or economic models) – but in the past decades the tendency in scientific magazines and journals was to focus on questions regarding everyday life and social and business phenomena.

Whenever someone embarks on a career as a researcher, very often the first big challenge is finding an issue or topic, that hasn’t been answered thoroughly yet – especially if the young researcher is searching for challenges in his or her own concrete field of interest, which further narrows the scope of possibilities.

I too firmly decided to pursue an academic career early on, so it came sort of naturally to me, that I would continue my education with doctoral studies after completing my courses in the Bologna process. By the time I started my studies in higher-education, I knew exactly what field offers the best challenges to me, where I want to focus my attention on a daily basis, and where I would like to accomplish something new.

My career related to e-learning started at the same time as my university studies, where I got into the world of e-learning both as part of charitable activity and as a professional career too – and as a person always ready to acquire new knowledge, I was constantly looking for such opportunities from the student side as well. By the time I got to the end of my MSc studies, I could confidently say that I wanted to research this topic at an academic level as well, and thanks to the practical experiences I gained during the years, I quickly found a subfield that had many unanswered questions on the topic.

The underlying motivational factors behind my dissertation will be covered in detail later on as part of the research model.

1.1 Acknowledgments

Before I start the main body of my thesis, I would like to offer a few words of gratitude to those who helped me along the way. Although a doctoral thesis is fundamentally presented as the work of one single person, I consider it important to give mention those individuals who have continuously supported me from the beginning of my studies to this very day – and I'm positive will continue on to support me in the future too.

I have received a huge amount of support from my supervisor dr. László Duma during my academic career, without his guidance I would have not been able to reach the last phase of completing my doctoral degree. I first came into contact with Laci at the beginning of my university studies while completing my BSc thesis and was lucky enough to have him as my supervisor. This professional relationship eventually formed into a friendship, becoming another invaluable experience I gained during my academic years. Thank you, Laci!

There were many random factors and coincidences that resulted in me ending up in the world of e-learning, but besides these a huge factor was my friend and colleague Zsolt Orbán, who we now share with over a decade long friendship and mutual professional career. Since 2009 we have had many joint projects, mutual brainstorming sessions of seemingly insolvable problems, persistent reactions to new challenges and countless publications and conferences, and I also continuously received personal and professional support from him, that all helped me in completing my dissertation in a substantial manner. Besides Zsolt I deem it important to mention my research partner and colleague Péter Balkányi, who I've also learnt from a lot regarding the subject of e-learning thanks to nearly 10 years of joint work and research. Thank you Zsolt and thank you Péter!

As many of us I was also fortunate to receive the endlessly subjective, but extremely inciting support of my family along this bumpy road, that always motivated me to keep on going on the right path even during the most tiring and trying times. Thank you!

As the saying goes: behind every successful man there is a great woman. Whether I am successful or not is not my role to adjudge, but what I definitely am is

lucky. My partner's boundless patience and persistence taught me how to be patient and persistent with myself too – without these I would have surely stepped down at the first step when attempting to climb the mountain of my doctoral studies. Thank you!

1.2 The research topic of the dissertation

As mentioned in the introduction, my research topic is the field of e-learning which is a rather new form of education. There is a lot of potential in e-learning research, since it is a relatively new tool set that is dynamically evolving almost day by day, therefore posing many unanswered questions.

The core research topic of my dissertation is the review and development of e-learning education measurement tools. My research question in the thesis is how to / what methods to use to best measure the efficiency levels of e-learning education: both the efficiency rate of knowledge transfer, as well as the financial-economic aspect of it.

So far there hasn't been any methodology created for this, those methods that are used in traditional classroom education is not fitting for e-learning courses in my opinion – I will discuss my opinion regarding this in detail in a later chapter. My goal was to create methods and solutions, that would be suitable to measure the efficiency and effectiveness of knowledge transfer in an e-learning course by themselves. It is worth noting, that the tool set I have created is not intended to compare a course with the classroom variant of it (or to another e-learning course), since during my research I have identified so many influencing factors, that makes comparison of two different courses virtually „ceteris paribus" incomparable.

My doctoral thesis is intended to answer the following research question and its sub-questions:

1. How do we measure the efficiency and effectiveness of e-learning?
    a. How do we measure the efficiency and effectiveness of e-learning knowledge transfer?

b. How do we measure the financial efficiency of e-learning? (Or otherwise: how do we determine the break-even point?)

A detailed elaboration of these questions can be found at the beginning of the relevant chapters.

From a financial standpoint I wish to draw a comparison with classroom courses while searching for the appropriate analysis method which can examine the pay-off when converting to an e-learning format of education – that is examining the financial efficiency of it. There are many financial business tools available of course that are able to measure this: my goal is to create a standardized calculation system, which can determine the break-even point of e-learning education formats compared to classroom education formats after input of relevant source data into the model.

1.2.1 Questions that go beyond the research subject

During my research I came across many areas within the e-learning world, that are awaiting to be explored and solved. In the following few paragraphs, I have highlighted the relevant topics, that go beyond the focus and extent of my current dissertation.

Although there have been different models now for a few decades that set benchmarks for newly created or existing courses connected to education development - like the ADDIE-model or SAM-model on how to analyze the target audience, how to decide if it is worth applying the e-learning tool set, how to measure students' results etc., - using these models are rather difficult because of overly specific courses and organizational requirements; therefore there is many room for potential in creating developmental proposals in this regard. The researches of Molenda (2003) and Kearsley (2000) provide very good base knowledge for readers and researchers interested in this topic.

Taking a step back from the subject above, the pedagogy of e-learning itself is debatable too: critique regarding this questions whether students who are virtually left by themselves are able to individually take on the task of studying, or do we generate the opposite result with this approach and this new educational method is ab ovo doomed. It is worth looking into researches in this field regarding learning motivation, virtual coaches and tutors, but McGonigal's (2011) book on gamification also offers many useful conclusions.

Examining the financial aspect of it an interesting question arises regarding which methods are most suitable during introduction of e-learning methods: is e-learning implementation an IT project or do we have to approach it from another direction? Although I will touch upon the topic of the main challenges faced during the introduction of e-learning projects in a few paragraphs, I will not provide a solution to this in my current thesis.

1.3 Field of science categorization

E-learning itself is regarded as a multidisciplinary field, as it is a combination of natural sciences and social sciences. Since the main subject of my thesis is the efficiency and effectiveness of knowledge transfer and the financial efficiency of e-learning education, I categorize the primer field of science of the dissertation as economic operations research and decision theory within the economic sciences of the human- and social sciences category, based on the nomenclature[1] of MTA disciplines.

1.4 Subject actuality

One of the biggest difficulties of knowledge transfer is its measurability (not only in the case of e-learning, but also in the case of attendance training, as I will explain in more detail later). Exam situations are, of course, easy to simulate, and this way the degree of knowledge acquired can be tested, and the quality of education can also be measured by the satisfaction of users (students, tutors, administrators, etc.), even if subjectively. (Wang, Wang & Shee, 2007) However, these measurement methods do not provide satisfactory answers to the questions I have formulated regarding the efficiency and effectiveness of knowledge transfer, as they examine the final state (the existence of knowledge), not the goodness of the process.

The topicality of the subject is best demonstrated by the fact that there is no accepted solution for measuring the efficiency and effectiveness of e-learning yet. Initiatives - such as the work of Favretto, Caramia & Guardini (2005) who examined the comparability of traditional and e-learning training, or Selim (2007) who analyzed

[1] See in detail: https://mta.hu/doktori-tanacs/tudomanyagi-nomenklatura-106809

the university adaptability of e-learning – can be found, but the measurements still focus on traditional, attendance education, and the toolkit used there also receives a lot of criticism, which I will summarize in more detail later.

At the same time, the need to set up a metric is growing, as with the continuous spread of technology and the "digitization" of generations, this form of education can be expected to grow in popularity from the student side as well, and on the business side, early adopters can even gain a competitive advantage by exploiting its potential. (Ruth, 2006) This, in turn, requires a unified measurement method and system that encourages decision-makers to open up towards this new field.

Another simple indicator of a subject's actuality is the reach and number of views of related online contents that are accessible to everyone. TED videos are currently very popular and they also include many learning and education related content (particularly significant is Sir Ken Robinson's performances from 2006 and 2010), including performances related to e-learning, and if we search by the keyword „learning" we can browse between 690 talks on the site, from which 54 are e-learning related.

We can also deduce important information by examining market trends and statistics. In the following list I have gathered some interesting and remarkable data, that supports the fact of the continuously growing significance and expansion of e-learning:

- the total value of the e-learning market was 107 billion dollars in 2015, and it is expected to triple by 2025 to 325 billion dollars – showing a 900% increase since the turn of the Millennium (Global Industry Analysts, 2020);

- 77% of American corporations applied some form of online education in 2017, and the training time of those employees who were trained online decreased by 40-60% (Forry, 2017);

- 72% of organizations believe, that e-learning grants a competitive advantage (Pappas, 2019);

- 49% of students said they attended some kind of online course in the past 12 months (Duffin, 2020);
- 68% of employees prefer to study at their workplace (Spar & Dye, 2018);
- 42% of corporations experienced an increase in revenue following the introduction of e-learning (Gutierrez, 2016);
- The biggest e-learning motivational factors are individual learning tempo (95%) and termination of travel (84%) (Wildi-Yune & Cordero, 2015)
- e-learning increases the retention rate of students by 25-60% (Pezold, 2017);
- 45% of primary and middle school students' favorite learning method is watching online videos or using digital educational games (Gallagher, 2018);
- the rate of secondary school graduates taking part exclusively in online classes rose from 6,1% in 2008 to 27,3% in 2016 (Snyder et al., 2019).

A similar related phrase that further increases the actuality of this subject is "lifelong learning", which possesses quite a large array of specialized literature (more on this in detail: Field, 2000). There have been studies in relation to this to e-learning for over 30 years now. (Clark, 1989)

My thesis provides valuable reading matter for those specialized in this subject, as well for laymen: those with a lesser understanding of e-learning can familiarize with it in the beginning thanks to the explanation and description of connected concepts and phrases from a student-tutor or business decision maker perspective alike; and those readers who are familiar with the topic can deepen their knowledge through the results and conclusions of efficiency and effectiveness measurement findings. However, I would like to emphasize, that – although there are many discussions on the pros and cons of the use of e-learning methods – I do not wish to convince anyone on the omnipotence of e-learning in my dissertation.

In the following segment I will give a short overview of those sectors where the e-learning education method is continuously expanding and spreading nowadays: the corporate sector, where they consider e-learning primarily as a sustainable cost-cutting measure opportunity, the public sector one step behind, and higher education, particularly MOOCs (Massive Open Online Courses), that are almost surely a trend of the future – and serve as the catalyst of a slight worldwide higher education reform -, and I will also mention e-learning contents created specifically for commercial purposes.

1.4.1 Corporate sector

E-learning solutions offer the opportunity of cost-cutting, a fact that instantly catches the attention of decision makers in the corporate sector. A generally applied corporate governance tool/method is creating some sort of automation for regularly recurring tasks, which enables corporations to decrease required human resources (Brown & Hellerstein, 2005), and therefore expenses too – the same is true for education, where automation is possible with conversion to the e-learning education format. We can identify two large segments in the – mostly large enterprise – sector where regularly recurring courses might be common.

1. **Recurring (compulsory) trainings**: trainings within corporations that concern the most people are those that are held (usually) yearly and are prescribed by law (for example trainings in relation to health and safety, or other sector specific regulatory trainings).

2. **Onboarding courses for new entrants:** especially in the case of large corporations there are a high number of new entrants on a daily basis, who pass through an onboarding process, that contains a general introductory course. These types of courses are usually independent from the field of work and are generally applicable to everyone at the corporation, but the employees might be geographically spread out over different sites or locations, which means it is not an easy task to coordinate such events. This issue can be easily solved with e-learning solutions. Besides this, converting profession specific onboarding courses to e-learning format is usually a very cost-efficient move, especially in the case of jobs with a high fluctuation rate.

By making a one-time investment in an e-learning solution, corporations can decrease the amount of money allocated for tutors, classroom rentals and related infrastructural expenses – and we can also take into account the easing of administrative duties that is present when organizing and managing such courses.

Besides the cost-cutting benefits there is also a competitive advantage aspect of the conversion to e-learning education, that is not only relevant for large corporations, but for entities of any size. An efficiently compiled e-learning course with efficient knowledge transfer to employees can improve their results in the workplace, thus indirectly generate a positive effect on the corporation's profits. It is worth noting though, that efficiently compiled e-learning courses do usually cost more, which might occasionally result in a negative effect on the corporation's profits in the end.

1.4.2 Public sector

The driving force behind the education system of the public sector is basically the same as in the corporate sector. Although profit orientation is not a factor in this case, economic efficiency is just as important for these organizations too – recurring courses and training of new entrants is just as relevant here as in the corporate sector. Furthermore, besides cost-cutting initiatives in the civil sector efficient knowledge transfer and its positive effects on workplace output is similarly important: its consequences – from a very high, almost majestic perspective – is a more stable and economically efficient country, whose population can reach a higher level of complacency due to this.

1.4.3 MOOCs and higher education

MOOCs (Massive Open Online Courses) broke into the public consciousness as the leaders of the mass production of e-learning contents. These contents were primarily uploaded by renowned universities (e.g. Harvard, MIT), that made their standard classroom courses available to the general public in e-learning form, divided into smaller trainings instead of complete courses, regardless of location or time. As a result, quality courses from renowned instructors could be taken online even from another continent, all of which typically was available free of charge. The content of these sites contained mainly video-based solutions, where tutors tested voluntarily enrolled students at the end of the typically 2-3-month long courses with online tests following the knowledge transfer. Universities also issued an official diploma for completing the courses, although this was integrated into the MOOCs' business model as a fee-based service.

In addition to the market-based e-learning services offered by these higher education institutions, participating educators can add color to their classroom courses too, as created content can be used and duplicated unlimited times. This can make learning easier and more flexible for students, as it can be used to turn a previously exclusively classroom type course into so-called blended learning (see later).

In addition to those above, it is worth mentioning, that similarly to the corporate sector or the public sector, internal trainings (annual recurring and onboarding trainings) appear in higher education institutions too, in which cases they can achieve cost-reducing and profit-increasing effects by using e-learning solutions for internal purposes, as discussed earlier.

1.4.4 E-learning for commercial purposes

Encouraged by the example of MOOCs, two other market segments are also open to e-learning content, in which cases we can talk about e-learning content created specifically for commercial purposes. They operate on practically the same principle as MOOC-type trainings (the online platforms that offer them are also very similar), with the difference being, that here content is not (only) created by higher education institutions and university professors, but by an expert of a topic or profession, making the e-learning curriculum available as part of a paid service.

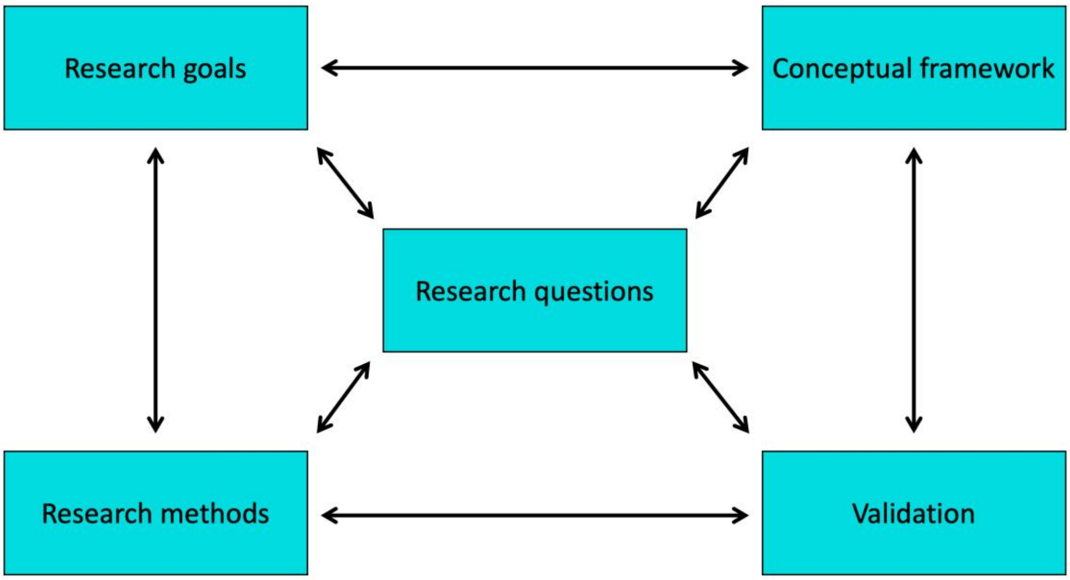
These can be - following the terminology of Jovarauskienė & Pilinkienė (2015), which also describes e-business models - B2B, B2C and even C2C solutions. In the case of the former, specialized companies produce professional e-learning materials that are sold to other businesses or individuals. In the case of C2C solutions, the broker or marketplace model defined by Rappa (2004) prevails, during which content is not created by companies, but by private individuals and sold to other individuals. This design works along the same logic as markets for (used) goods (e.g. Jófogás.hu, Vatera): the enterprise only provides the site in the background where the "commercial" activity of private individuals takes place; in our case, however, it is not used goods that change hands, rather buyers receive educational services for their money.

2 THE RESEARCH

In this chapter, I will present the framework for the research of my dissertation. During my research I will use both qualitative and quantitative tools: for the methodological elaboration I will review and synthesize a wide range of professional literature, while for testing and validating the methodologies I will apply quantitative analysis of data sets with the help of the developed measurement systems.

I designed my research with an interactive model where the central research questions interact with the research objectives, conceptual frameworks, research methods and validation. The interactive model of research design detailed below is based on the work of Maxwell & Loomis (2003).

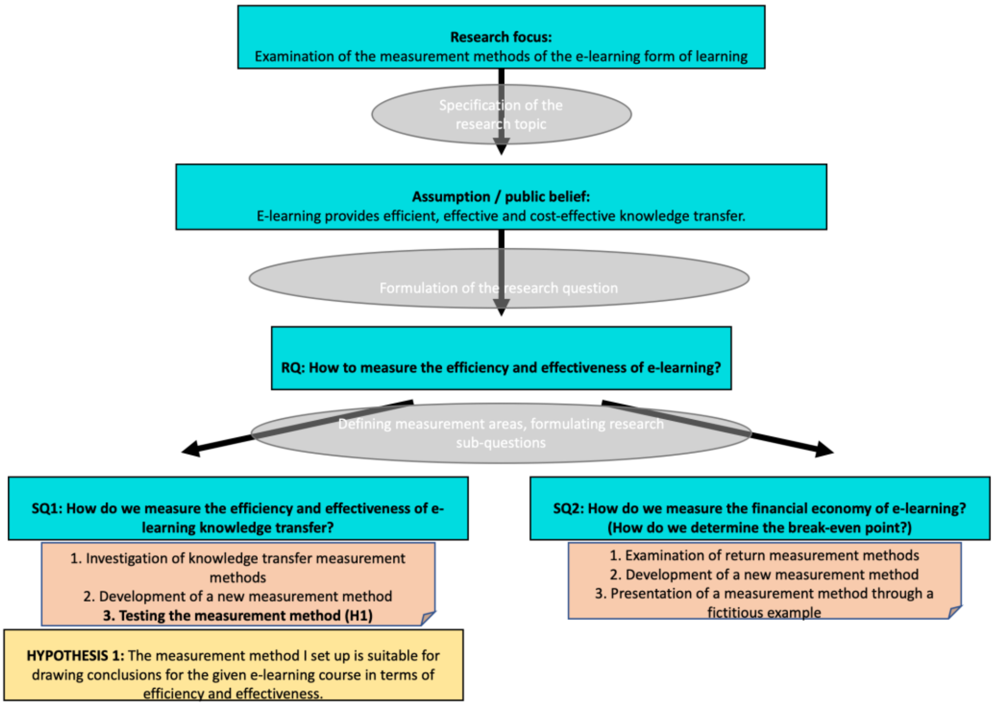
1. figure: Presentation of the interactive model of research design based on Maxwell & Loomis (2003)



2.1 Research question and hypothesis

The research question is the central factor of the interactive research model. When planning the research, the researcher formulates the question or questions in the given framework to which he/she wants to find an answer. During the process of implementing the research, this is what the researcher focuses on, this is what keeps the research in the right direction. The logical connecting points of my research field and research questions are illustrated in the following figure.

2. figure: Logical relationship system of the research question and sub-questions of the present dissertation (own creation)



As mentioned before, the focus of my research is on examining the efficiency and effectiveness of the e-learning form of learning, which includes knowledge transfer and financial implications. The basic assumption is that knowledge transfer through e-learning education is more efficient and effective (see the explanation of the concepts later in the section of the development of methods) and can be more economical (i.e. more financially efficient) than traditional classroom education.

The two research topics are worth examining completely separately:

- **Central research question:** How do we measure the efficiency and effectiveness of e-learning?
    - **1. research sub-question:** How to measure the efficiency and effectiveness of e-learning knowledge transfer? – After researching relevant literature, I will examine the available measurement solutions, set up a system of criteria for developing a good measurement method, and then develop methods for measuring the efficiency and effectiveness of e-learning education.

- **2. research sub-question:** How to measure the financial economy of e-learning? (In other words: how to determine your break-even point?) – Based on my experiences and specialized literature, I will determine the cost system of the two forms of education, and based on these, I will develop a calculation method to determine the break-even point of the e-learning form of education compared to classroom education. Finally, I will apply the developed method of return calculation on the training indicators of a (fictitious) e-learning investment I have created, and will find its break-even point.

The hypothesis of my dissertation is as follows:

The unique measurement method I have created is suitable for drawing conclusions for the given e-learning course in terms of efficiency and effectiveness.

To examine this, I will apply in practice a new, unique measurement method developed along the first research sub-question to a data set extracted from an e-learning course, and I will analyze the efficiency and effectiveness of knowledge transfer in this course with quantitative tools. The uniqueness of this method stems from three factors: (1) no method for measuring e-learning efficiency has been developed yet in specialized literature; (2) no control group is required for the measurement, the selected course becomes evaluable in itself; (3) the measurement method does not rely on subjective analysis (e.g. questionnaire text analysis), but calculates from objective, machine-recorded indicators using mathematical methods. I will consider the hypothesis justified if I can extract interpretable information from the data analysis and draw conclusions regarding the e-learning course.

It is important to mention, that general conclusions about e-learning could only be drawn after many similar studies, but this is not the purpose of the present dissertation, nor is the relationship between the two branches – as the pursuit of financial economy may be detrimental to the efficiency of knowledge transfer, and vice versa.

2.2 Research goals

When formulating the goals of the research, it is important to set various goals (personal, practical, intellectual) in addition to answering the research questions, which ensures continuous motivation during the implementation of the research. This helps to keep the focus on the research issue while also viewing the research from a distance, and adding motivation for the researcher during the research implementation.

The intellectual goal of my research is to better understand and comprehend the e-learning learning process and the factors influencing it. This can be important for students, as they get to see another viewpoint and learn from the experiences of others. It can also be useful for online content developers, or even for classroom tutors, whose tool sets can be expanded this way by learning about the factors influencing and effecting the efficiency and effectiveness of the e-learning form of learning; giving the opportunity to turn to blended forms of training to ensure a better and more flexible learning experience for more efficient and effective knowledge transfer.

Personal motivation during my research is improvement in my field of research and “gaining fame”. By successfully developing my research and defending my dissertation, I will get closer to obtaining my doctorate and moving forward in academic life. The conclusions of my dissertation will also provide a good basis for writing and publishing prestigious articles in journals and appearing at relevant professional conferences; through these I can receive additional inputs (even critiques) regarding the topic, which can help to fine-tune and further develop my research results.

Regarding the practical motivation of my research, the use and incorporation of the research outputs can result in significant development in my e-learning company. The company is engaged in the development of online e-learning curricula, during which we typically transfer a classroom education to the online space using IT tools with multimedia and interactive elements based on various methodologies. The results of the research may also provide me with a wider set of tools during business negotiations with clients. Also, by examining the efficiency and effectiveness of e-learning trainings prepared and developed by my company, we can pay even more attention to adapting it to the needs of the students when developing subsequent e-learning trainings. Curricula developed this way can lead to more efficient and effective learning and greater customer satisfaction among our clients.

2.3 Conceptual frameworks

Conceptual frameworks provide the “antecedents” that help a researcher conduct the research. There can be several sources for this (for example, previous research and literature materials, the researcher's own experiences, possibly experiments). The task of the researcher is to combine and frame the different sources, to recognize the synergies between one another and to synthesize them.

The conceptual framework of my research will primarily be based on my previous basic researches in the field of e-learning, which I have put out for review on various professional conferences and in peer-reviewed journals. In the regarding chapters of the dissertation I will indicate the sources for the given results.

2.4 Research methods

This is the part of the research plan, where the researcher defines the techniques and methods by which he collects and analyzes the acquired data. At this point, it is important to define and lay down the researcher's relationship (if any) with the research subjects (e.g. whether the researcher is present as an external observer or is an active participant), the form of sampling (what/who, when, where, under what conditions do we examine), as well as how data will be collected and what will the data analysis method be.

The aim of the qualitative analyzes related to the research sub-questions is to provide a comprehensive review of literature regarding the methodologies examining the efficiency and effectiveness of knowledge transfer and the break-even point. In the case of knowledge transfer, the essence of the research will be to explore how to develop a good measurement method, incorporating the appropriate elements of existing methods for measuring the effectiveness of classroom education.

In the case of the break-even point, the research will focus on exploring the cost elements of e-learning and classroom education. After identifying the costs, I will develop and introduce the mathematical model with which the two cost structures become comparable.

The sampling process related to the first research sub-question will be described in a later chapter of the dissertation entitled “Empirical research”.

2.5 Validation

When planning the research, it is also important to lay down when we consider the conclusions drawn from the research to be correct, so that we can prepare in advance for the possibility of errors. By identifying the danger points in advance, we can modify the research method during the research planning stage (e.g. in terms of personal influencing), thus the designing process of our research model becomes interactive.

There are serious dangers in the topic’s connection to IT, both in terms of technological implementation and human factors (e.g. IT affinity): you can completely ruin the learning experience and thus even the knowledge transfer if the interface developed for e-learning is difficult to use – regardless of whether the fault is in the structure of the system or the user is not able to use IT solutions with sufficient routine. To prevent this risk, when sampling empirical data, it is worthwhile to conduct a preliminary, general survey of the students' IT skills (thus setting a minimum requirement for participation in the sample).

2.6 Targets and expected results

When planning a research, I consider it an important step to formulate, in addition to the research (sub-)questions and their implementation, specific results that I expect from the implementation of the research. This in itself maintains motivation during the implementation of the research, and can also set up certain success criteria, which can have a positive effect on the quality of the research. However, I also consider it important to keep in mind that these goals and assumed results do not in any way influence the research process or the conclusions drawn from its results, as we would draw distorted conclusions at the end of the research.

As I stated when setting up the hypothesis, I consider the measurement methods developed for measuring knowledge transfer to be successful and effective if it is suitable to measure the efficiency and effectiveness of knowledge transfer of any form of e-learning education independent of its topic. This method of measurement must be self-explanatory, i.e. there should be no need for a control course or a traditional training as a basis for comparison in order to interpret the results obtained from the analysis of a given course.

I consider the tool developed to measure the break-even point to be successful and effective if it provides a method for decision-makers on e-learning education to make a clear decision on (disregarding the efficiency of knowledge transfer) whether it is economically worthwhile to choose the e-learning form of education instead of classroom education, and if so, what time period is expected to reach its break-even point. It is important to note that in the framework of this dissertation I am not looking to answer the question on for what topic is it worthwhile or at all possible to implement knowledge transfer with e-learning methods, so the answer to the economic question alone does not provide an exclusive and clear answer on whether it is worthwhile to implement a specific education, training, or course in the form of e-learning.

An additional expectation regarding my research is that after the development and selection of the measurement methods mentioned above, I can prepare an appropriate data set on which I can test the implementation of the methods. I will consider the empirical analyzes to be effective if they provide a clear answer to the questions asked: that is, whether knowledge transfer was effective and efficient in the chosen course; and whether (and if so, where) the implementation of the selected training to e-learning format has a break-even point. (Note: I will test the two methods independently on different data sets.)

2.7 Structure of the dissertation

In this subchapter I will briefly present the structure of the dissertation.

First, I will do a general literature review on the topic of e-learning: I will examine the definition of e-learning with its related approaches and outline the main cornerstones that define it. I will present related concepts (e.g. distance learning, mobile learning, microlearning) that sometimes appear as synonyms, sometimes as complements and sometimes as substitutes in e-learning terminology, and I will also present essential components that make up the e-learning ecosystem. At the end of the chapter, I will compare the e-learning form with the traditional form of classroom learning.

The next main chapter is dedicated to the knowledge transfer measurement methodology. Here I will first review the characteristics of good measurement systems, thus preparing the development of a measurement method for knowledge transfer. I will start the latter with an overview and critique of the current method of measurement of the traditional form of education, then based on this - taking into account the specialties of e-learning - I will propose new measurement methods: by introducing a knowledge transfer-centric (efficiency test) and two improving basic elements (effectiveness test) measurement method.

The next main chapter focuses on the method of calculating the break-even point. I will start this with an overview of the specifics of e-learning implementation projects, then I will determine the cost elements and financial factors that characterize the financial costs of traditional classroom and e-learning forms of education. Finally, I will develop a break-even point calculation method that shows the break-even point of e-learning investments as opposed to classroom education. In the end I will test this method by implementing the financial characteristics of a fictitious training.

In the next chapter I will describe the data acquisition method required for data analysis and present the collected data. I will apply the developed and selected efficiency and effectiveness measurement methods to the data, then I will analyze the obtained results and draw the possible conclusions, which will also mean the confirmation of my hypothesis.

Finally, in the last chapter of my dissertation, I will summarize the obtained research results, evaluate the success of the research, and make suggestions for further research questions.

3 THE CONCEPT NETWORK OF E-LEARNING

The primary goal of this chapter of my dissertation is to interpret the different definitions of e-learning, to bring the words and phrases of the topic to a common denominator, and to define and present the building blocks that make up e-learning. In this chapter, I will build on my previous research on the topic. (Nagy, 2016)

It is true not only for e-learning, but also for other research areas, that the novelty of a topic in its initial stage somewhat hinders the work of researchers and experts due to the lack of a unified language. As a result, it is easy to get lost in a discourse if the parties involved interpret the same words differently; but it can also be easy to misinterpret the data in the data sets in the case of empirical research, or to determine the comparability of the answers of the respondents in the case of questionnaire research, if they suffer from a lack of precise definitions. (Moore, Dickson-Deane & Galyen, 2011)

The fact that e-learning is in its infancy is further complicated by the fact that with the rapid development of IT, new and new elements are constantly being added to the e-learning tool set. Of course, this expands and hinders the possible research areas at the same time, because as long as there are at least a few uniformly accepted basic theses, it is difficult to build further research on common grounds.

3.1 Declaring uniform vocabulary

As I have already pointed out in the introduction, when discussing the relevance of the topic, e-learning can be applied and interpreted in many environments (e.g. higher education or business, education for internal or commercial purposes, compulsory or voluntary education, etc.). The aim of my dissertation is not to extract and analyze one or a few of the contexts above, but rather to develop a general toolkit independent of the medium it is used in.

Due to the above, I will refer to the individual actors of e-learning in a uniform way, regardless of the different areas of use (see the latter in more detail later). Below, I have highlighted a few key terms and phrases that I will use universally in the future.

1. table: Terms seeking a uniform vocabulary for the dissertation (own creation)

Concept	**Intended interpretation(s) in this dissertation**
Student	As a student, I will hereafter refer to students in public and higher education, employees involved in in-service training at the workplace, or even individuals who consume e-learning content on the Internet as a service purchased for personal use.
Tutor	As a tutor, I will refer to educators and professors behind the pulpit in public and higher education, trainers or coaches who provide on-the-job training, and teachers and instructors in the service market.
Traditional, classroom, attendance education	As traditional, classroom, attendance education, I will refer to classes, lectures or seminars in public and higher education, on-the-job trainings, and forms of education either in the classroom or in the field, which take place in the personal presence (possibly under the supervision) of a tutor.
E-learning curriculum	As e-learning curriculum, I will refer to any digitally generated content that supports online teaching and learning processes that carry knowledge, including instructional videos, interactive clickable content, or even gamified virtual reality media designed for educational purposes.

I will elaborate the more precise definitions of the above terms, their roles, and their location in e-learning in latter subchapters, but I considered it important to state that I will treat these words as collective words during my dissertation, using them in the broadest interpretation of usage as possible.

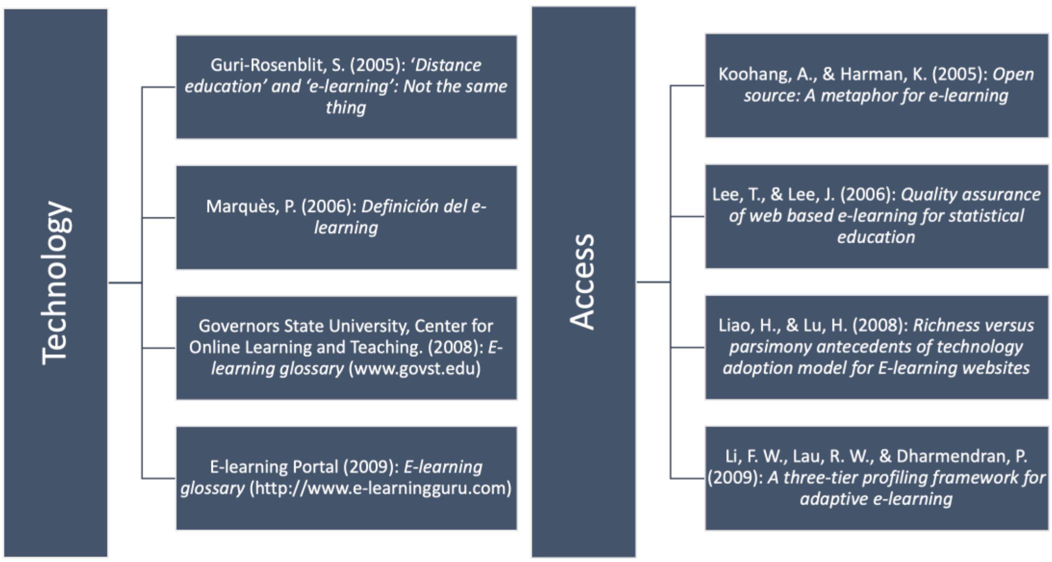
3.2 E-learning definitions

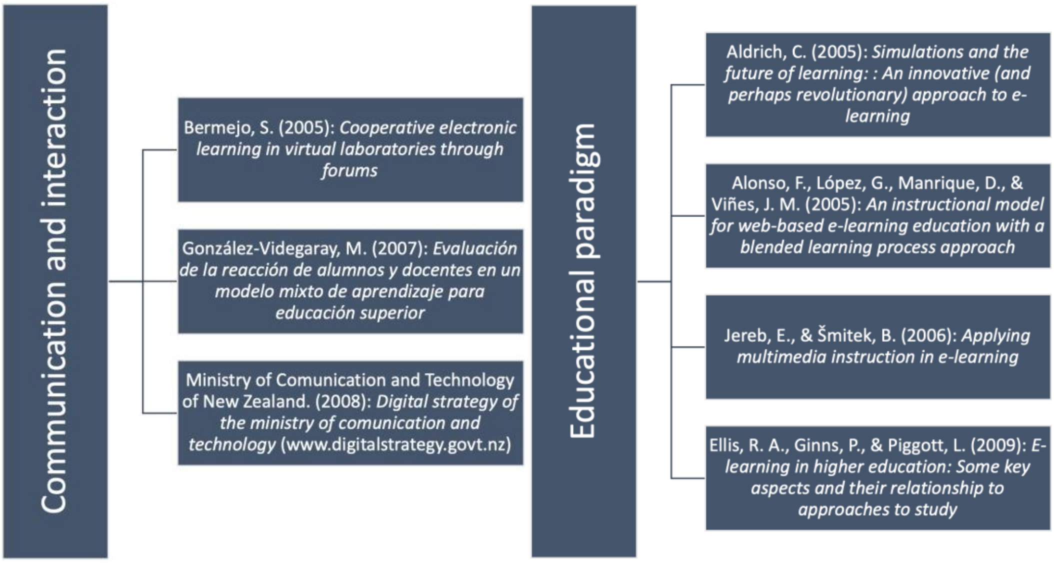
As the plural of the title shows, there is no single consensus on the definition of e-learning, but the enthusiastic research community has already, through many attempts, formulated some simpler or more complex definitions for e-learning as a form of education. Prior to me, several authors (see e.g. Guri-Rosenblit & Gros, 2011; Sangrà, Vlachopoulos & Cabrera, 2012) have recognized this phenomenon, and have categorized the different definitions of e-learning into groups, as follows:

- definitions based on a **technological approach**,
- approaches arising from the path of **accessibility**,
- definitions focusing on **communication and interaction**,
- interpretations of e-learning as a new **educational paradigm**.

Sangrà, Vlachopoulos & Cabrera (2012), in addition to grouping, also collected a bunch of studies by various authors, where they experimented with defining e-learning. These definitions are somewhat different in each case, yet they can be classified according to the above logic into an approach "school". The classification of each author and their studies is summarized in the following figure.

3. figure: Grouping of e-learning definitions by Sangrà, Vlachopoulos & Cabrera (2012) (own creation)





3.2.1 Technology

Perhaps the most obvious solution is to parallel e-learning with technological innovations and derive its definition from it. This approach may have been appropriate in the early days, when the alternatives meant blackboards and chalk, or flipcharts and felt-tip pens, but it did not anticipate that digital technologies could be integrated into attendance training (e.g. smart boards and projectors). Originally, e-learning methodology was based on differentiation from attendance education, but with the solutions mentioned above, e-learning was brought back into classrooms to some extent.

Another problem I can identify in these definitions is that in many cases they are specifically about online, internet-based learning, as early e-learning contents appeared in this form to the general public – but nowadays we can also see many offline e-learning solutions.

The definition given by Governor State University (2008) also refers to the tools used in e-learning as “handheld devices”, which again gives rise to misunderstandings – this definition, when applied to large, stationary workstations, or complete virtual reality simulation environments, no longer stands its ground.

However, in addition to what has already been mentioned, I consider it important to include technology in the definition of e-learning in some form and to emphasize its technological background, because without these technological innovations e-learning would not have been able to appear among the forms of education.

3.2.2 Delivery method

The delivery system-oriented approach is very similar to the technology-based approach, but in this case, we do not focus on the specific nature of the technology – on the contrary, in the previous chapter, media, digital devices and even the Internet were highlighted in some way. This approach actually states that e-learning provides some alternative path to learning (enabled by technology); that is, the "way of delivering" knowledge in e-learning is changing.

Abbas et al. (2005), for example, defines e-learning as a wide range of processes that can be achieved through electronic devices available at the time. In this wording, I find the phrase "available at the time" to be particularly practical, as it involves the constant change and development of technology, thus providing a long-term sustainable definition for e-learning.

3.2.3 Communication and interaction

In this approach, the wording of Herrington & Oliver (2000) deserves special mention, as they speak among the first not only about the tutor-student, but also about the student-student relationship as an essential and supportive element of the learning process. According to Herrington & Oliver, interaction and communication are essential elements of learning, and e-learning can (also) support this effectively, both between tutor and student and between student and student.

We can see that technology is also a key element of the approach that focuses on communication and interaction, since without it the added value of e-learning would not be realized. Here, on the other hand, e-learning itself appears less as an independent source of learning, but rather as a complementary, supportive tool - while in the previous two cases e-learning was referred to as an element that fully covered the learning process itself.

3.2.4 Educational paradigm

This approach is best illustrated by a quote from Khan (2005: 140): "[E-learning is] an innovative approach for delivering well-designed, learner-centered, interactive, and facilitated learning environment to anyone, anyplace, anytime […]".

Khan highlights the benefits of e-learning, with perhaps one of its most important elements: independence from space and time, but also lists its learner-centricity.

Also included in the definitions of e-learning with an educational paradigm approach is the writing of Henri (2001), who focuses on the use and contribution of the Internet. In my opinion, however, this is again too technology-centric, although the author emphasizes that e-learning must always be considered independently of the technology used - the Internet itself is a technology that is not necessarily a required element of e-learning.

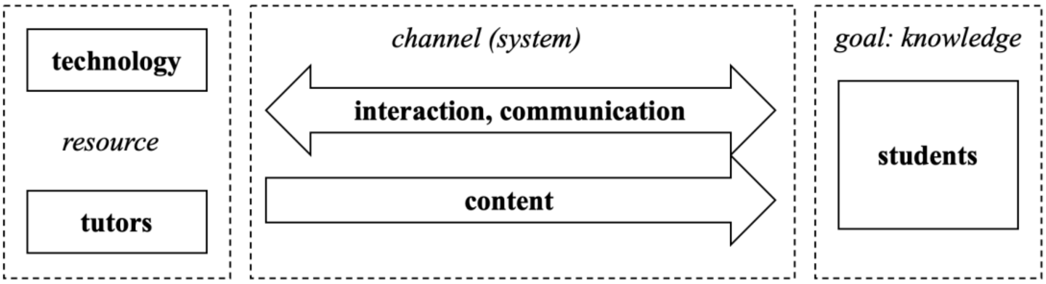
In my opinion, this is perhaps the most difficult approach to e-learning of all the approaches. Since this kind of definition is subjective and basically ignores specifics, it is difficult to apply it to, for example, classification or grading (i.e., to decide whether a form of education qualifies as e-learning). On the other hand, it provides much more emphasis on e-learning than when viewed as a purely technology-driven innovation.

3.2.5 Criticism of approaches

The grouping of four, although they appear to be completely different in name, ultimately includes the involvement of technology in e-learning in all of them. However, this technological environment is constantly evolving and changing, and its content cannot be considered a constant element in the line of definitions. By claiming that e-learning is so technology-based, we can conclude that changes in technology will constantly change e-learning itself, including its (non-existent) definition.

In my previous research, after examining the definitions above, I illustrated the form of e-learning education as a process. In this, the approaches above are integrated simultaneously: technology as a resource (but like Khan, it is no more than a potentially exploitable tool here); interaction and communication as a channel between tutors and students; and access is provided by the process itself.

4. figure: Process-based representation of conceptual approaches to e-learning based on Nagy (2016)



3.2.6 Proposal for a definition of e-learning

My personal suggestion is that e-learning should not necessarily be conducted on its own, but as a kind of complement to attendance education. I propose an approach that focuses on that **the form of e-learning provides a learning opportunity that is unrestricted in space and time, which enables learning independently of the tutor by using digital solutions**.

With this definition, I do not claim that there is no need for the role of a tutor in the case of e-learning, yet I emphasize its optional nature; perhaps by using the term ‘digital’ we make the technological aspect a bit more timeless; and I also emphasize the two most important elements of e-learning propaganda: flexibility thanks to independence from space and time.

3.3 Technology or society driven innovation?

Looking at e-learning in general, an interesting starting point may be whether we are talking about a technology- or societal-demand-driven innovation. Let's examine both dimensions to find the origin of the specificities of the e-learning form of education that has developed today.

Viewing the need for e-learning from a social point of view, it is worth going back to the general phenomenon that we now describe as “our busy world”. Central to this is the cumulative focus of attention, the shortening and fragmentation of time spent on one thing, and a series of continuous conversions to our next activity. (DeGreeff, Burnett & Cooley, 2010)

This kind of lifestyle and approach is embedded in all areas of life now: the shortening of conversations (shortening and fragmentation of calls and messages), the shortening of meals (fast food networks), but also manifests itself in the workplace in the breakdown of interactions and tasks, in increasingly frequent organizational transformations. (Cran, C., 2015)

The process of learning isn’t an exception either, where it is already inconceivable, especially for the new generations, to concentrate on one thing, to study and prepare for days. This has also been replaced by a much more fragmented approach, breaking down learning units into smaller parts and mastering them through those (this is called microlearning, see later for more details) (Kovachev et al., 2011)

This kind of form of learning can no longer be realized within the traditional classroom framework: students are not able to constantly pay attention to and concentrate on one thing, the curve of learning is constantly interrupted by some event. Education must therefore also adapt to this new way of life and social phenomenon, as a means of which can be the form of e-learning that is independent of place and time and can be customized and adapted to the required needs.

Examined from another point of view, from a technological standpoint, all requirements for the emergence of e-learning have gradually become available: the continuous spread of computers and other mobile communication devices and their availability (from both a material and supply viewpoint); widespread availability of the Internet and a rapid increase in bandwidth and internet speed, increasing mobility.

At the same time, software solutions coupled with these technologies have also made it possible for tutors to create educational materials that are easily accessible to students from the Internet, without the need for in-depth IT (e.g. programming) skills, and for which the involvement of special IT professionals was not required at all or only to a limited extent.

It would be difficult - and not my aim in the present context - to decide whether the hen or the egg came first: whether e-learning was formed and developed due to the opportunity provided by technology, or technology reflected this growing demand with this innovation. This question can be asked in countless other areas as well (McMichael, P., 2012) and has been of interest to researchers for decades. (Yearley, S., 1988) However, change has already taken place in the field of e-learning, as this new form of education is gaining ground.

3.4 E-learning pillars

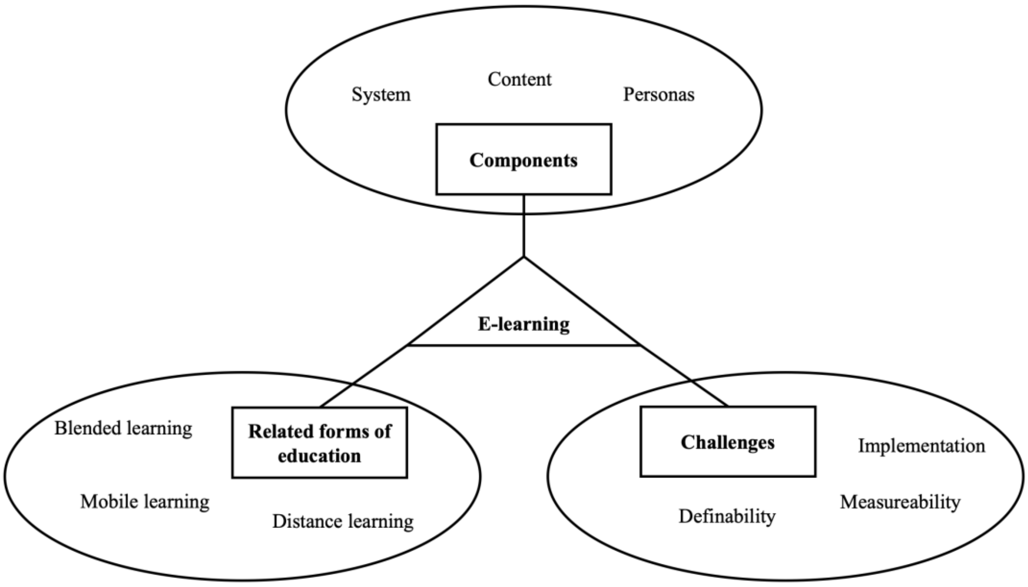
To gain an insight into today's e-learning ecosystem, I have broken down e-learning into three main elements in my previous research. (Nagy, 2016)

- **Challenges:** which shed light on current issues that engage both everyday e-learning users and researchers;

- **Related forms of education:** which indicate ways of learning that are sometimes used as a synonym or sometimes as a complementary concept to e-learning;

- **Components:** which are the basic components of e-learning.

5. figure: The e-learning ecosystem based on Nagy (2016)



In the following subchapters, based on and supplementing my previous research, I will first explain in detail the examples of the different forms of education that are closely or loosely related to e-learning, expanding it with a new concept that is increasingly mentioned nowadays, microlearning. Following that I will focus on the components of e-learning and examine its three main elements in detail.

3.4.1 Challenges

I have already addressed two of the challenging topics in previous chapters: I have examined the definition of e-learning and its approaches, and the question of its measurability is the central topic of this dissertation. I have discussed the dilemma and arisen issues in the introduction, and later main chapters will be used to solve these dilemmas. In addition to those above, I will discuss the specifics of e-learning implementations tangentially in the introduction of the chapter on the break-even point.

3.4.2 Education forms

In this subsection, I will describe forms of education that often interfere with straightforward orientation in the e-learning ecosystem. With their description, my goal is to make the meanings of these old and new concepts and their connection points to e-learning clear and unambiguous even for those not familiar with them. I have identified a total of four forms of education that are related to e-learning in some way:

1. **Blended learning;**
2. **Distance education / distance learning;**
3. **Microlearning;**
4. **Mobile learning.**

3.4.2.1 Blended learning

Blended learning (synonyms: mixed learning, hybrid learning) in today's sense is a concept that becomes incomprehensible without the presence of e-learning. This is because both e-learning and traditional classroom training are an integral part of this form of education. The aim of blended learning is to provide good learning opportunities for students by taking advantage of both forms of education. It is up to the training planner what proportion of the total training structure the e-learning and attendance form constitutes.

For the exact conceptual definition, I quote from a multi-author study, where researchers have analyzed hundreds of publications and dissertations, and from this they have developed an interpretation that is as follows: “[Blended learning is] the thoughtful integration of online and face-to-face instruction.”. (Drysdale et al., 2013:90) The authors also pointed out that this form of education can be found in many places in both the higher education and market sectors. It is typically used in situations where an e-learning tool set is used for some kind of pre-preparation or even just competence measurement, followed by a one- or multi-occasion attendance training, then an e-learning follow-up - primarily for knowledge revision and knowledge assessment.

3.4.2.2 Distance education and/or distance learning

Although I have included the two concepts into one chapter based on the many similarities, it is worth immediately highlighting the difference between distance education and distance learning, in which I will primarily rely on the work of King et al. (2001). Although the two terms are often confused, interchanged, or possibly used as the same word, one of them actually includes the other:

- **Distance learning** is the broader term, as it is not limited to a tutor-student relationship, but can be used to acquire virtually any knowledge in which a mediator has a role to play in overcoming distance.

- **Distance learning**, in contrast, is a special type of distance learning where the tutor also appears and typically supports learning in some organized setting.

After separating (and at the same time linking) the two concepts, it is easier to analyze their relationship to e-learning. First of all, it is important to note that distance can apply not only to space but also to time. This is also highlighted in the publication of Moore, Dickson-Deane & Galyen (2011), who primarily examines learning environment in their quantitative research.

Distance learning and e-learning go hand in hand usually: since e-learning is typically space- and time-independent, it fits exactly into the basic essence of distance learning, to the distance from the tutor in space and / or time. However, it is important to emphasize that e-learning is not a necessary corollary of distance learning, since without the use of digital technologies we can no longer talk about the form of e-learning education.

3.4.2.3 Microlearning

In contrast to the two concepts above, microlearning is a methodological tool that is gaining ground in today's fast-paced world (see previous chapter). For example, the work of Hug (2007) is worth highlighting, who devotes an entire book to the analysis of microlearning. The essence of this is that students acquire knowledge in units as small as possible, even broken down into minutes, and not in the previously usual structure, typically 45-60-90 minutes - or even through whole-day, day-long lessons.

Microlearning and e-learning can easily come hand in hand, as this fragmentation method is difficult to achieve in the context of face-to-face education - for example, a situation in which an instructor passes important information in one and a half minutes, then students take breaks of various lengths, after what they get more crumbs of knowledge, is unrealistic.

An essential part of microlearning is an independent schedule, in which the student determines when and how much time he or she devotes to learning. This is perfectly achievable using the e-learning form of education. The most obvious example of microlearning might be the language learning applications that can be downloaded to smartphones, where in just a few minutes, little by little, students have the opportunity to learn, repeat and practice their knowledge.

3.4.2.4 Mobile learning

When interpreting mobile learning, it is first and foremost important to keep in mind the English origin of the word, where mobile does not only mean phone, but mobility means any device that is portable (such as notebooks, tablets, smart watches, smart glasses, or any other wearable digital device) and can also be used for learning.

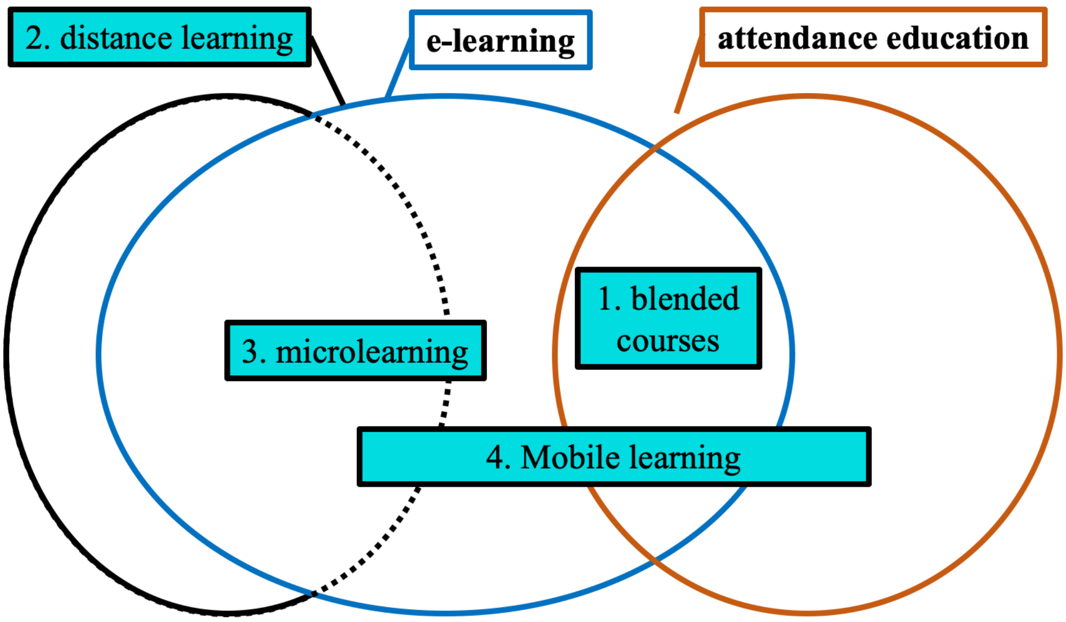
Mobile learning is also an important inherent and connecting point of e-learning, as (again thanks to digital technological revolutions) it facilitates the realization of non-stationary learning, precisely due to mobility. Thanks to mobile devices, we can find increasingly advanced solutions using virtual and augmented realities, which greatly facilitate the learning process in 3D visualization environments.

However, Martin & Ertzberger (2013) also points out that mobility is not about people (i.e. students) but about the portability of devices, so mobile learning can be included in the tools of attendance education. An increasingly popular example of public and higher education is the use of an online quiz application called Kahoot, where students can use their smartphones to answer questions asked by the tutor at the beginning of the lesson, thereby generating a competitive situation to deepen their knowledge.

3.4.2.5 Relation of the concepts above to e-learning

After clarifying the concepts above, it is worth visualizing how the four terms relate to e-learning. Given that some concepts are an integral part of e-learning, others are only related to it from the outside, the best option is to place them on a diagram. This self-made figure below is, in my opinion, a good illustration of where the concepts just discussed and explained are (with a blue background) and where their connection points to e-learning are located.

6. figure: Relationships between e-learning and related forms of education (own creation)



3.4.3 Components

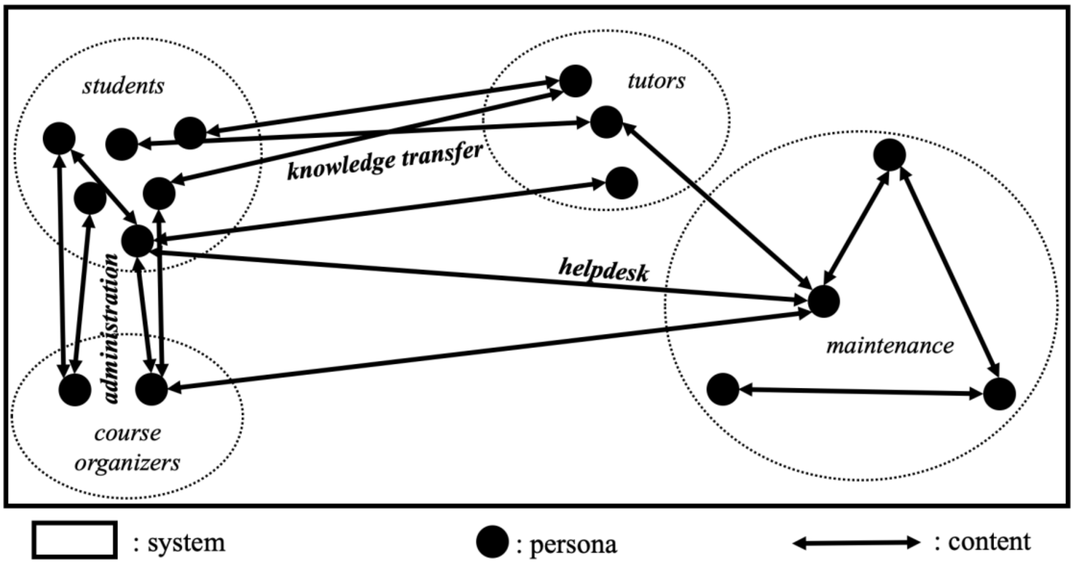
As I have already pointed out when describing the pillars of the e-learning ecosystem, I based the presentation of the components of e-learning on my previous research. According to this, there are three main components to e-learning, all of which prove to be indispensable. (Nagy, 2016)

2. table: The three main components of e-learning based on Nagy (2016) (own creation)

Component	**Description**
Persona	The category of personas includes all human participants in the e-learning environment who take part in the learning process, albeit to a small extent, either as active or passive participants.
Content	We can practically group under the collective word of content the materialized version of the knowledge to be transferred and learned, which the student must acquire - including learning elements that complement the education.
System	The system is an IT solution responsible for the administration and proper functioning of e-learning trainings, which on one hand serves as a repository for content elements and facilitates the communication of personas, but can also provide process-level support in training organization and monitoring through programmed automations.

Is it difficult to imagine an e-learning studying process omitting any of the components above, as these three categories provide an answer to who? (the student), what? (the curriculum) and how? (via e-learning system). The possible connection points between the individual elements are well illustrated in the following figure. In the following subsections, I will dissect and detail these components.

7. figure: A possible network of the components of e-learning based on Nagy (2016)



3.4.3.1 Personas

Out of the three components I will first introduce the personas. We will look at the e-learning learning process from a broader perspective, so we will not look only at the student-tutor relationship, as many participants with a supportive role also contribute to a successful, efficient and effective knowledge transfer. It is worth segmenting the personas into groups according to their functions:

- **Receiving function (target):** here we can list those personas who are on the receiving side of the knowledge transfer, i.e. who want to acquire knowledge. In an earlier chapter of my dissertation, I have stated that I would call this type of persona uniformly a student (regardless of the educational environment in which we are). The participation of students can be the result of their own will or of some compulsory regulation (for example, corporate compulsory trainings or trainings required by law)

- **Transfer function (source):** characters in this category are those who are in possession of the knowledge to be transferred. There are primarily two types of participants here: on one hand there are teachers in the traditional sense, who add and provide professional content to the e-learning development process, and on the other hand there are tutors who provide the students with professional advice and additional knowledge during the e-learning learning process. Tutors can also perform a supportive role due to their mentoring activities. For e-learning solutions in the introductory phase, instructors and tutors are typically not separate individuals. (Allen, 2013)

It is important to note that students who are in the receiving function can also have a transfer function, as one of the key elements of collaborative learning is the appearance of the student-student knowledge transfer alongside the tutor-student relationship.

- **Supportive function:** we can list here personas who support knowledge transfer in some other way, i.e. not by sharing professional content. A typical example of a support function is a training coordinator who oversees the development of appropriate student-tutor pairings in the e-learning system.

  Another example is the e-learning screenwriter and curriculum developer, who, although not in possession of the professional knowledge to be taught, is able to transform the training material into e-learning curriculum with the appropriate digital tools. This requires both pedagogical and IT skills.

  We should also not forget the personas who enable, maintain and support the day-to-day use of e-learning solutions, such as IT system administrators or helpdesk administrators.

It can be seen from the list above that the e-learning learning process is also a rather complex and multi-persona system. Among the different roles and functions, as I mentioned with examples above, cross-sections do exist that are unique to every e-learning ecosystem. However, in order to adequately fulfill each role, it is recommended to separate them as much as possible, so that everyone can work on implementing their own role with maximum efficiency.

3.4.3.2 Content

One of the most defining factors of e-learning content from a technological point of view is the type of standard used. The significance of this lies in the fact that the e-learning systems discussed later should be able to provide the prepared curricula with appropriate display and functionality, and also, the information obtained from it should be managed in a uniform way, visualized for later follow-up and returned to the training organizers, educators, tutors and students alike.

In terms of standards, unfortunately, technological development is not at a satisfactory level – despite the existence of playful, personalized content that provides an extraordinary visual experience among digitized e-learning curricula, e-learning standards aimed at unifying their functionality and communication scheme are lagging behind in development. The e-learning developer can primarily choose between two options:

1. **SCORM (Sharable Content Object Reference Model) standard:** the SCORM, although its latest major version is the 2004 edition, is still the most common e-learning standard to date due to a lack of adequate alternative. It uses a schema that applies a set of rules that determine the form in which the information in learning materials produced in accordance with this standard are conveyed to the player – this provides an opportunity to monitor the students' progress in a coherent way within the framework. (Parmar, 2012)

2. **TinCan API:** a much more flexible and at the same time much more transparent solution is the TinCan API, which was originally intended to replace the SCORM stalled in development. This allows tutors to create individually compiled reports in the e-learning system instead of a uniform bound form, which can give an accurate picture of student behavior and results achieved in e-learning. Unfortunately, the spread and development of this standard is also lagging. (Poltrack et al., 2012)

Beyond standards, another technological approach is to use the software (application) used by the curriculum developer to produce the e-learning curriculum.

In addition to the use of certain software, it is methodologically and pedagogically important to examine the type of material we are talking about. In this, the classification of Mittal, Krishnan & Altman (2006) can be the point of reference, who classified e-learning curriculum types into four categories:

1. **Text curriculum:** simple, but as a result static curriculum with low development costs, where we expect no or only very low levels of interaction from the learner. In addition to its economy, it offers more than a simple (even online) book in the sense that, thanks to the e-learning standards discussed above, the student's progress can be tracked, i.e. it can be checked what content the student has viewed in the e-learning system.

2. **Interactive curriculum:** as the name suggests, unlike the text curriculum, it contains much more interactivity, and expects much more interaction from the student. It draws a wide range of tools from gamification, as the e-learning curriculum encourages and helps the student to learn through solving various interactive tasks.

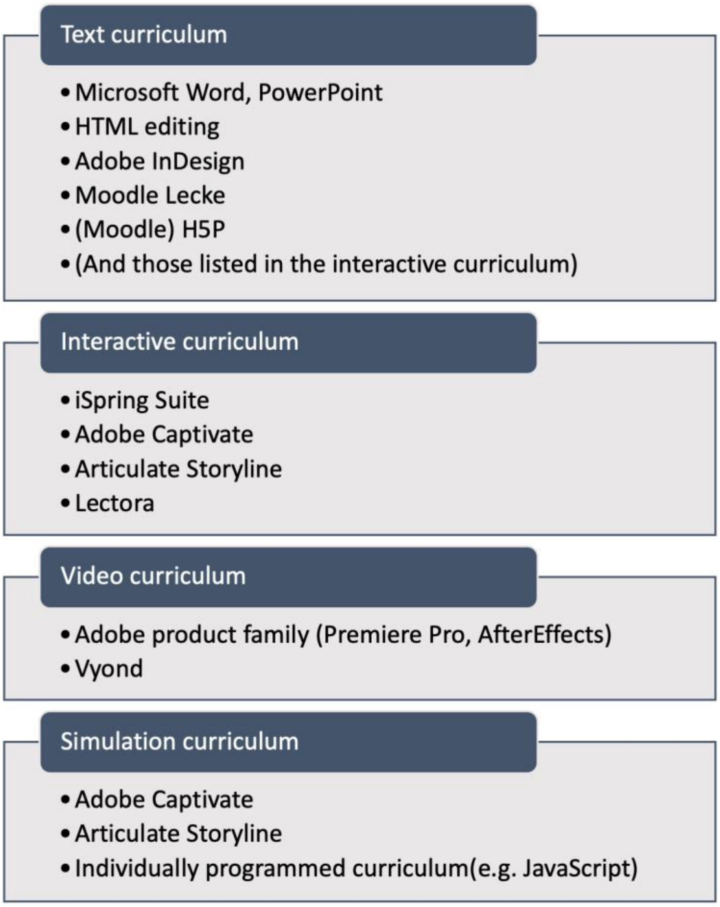
3. **Video curriculum:** this type of curriculum primarily exploits the potential of visualization. There are both live-action and animated versions. In the case of the former, it is worth mentioning classroom sessions recorded with camera, or video content recorded in studio conditions, post-processed with effects. In the case of the latter, we can talk about animated short films, where the content provides a digitally drawn and edited appearance, through which, for example, it is worth presenting situations that are difficult to record in real life. In the case of video teaching materials, it is generally recommended to aim for a short viewing time and the smallest possible layout, due to the social needs for microlearning already explained in previous chapters.

4. **Simulation curriculum:** these learning materials include e-learning content where the student is encouraged to solve real situations by placing them in a virtual environment. This way, they can practice the

right attitude they need to face these problems through real-life examples and learn how to solve these problems.

In the figure below, I have collected the more well-known computer applications and solutions in e-learning curriculum development circles, with which the types of curricula above can be developed according to standards.

8. figure: Curriculum types and computer applications used to develop them (own creation)



To conclude the chapter on the content of e-learning, it is worth mentioning that in addition to the e-learning curricula that transfers specific knowledge, we can also include other learning / checking tools that expand the possible channels of knowledge transfer. Such tools include, for example, tasks and exams, which are usually evaluated automatically, and knowledge libraries compiled by teachers or even students (e.g. a collection of concepts, references, terms and abbreviations).

3.4.3.3 System

As I have outlined when describing the components of e-learning, a key element in the e-learning ecosystem is the e-learning framework itself, which serves as a kind of a background administrative function. For systems, we can re-apply the previous grouping logic, i.e. we can categorize them based on their set of functions and tools.

3. table: A possible grouping of e-learning systems (own creation)

Curriculum type	**Features**
Content management systems	Initially, e-learning systems were only content management systems with simpler functions, where the various e-learning contents could be made available to the students in a systematic and structured way, depending on access rights. Thus, at first, they did not provide much to users other than student registration or some online curriculum library functionality. Later, the systems were gradually expanded, equipped with e-learning tools (for example, taking online tests, evaluating assignments online, supporting group work, using Wikipedia-like knowledge base building features, communication opportunities) and developed into learning management systems (LMS - Learning Managements System and LCMS - Learning Content Management System). (Mahnegar, 2012)
Training organization systems	Just as LMSs grew out of content management systems that were originally independent of e-learning, so did training organization systems integrate into the world of e-learning. These systems were originally intended to address attendance trainings (classroom occupancy, classroom training applications and registration, etc.), but these needs have also emerged in this area with the spread of e-learning.

	Training management systems offer more than LMSs in that they are able to automatically pair students with the trainings they need after setting the appropriate parameters and conditions once – thus, its primarily role is not supporting the transfer of knowledge, but the facilitation of administrative work in the background.
Artificial Intelligence	Equipping the e-learning system with artificial intelligence opens up another dimension compared to the above two. These systems are the so called LXPs – Learning Experience Platforms. The emergence of machine learning and artificial intelligence can be found in many areas of digitization – consider, for example, the automatic recommendations of various video sharing or streaming portals that suggests new contents based on our habits and history of content consumption. This operating principle and user need have been incorporated into LXP systems, where the platform offers users additional e-learning content based on previous learning habits, continuously building a student competency map in the background that reflects students' personal professional profiles and interests. In addition, these systems also have functions known from social media, thereby increasing student interactions. A good example of an LXP system is LinkedIn's e-learning program, developed in collaboration with Lynda.com.

When selecting e-learning systems, in addition to their functions, their customizability and adaptability is also an important aspect, and when examining them we have to ask the following key question: is the range of personas who can change the workings of the given e-learning system (at a coding level) limited? If the answer is yes, then we are talking about closed source systems, and if not, that is, anyone can modify it, then we are talking about open source systems. (Krishnamurthy & O'Connor, 2013)

A good example of the former is a range of applications integrated into enterprise management systems (such as the German-developed SAP SuccessFactors or Oracle's iLearning system). Among the latter, open source systems include applications whose development usually began with some small community initiative and then built themselves into world-class e-learning systems based on successes in widespread application (such as Moodle or Ilias).

3.5 Comparison with the traditional (classroom) form of education

In the previous subsections, I examined the possible definitions of e-learning and its approaches, the closely related concepts and forms of education, and then explained in detail the three components that make up the e-learning ecosystem: personas, content and system.

Now that an interpretable picture of e-learning has been outlined and clarified, the next step is to examine what typical differences can be observed between the traditional and the e-learning form of learning. Based on my own personal experiences and related research, I have collected the following nine aspects that differentiate e-learning from classroom trainings.

- **Flexible in time:** in traditional classroom training, students are "forced" into a certain timeslot, usually of a specified regularity, when knowledge transfer takes place. Due to one's nature and everyday routine and habits, people are opened to absorb new knowledge at different times of the day, which e-learning satisfies perfectly with its time flexibility. Students learn when it suits them best. (Korucu & Alkan, 2011)
    - **Can be viewed several times:** perhaps one of the biggest disadvantages of classroom education is that all students (sometimes up to hundreds) have to pick up and adapt to the pace of the instructor. This is especially difficult when you consider that everyone starts to absorb the new knowledge with different qualifications and base knowledge. In addition, all

this, coupled with a fixed schedule, provides a rather narrow framework for repetition, for explaining heavier content multiple times. Content in e-learning, on the other hand, can be consumed at a comfortable speed by anyone at their own discretion, and you can watch it over and over again and test your knowledge continuously.

    - **Individual learning pace:** another direct consequence of time flexibility is that individual students do not have to learn the given knowledge in the same amount of time. Some are able to pay attention for 120 minutes, while some are able to process new information most efficiently in much shorter, 20-minute stages (see microlearning). However, thanks to the modular structure of e-learning, everyone can learn at a pace that is ideal for them and does not have to adapt to other students or the tutor.

- **Flexible in location:** one of the key elements of effective learning is a relaxed environment. An oxygen-deficient lecture hall crowded with hundreds of people with poor lighting and continuous background noise can greatly impair students' ability to concentrate. In the case of e-learning, thanks to mobile devices, the student can choose the place of learning, be it in a public space, in a green environment, on a monotonously rushing train while traveling, or in the children's room. (Yigit et al., 2014)

- **To ask or not to ask:** the personal presence of the tutor allows students to ask questions immediately during a face-to-face training, so that they can quickly clarify unclear content elements, thus speeding up the learning process. In e-learning, this is typically only possible in an asynchronous way, which can hinder the learners' progress. E-learning materials, on the other hand, have the ability to sustain the students' attention through interactions that help them progress in learning. This kind of interaction can be able to compensate for the ask-and-answer opportunity provided by the classroom trainings.

- **Much more tutor independent:** the tutor's personal and presentation style can be decisive in how he or she manages to pass on knowledge to students. In a classroom, the student usually has no choice and must accept the tutor in terms of both his or her appearance and presentation style. (Chau & Cheng, 2010) However, in the case of e-learning, content can be created independently from any tutor, which in turn can appear as an advantage as well as a disadvantage: a tutor who teaches in an engaging style in the classroom can be as motivating as an inexperienced lecturer can make learning difficult. This can be easily - albeit costly - eliminated when using an e-learning form of education, for example, by providing a curriculum in multiple styles and students studying from the version that is most desirable to them.

- **Possibility of a unique learning path:** in the case of traditional education, there might be students who are already half-familiar with the material, thus half of the information provided isn't new to them and it is unnecessary repetition, but they are forced to adapt to other students with lower qualifications in the classroom. Through e-learning, on the other hand, students are given the opportunity to select the content elements they want to become familiar with and to test and validate their previously acquired knowledge in the form of continuous self-checks and feedback. Thanks to technological advancements, it is even conceivable that the system itself offers possible learning paths through artificial intelligence (see LXP systems). (Lu, 2004)

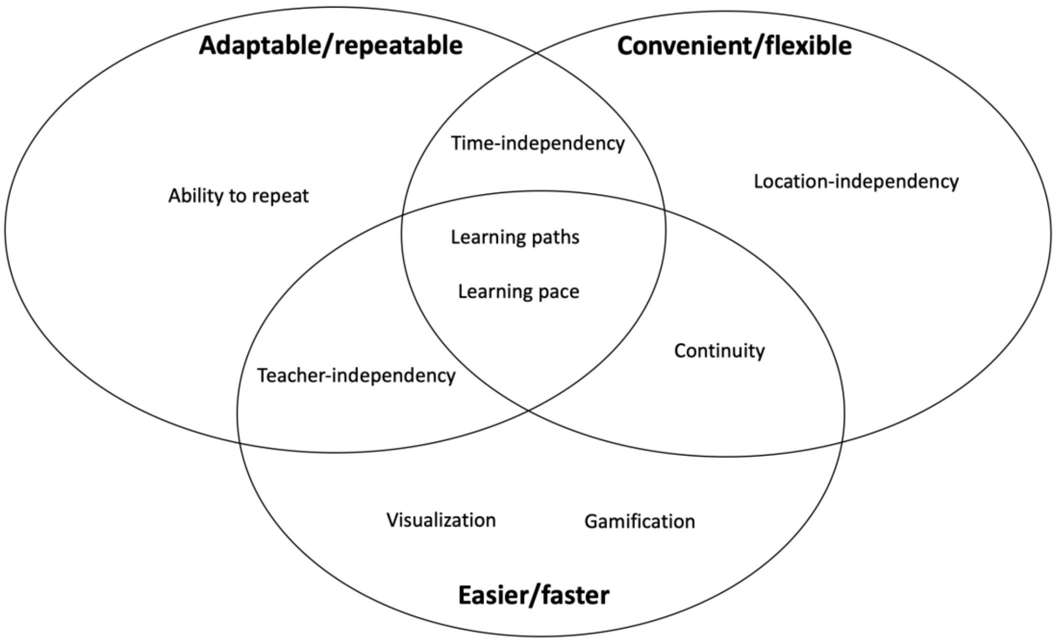
- **Visualization:** one of the most effective tools for learning is visual presence. While presentations for classroom trainings are mostly for the instructor's guidance and do not help the student's understanding, all visual (or even audio) elements in e-learning are used for faster knowledge processing. In the case of e-learning materials full of videos, animations and illustrations, the varied content enables much faster comprehension.

- **Gamification:** regardless of age groups, people have kind of a competitive spirit, which can be used as a motivating factor in learning.

> Within the classroom, this is only possible to a very limited extent (due to the absence of time, for example) by solving smaller tasks and assigning good marks, but e-learning can provide a much more varied toolbox in the field of gamification. We can compete with other students or with a fictitious opponent, but we can also have the opportunity to conquer ourselves, which not only motivates us to learn as quickly as possible, but it can further deepen the acquired knowledge. (Muntean, 2011)

To make the complexity of the distinctive features of e-learning more transparent, it is worth grouping them into three overlapping dimensions: some distinctive features of e-learning satisfy the adaptability and repeatability factors; other features are best described as convenient and flexible; while some are categorized by making learning easier and faster. In addition to this grouping in accordance with my own research, it is worth mentioning a different approach to systematization, for example the categories by Nesterowicz et al. (2016), that are easy accessibility; flexibility; and time and cost / investment proportional benefits.

9. figure: Grouping the distinctive features of e-learning based on Duma & Nagy (2018)



The criteria above perfectly reflect the differences between traditional classroom education and e-learning. In short, in classroom trainings, students must acquire new knowledge under many constrained circumstances, and there is certain emphasis on the person of the tutor. In contrast, e-learning gives the student the freedom to learn in the place, time, pace, and style that is comfortable for him or her, and the tutor's personality (which can subjectively affect learning efficiency in both directions) is not necessarily directly reflected in e-learning materials.

However, practical observations may differ from this in some cases. It is therefore important to actually examine and observe the fulfillment of the above from the perspective of the students as well: it is a fact that you can start, stop and continue an e-learning course at any time, but the question is how this affects your learning habits, how it fits into your rhythm of life compared to the previously fixed schedule. It is possible that the learning process will be slower as if an external regulatory force determines the pace, and thus learning will be less effective overall. Another interesting question is whether this freedom adds more value to the student (if it does at all, see the dilemma posed among further potential research questions), than as much damage the non-existence of the physical presence of the instructor, the possibility of immediate questioning, and the toolbox for discussion with fellow students causes.

3.6 Further conceptual connections

In addition to the narrower interpretations of e-learning, I consider it important to mention some other concepts that are directly or indirectly related to the e-learning ecosystem.

4. table: Additional definitions related to e-learning (own creation)

Gamification	Gamification in a broader sense means the use of game dynamics, game psychology, and game mechanics in typically non-playful environments. (Deterding et al., 2011) In the field of e-learning, gamification is an educational methodological tool that effectively helps students through the learning process with the help of playful tools. (Kiesler et al., 2011)

Web Based Training	A rather broadly defined concept is web-based teaching, which includes all forms of education that use web technology. (Horton, 2000)
Computer Based Training	A very similar, almost hand in hand concept to web-based teaching – computer-assisted learning is broader in the sense, that it does not necessarily require the use of web technologies. Here, the emphasis is on making the computer the primary channel for knowledge transfer. (Alexander et al., 2005)
Self-paced Learning	Self-paced learning is essentially an important component and feature of e-learning, according to which the curriculum is able to adapt to the student's own pace of learning during the learning process. (Jiang et al., 2015)
Life Long Learning	The concept of lifelong learning became popular in the 2010s, describing a social situation where learning is a resource that is continuously available and provided for all. (Fischer, 2001) In this spirit, education and knowledge should not be seen as just an activity available between the four walls of the classroom, but as an opportunity that can be accessed at home, at work, or even while playing. (Klamma et al., 2007)
MOOC – Massive Open Online Courses	Massive open online courses are a grateful concept, and we can easily deduce its content from its name. These cover online trainings that are accessible (open) to anyone, and they offer a wide range of services that can be carried out simultaneously by the masses. (Kennedy, 2014) In the beginning typically universities made their courses available this way, as a means of promoting their educational activities.

By the end of this chapter, the reader could get a complete picture of the definition of e-learning and its approaches, and I have defined my own definition of e-learning along these experiences. I then broke down e-learning into its components, characteristics and challenges, compared it with the characteristics of traditional education, and also presented additional concepts that are in some way related to the e-learning ecosystem.

4 DEVELOPING AN E-LEARNING MEASUREMENT METHODOLOGY

After a comprehensive review and understanding of the e-learning learning format, I will focus on developing the first measurement methodology, which will focus on the efficiency and effectiveness of knowledge transfer. In this chapter, as a first step, I will define the characteristics of good metrics, which will serve as the basis of the development of the measurement methods later on.

Following this I will develop measurement methods from two approaches:

1. **Knowledge transfer-centric efficiency study:** from which I will define a mathematical-statistical measurement method that, on the basis of IT data obtained from e-learning courses, can determine on its own (without comparison to other courses) the effectiveness of an already completed e-learning course in relation to the process of knowledge transfer.

2. **Result-based effectiveness study:** Due to the occasionally difficult nature of data collection required for the method above, I also offer a simpler solution, which examines the success and effectiveness instead of the efficiency of knowledge transfer. The method compares the students' prior knowledge level with their knowledge level at the end of the course, including their activity measured in the e-learning course as an additional variable, thus, in addition to the to be decided question of effectiveness, it shows a cause and effect relationship, i.e. it highlights whether the success of knowledge transfer was due to e-learning or not.

4.1 Characteristics of good metrics

Defining metrics isn’t easy: even on simple issues like a car’s fuel consumption, we can easily run into contradictions. Some countries look at the distance that can be covered with 1 gallon of fuel, other countries look at the amount of fuel burned per 100 kilometers. The two metrics work by a completely opposite logic: in the case of the former, a higher number means a more positive result (regarding economical operation), in the latter we aim for the smallest number possible. (Larrick & Soll, 2008)

In order to develop a suitable measurement method, it is first necessary to define the characteristics and properties of a good measurement system. For this, I have compiled the seven critical principles that have become well-known in the financial world (Jonas & Blanchet, 2000) and, as far as possible, have interpreted them in general to the environment of the education system.

5. table: Requirements for a good measurement system accepted in the financial world as interpreted for education (own creation)

Relevance	Suitability for decision making. (Obaidat, 2007) We should be able to draw conclusions from the measurement system as to whether the education was successful or effective, and this can provide a basis for further decisions (e.g., remuneration, retaliation).
Reliability	Free from errors and misstatements. (Obaidat, 2007) That is, the measurement should not be subjective or questionable.
Representative faithfulness	It must show a real relationship between the phenomenon to be measured and the measured result, so the method must actually measure what we want to measure. (Barua, 2005)
Verifiability	Independent measurements should give the same consensus value and result, i.e., for example, the identity of the person performing the measurement should be irrelevant. (Beest, Braam & Boelens, 2009)
Neutrality	The data to be measured should not be (subjectively) selected to the benefit of someone. (Jonas & Blanchet, 2000) For example, in a tutor evaluation, consider more than just positive feedback.

Comparability	Comparability with measurements made either over time or on other data. (Cole, Branson & Breesch, 2007) This can be interpreted, for example, as a comparison with other courses or with several groups of students in the same course.
Consistency	It means the invariance and temporal stability of the measurement system. (Obaidat, 2007) This does not preclude the use of several measurement systems if there is interoperability between them.
Understandability	Easy interpretation of the final result, and its suitability for further work, of course with some (even minimal) background knowledge. (Iu & Clowes, 2004) With regard to education (e.g. unlike in accounting), there is no special expertise that could hinder the comprehensibility of these measurements.

In addition to the above, it is worth formulating additional criteria that take into account not only the person performing the measurement, but also the personas who participated in the implementation of the subject of the measurement (i.e. in this case the development of the e-learning curriculum). In this, for example, Seang's (2003) study of KPIs can provide guidance.

- **Communicability:** somewhat overlaps with the above "understandability" criterion, but this is more of an easy interpretation for those who are not familiar with the subject matter;

- **Motivation:** the results of the measurement should be suitable for motivation and improvement of the subject of the measurement;

- **Resource optimization:** the measurement should highlight the points where it is worth improving in proportion to resources;

- **Planning, controlling, evaluation system support:** that is, that the method of measurement is also suitable for the personal assessment of the person making the measurement.

Specifically, for education, according to Tyler (2010), four main criteria must be met when determining the measurement system set up. I wish to note that the system of criteria below is primarily tutor-centered, i.e. it does not primarily consider knowledge transfer, but the tutor as the subject of a potential measurement system:

- **Generalization:** the course (tutor) should be measured not once, but several times, on the basis of which general conclusions can be drawn.

- **Evaluation:** metrics and indicators should be timely and consistent so that education and tutors can be compared objectively, both in space and time, regardless of the educational topic.

- **Extrapolation:** it is important that there is a correlation between the metrics and the effectiveness of the education, i.e. it is necessary to make sure that good student results and performance are really due to the teaching method and the tutor.

- **Implication:** that we use the developed methodology as an appropriate tool, be it to set up rankings between institutions or even to compare people (tutors).

It is perhaps an overly ambitious goal wanting to set up a measurement system that perfectly meets all the criteria listed above – however, when developing a measurement system, it is important that these aspects are kept in mind and we strive to meet them as closely as possible.

4.2 Knowledge transfer-centric measurement methodology

During the development of the knowledge transfer-centric measurement methodology, I will rely heavily on our joint research with dr. László Duma, the supervisor of my doctoral studies. (Duma & Nagy, 2018)

As the very first step in developing my measurement method, it is important I determine exactly what kind of efficiency I want to measure – since, in everyday life, the concepts of efficiency and effectiveness are often confused. In management sciences, the difference between the two has already been discussed, but at the moment I consider it important to clarify the difference between the two concepts in terms of education based on Nelson (2018) and Vilaseca & Castillo (2008).

- **Efficiency[2]:** we call something efficient if it minimizes losses. A good example is the previously mentioned fuel consumption (the less it consumes, the more efficient it is) or the thermal insulation of a window (the less heat it transmits, the more efficient it is).

  From another approach, efficiency answers the “how” question. By working efficiently, we do things right.

- **Effectiveness[3]:** we call something effective if it produces some (not necessarily tangible) result. For example, a political speech (resulting in a “convinced” crowd) may be effective, or a medicine (resulting in a healed patient) may be effective

  From another approach, effectiveness does not address the “how”, it only examines the existence of the result achieved. By working effectively, we do the right thing.

Interpreted in the field of education, effectiveness means the result of the knowledge transfer, while efficiency means the ratio of the result achieved and the investment. In other words, education is effective if the student has acquired the necessary knowledge; education is efficient if the student has acquired the necessary knowledge without wasting resources. For example, if he or she learned more during a unit of time, or memorized a unit of learning in less time, or for a longer period of time.

The question of the effectiveness of the e-learning form of education arises when we have to choose between the attendance form and the e-learning form of education. Overall, the interesting question is whether the form of e-learning education is more efficient than the attendance form of education (can it be achieved with less

[2] Efficient: performing or functioning in the best possible manner with the least waste of time and effort.
[3] Effective: adequate to accomplish a purpose; producing the intended or expected result.

loss) – however, it is necessary to set up a metric that can determine this without a control group on its own from an e-learning training, as a “ceteris paribus” control group can never be created with which a real comparison could be made. This would require examining exactly the same students, starting from exactly the same zero state, where they do not yet have the necessary knowledge. However, this is practically impossible without time travel or memory erasure.

4.2.1 Possible efficiency measurement systems

The efficiency and success of e-learning implementations can be examined from several perspectives, from several theoretical approaches. In the following table I have systematized the potentially relevant measurement systems based on Bhuasiri et al. (2012), supplemented with the work of other authors.

6. table: Potential measurement tools for e-learning implementations based on Bhuasiri et al. (2012) (own creation)

Measurement system	Theoretical background, characteristics
CSF – Critical Success Factors	A seemingly relatively trivial method of measuring the success of e-learning implementations against a pre-set, weighted system of criteria. This measurement system works in such a way that it analyzes the case in comparison with the pre-defined minimum criteria, classifying the e-learning implementation on this basis. The criteria system can be grouped and structured along different categories, where the technological, tutor and student aspect can also appear (Volery & Lord, 2000), or even higher-level aspects such as organizational support. (Selim, 2007) This method was also used by Monda (2014) for the e-learning adaptation used in the Hungarian public administration, during which the author mainly examined the curriculum development aspect, but did not analyze the efficiency of knowledge transfer.

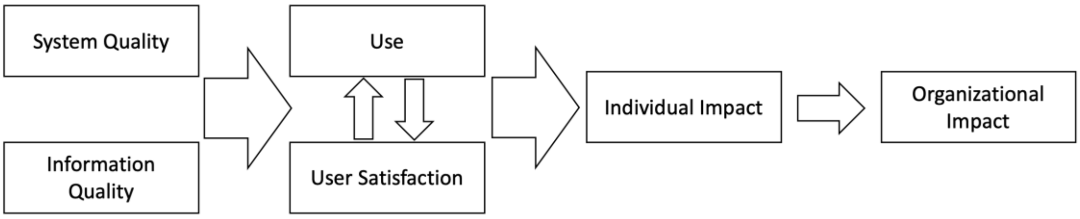
SCT – Social Cognitive Theory	The advantage of the social cognitive theory is that it presents a human-centered measurement system instead of a technology-based one. Here so-called “self-efficiency” and output expectations are in the focus of the analysis and measurement. The claim of the developers of the measurement is that these two can together characterize the willingness of users to use new technologies. (Gong, Xu & Yu, 2004)
MT – Motivation Theory	Another human-centric approach is the measurement method called motivational theory, that shows some similarities with the social cognitive theory. It divides motivation into two main categories: internal (curiosity, self-satisfaction) and external (goal-oriented, result-oriented). (Meyer & Gagne, 2008) As e-learning solutions are in themselves divisive among those who are not familiar with the subject, it seems a practical solution to examine the motivation of the participants already detailed (not only students, but also tutors, training organizers, management, etc.), as this can play a central role in success.
ISSM – Information System Success Model	This model is much more comprehensive and can be applied more widely than examining the adaptation of e-learning solutions – the model of the success of information systems can be used to analyze any IT tool. On the other hand, this is why it is not really suitable for the study of knowledge transfer, as the primary aspects of this method include user satisfaction and willingness to use the system, the quality of the system, the information (data, content) and the service, and net return. (Delone & McLean, 2003) The model can be applied for example to the e-learning framework itself, but not to knowledge transfer and learning.

TAM – Technology Acceptance Model	The fifth and final analytical tool is the technology acceptance model, which is also a very IT and technological approach, so it is also unsuitable for measuring the efficiency of knowledge transfer. The original version of the model starts from two dimensions: from the perceived usefulness of the technology and the perceived ease of use (Hsu & Lin, 2008). The model was later developed by several people, resulting in TAM2 (Venkatesh & Davis, 2000) and TAM3 for example. (Venkatesh & Bala, 2008)

The measurement systems above measure the success of e-learning implementations as such and do not serve as a comparison to classroom trainings. This approach is also fundamentally in line with my goal of making courses self-evaluable and measurable, without the need for comparison with other courses. However, none of the measurement solutions focuses on the efficiency of knowledge transfer, they are much simpler methods, focusing especially on the IT aspect on subjective scales. It is also worth mentioning the research of Holsapple & Lee-Post (2006), who specifically approaches the success of e-learning implementations from an IT point of view, with a logic similar to the methods above.

With regard to IT systems, DeLone & McLean (1992) already points out in general that it is worth observing and examining not only the impact on individuals, but also the impact on the organization. This logical idea, which can be independent in itself, can be transposed to the measurement of knowledge transfer, but in the present dissertation I will focus only on measurements related to the individual.

10. figure: Model of information system implementation success by DeLone & McLean (1992)



4.2.2 The current measurement system of education and its critique

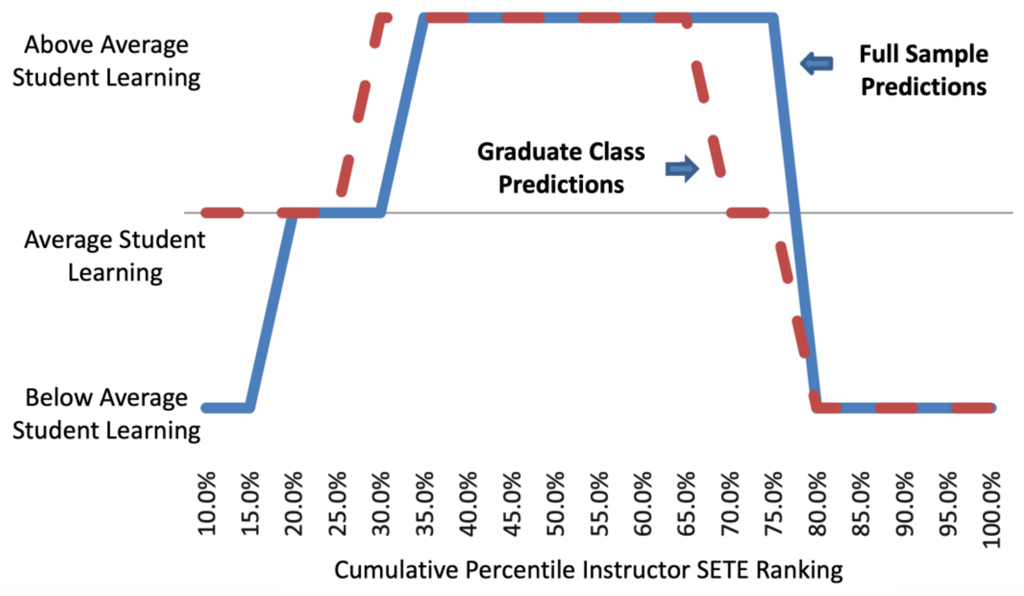
In this chapter, I will present the currently most commonly used assessment methods specifically for the field of education, and also mention the related literary critiques, as well as formulating critique of my own.

4.2.2.1 Student evaluation (SETE)

One of the most popular methods of measuring the effectiveness of teaching is student evaluation (SETE: student evaluation of teaching effectiveness). In a study by Galbraith, Merrill & Kline (2012), we see a contradictory example that the students' results are not linearly related to the tutors' evaluation – the authors support this claim with several different mathematical methods.

Students with the best results rate tutors along a moderate scale, while students with poor results favor the extremes: either the tutor is given a particularly good or a particularly bad score (illustrated in the figure below). When examining the SETE method, the authors also point out that new teaching methods, such as online e-learning courses and hybrid courses have emerged, which necessitate a revision of the SETE method. (Galbraith, Merrill & Kline, 2012)

11. figure: Analysis by Galbraith, Merrill & Kline (2012) of the relationships between students' results and tutors' evaluation



Emery, Kramer & Tian (2003) also formulate critique of the SETE method, relying on the following grouping:

- **Popularity and personality contests:** evaluations given to tutors often represent a measure of the popularity of the tutor rather than the effectiveness of the actual course. Students' subjective assessments are also influenced by simple things such as whether the instructor brings food (e.g. chocolate) for his / her students in class.

- **Student achievement:** although students' results are perhaps the clearest and most direct feedback on a tutors' effectiveness, studies supported by the examples presented above show the opposite, i.e. the tutors' ratings reflect the students' results only to a minimal extent.

- **Situational factors and validity:** there are connections between the courses and the assessments associated with them. For example, the authors compare human and real subjects with each other, and there is a generalizable difference between compulsory and optional subjects too.

- **User error:** misinterpretation of the results from SETE or their evaluation with a bad statistical method can also lead to serious problems. Given the generally small size of the samples (courses with less than 30 students), the potential for purely statistical errors is also much higher.

- **Rater qualification error and defamation:** the last aspect criticizes the students themselves. In general, students are stigmatized for not being able to think critically. Assessors do not undergo any pre-screening that validates them to assess tutors, so in extreme cases, even cases of intentional defamation may occur.

4.2.2.2 Student satisfaction

However, other authors examine student satisfaction and shed light on the fact that student satisfaction is strongly correlated with acquired knowledge. (Eom, Wen & Ashill, 2006) Ten years later, the same authors revealed, with some refinement of the model, additional explanatory factors for student satisfaction, such as course design, and the nature of tutors and dialogues. (Eom & Ashill, 2016)

The role of student satisfaction as a determinant is also well illustrated by an analysis of a large empirical sample. This emphasizes the importance of individual learning characteristics, from which we can conclude, that if we filter them out, the learning experience itself will ultimately show similarities for everyone. (Li, Marsh & Rienties, 2016). This finding is also in line with the findings of Creemers & Kyriakides (2006), cited later, that **filtering out the (socio-economic) background of the students, the dispersion observed in the learning outcomes disappears**.

4.2.2.3 Student performance

Thus, the current methodology for measuring the effectiveness of education is not found to be satisfactory by Creemers & Kyriakides (2006). They point to similar results from two studies written independently: Coleman et al. (1966) and Jencks et al. (1972) both filter out the background conditions of the students in the examined sample (individual abilities, family circumstances, socio-economic characteristics), as a result of which the variance of educational factors remained very low. Therefore, different tutors and teaching methods are almost equally effective for students from similar backgrounds. Heyneman (2005) also concludes that the socioeconomic status of students basically determines their performance.

Woessmann (2004) also points out that in developed countries such as the United States or Western Europe, students' family backgrounds have a large impact on their performance. Hanushek & Luque (2002) examines how student performance is related to the extent to which "resources" are used, but draws the conclusion from a comparison of developed and developing countries that these problems are independent of the level of resources available.

It is also worth exploring the Tennessee Value-Added Assessment System (TVAAS), which is designed to measure the effectiveness of education while filtering out the socio-economic situation. Ballou, Sanders & Wright (2004), among others, are also experimenting with modifying this rating system.

4.2.2.4 Proposal for further development

In addition to critical remarks, authors seek to formulate principles and suggestions for improving current methods. Berk (2012), for example, makes twelve suggestions for measuring the efficiency of education – more precisely, he names twelve possible sources from which we can obtain evidence (information, input) for the evaluation of tutors (and, as a result, unfortunately still not for knowledge transfer).

7. table: Summary of Berk's (2012) suggestions

#	Source of Evidence	Type of Measure(s)	Who Provides Evidence	Who Uses Evidence
1	Student Ratings	Rating Scale	Students	Instructors / Administrators
2	Peer Ratings	Rating Scale	Peers	Instructors
3	Self-Evaluation	Rating Scale	Instructors	Instructors / Administrators
4	Videos	Rating Scale	Instructors / Peers	Instructors / Peers
5	Student Interviews	Questionnaires	Students	Instructors / Administrators
6	Alumni Ratings	Rating Scale	Graduates	Instructors / Administrators

7	Employer Ratings	Rating Scale	Graduate's Employers	Instructors / Administrators
8	Administrator Ratings	Rating Scale	Administrators	Administrators
9	Teaching Scholarship	Judgmental Review	Instructors	Administrators
10	Teaching Awards	Judgmental Review	Instructors	Faculty Committees / Administrators
11	Learning Outcomes	Tests, Projects, Simulations	Students	Instructors / Curriculum Committees
12	Teaching Portfolio	Most of the above	Instructors, Students, Peers	Promotion Committees

Although Berk's suggestions go well beyond the SETE or student achievement-based approaches presented earlier (out if the 12 aspects, these represent only two), his approach is still too tutor-oriented rather than education and knowledge transfer oriented, so in my opinion it can also be applied to e-learning to only a limited extent. However, points 1, 6 and 11 might be able to play a role in measuring knowledge transfer through e-learning.

4.2.2.5 Criticism

Overall, a significant body of literature criticizes current the measurement methods designed to metricize traditional education. In the table below, I have summarized and categorized the relevant researches found in professional literature, with their critiques, suggestions, and the criteria formulated by them.

8. table: The main aspects of the current educational measurement system and its errors, formulated by professional literature (own creation)

Criticisms of student assessment (SETE)	Emery, C. R., Kramer, T. R., & Tian, R. G. (2003). Return to academic standards: A critique of student evaluations of teaching efficiency. *Quality Assurance in Education, 11*(1), 37-46. Berk, R. A. (2005). Survey of 12 strategies to measure teaching efficiency. *International Journal of Teaching and Learning in Higher Education, 17*(1), 48-62.

	Galbraith, C. S., Merrill, G. B., & Kline, D. M. (2012). Are student evaluations of teaching efficiency valid for measuring student learning outcomes in business related classes? A neural network and Bayesian analysis. *Research in Higher Education, 53*(3), 353-374.
Literature on the impact of student satisfaction	Creemers, B. P., & Kyriakides, L. (2006). Critical analysis of the current approaches to modelling educational efficiency: The importance of establishing a dynamic model. *School Efficiency and School Improvement, 17*(3), 347-366. Eom, S. B., Wen, H. J., & Ashill, N. (2006). The determinants of students' perceived learning outcomes and satisfaction in university online education: An empirical investigation. *Decision Sciences Journal of Innovative Education*, *4*(2), 215-235. Eom, S. B., & Ashill, N. (2016). The determinants of students' perceived learning outcomes and satisfaction in university online education: An update. *Decision Sciences Journal of Innovative Education*, *14*(2), 185-215. Li, N., Marsh, V., & Rienties, B. (2016). Modelling and managing learner satisfaction: Use of learner feedback to enhance blended and online learning experience. *Decision Sciences Journal of Innovative Education*, *14*(2), 216-242.
Studies that attribute great influence to the (economic-social) background of students	Coleman, J. S., Campbell, E., Hobson, C., McParttland, J., Mood, A., Weinfield, F., & York, R. (1966). *Equality of Educational Opportunity*. Washington, DC: US Government Printing Office. Jencks, C., Smith, M.S., Ackland, H., Bane, M.J., Cohen, D., Grintlis, H., Heynes, B. & Michelson, S. (1972). *Inequality*. New York: Basic Books. Hanushek, E. A., & Luque, J. A. (2003). Efficiency and equity in schools around the world. *Economics of education Review*, *22*(5), 481-502. Ballou, D., Sanders, W., & Wright, P. (2004). Controlling for student background in value-added assessment of teachers. *Journal of educational and behavioral statistics, 29*(1), 37-65.

	Woessmann, L. (2004). How equal are educational opportunities. *Family background and student achievement in Europe and the United States*. Heyneman, S. P. (2005). Student background and student achievement: What is the right question? *American Journal of Education, 112*(1), 1-9. Creemers, B. P., & Kyriakides, L. (2006). Critical analysis of the current approaches to modelling educational efficiency: The importance of establishing a dynamic model. *School Efficiency and School Improvement, 17*(3), 347-366.
Authors making suggestions for further development	Ballou, D., Sanders, W., & Wright, P. (2004). Controlling for student background in value-added assessment of teachers. *Journal of educational and behavioral statistics, 29*(1), 37-65. Berk, R. A. (2005). Survey of 12 strategies to measure teaching efficiency. *International Journal of Teaching and Learning in Higher Education, 17*(1), 48-62.

Thus, it can be stated that the primary metrics of traditional education and knowledge transfer are evaluated through the tutor, and even with suggestions made for their further development, they are not suitable for measuring the efficiency of knowledge transfer in e-learning. Moreover, in my opinion, the above metrics do not meet the previously defined good measurement metric standards in certain respects either – mentioning as an example the requirements for neutrality, extrapolation and implication.

There is no doubt that students' learning results, in other words the acquired competence, should be the decisive assessment criterion, but this does not always give representative answers, based on our research (Duma & Nagy, 2018) due to the following factors:

- Exams and other grades do not generally correlate with actual knowledge.
- We do not have the opportunity or it is too resource and cost demanding to actually measure knowledge and competence during or after the

educational process, i.e. not through final exams and artificial examinations, but by analyzing behavior put into practice.

- The abilities of each student and their pre-course knowledge levels are only roughly or not known at all.
- The characteristics of the educational process (person of the tutor, intensity of the course, methods used, etc.) cannot necessarily be identified and assigned to the person being measured.
- Performance may depend to a large extent on the student's current personal circumstances (state of mind, mood, etc.), which could only be screened through several measurements (subjectively), but the possibilities and capacities for this are also limited.

The somewhat contrary relationship between the "goodness" of the tutor and the students' results, previously indicated in the article by Galbraith, Merrill & Kline (2012), also justifies that knowledge transfer is worth measuring and should be measured even if it is measured through the tutor's performance.

Based on the above, I consider it **necessary** to set up a **new metric system**, which focuses on **knowledge transfer**, and which makes it easy to **evaluate e-learning materials** and courses of different styles, content and topics **on their own**, **without comparison** to others.

4.2.3 Measurement characteristics of education

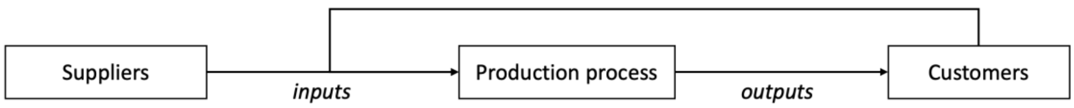
In order to develop a well-fitted method for measuring the efficiency of knowledge transfer (initially ignoring whether we are talking about traditional or e-learning education), we must first examine what the measurement characteristics of education are.

4.2.3.1 Education as a service

First of all, it is important to note that education is a kind of service, so the Unified Services Theory (UST) can be applied to it. (Sampson & Froehle, 2006) The UST is a model that incorporates user feedback (as outputs) into production process inputs. According to Sampson (2001), education can also be classified under the UST flag.

UST refers to the mind of the consumer as a source of input that represents a defining element of the service of education. Thus, using this model as a starting point, a framework for measuring the efficiency of knowledge transfer can be determined, since the goodness of the process and the service cannot be separated.

12. figure: UST model based on Sampson (2001)



In addition to the UST, due to the service nature of education, the specificities of services (the four characteristics) can be identified according to the marketing concept based on the so-called HIPI principle. Later on, I will also show how most of the following principles will fail in e-learning.

- **Heterogeneity:** the quality of the service varies as the performance of the service provider varies depending on where and when it is used. Many elements of the service are provided by people whose performance and quality of work will fluctuate despite the highest standards and controls. Although this kind of imbalance in the quality of service can be reduced to some extent, fluctuations depending on the person providing the service, the space and the time cannot be completely eliminated.

- **Intangibility:** in contrast to physical products, services are not a perceptible, tangible product of experience, as it is not objective, in order to familiarize with it, the customer must experience the use of the service.

- **Perishability:** service only exists when it is used. Neither the supplier nor the user can make up for its omission, unlike physical products, the fluctuation and seasonality of demand simply cannot be compensated for, the unused service capacity deteriorates, is goes to waste, it cannot be “moved” immediately.

- **Inseparability:** the provision and use of the service (production and consumption) cannot be separated in time because their origin coincides with their consumption.

4.2.3.2 What changes in e-learning?

Thanks to technology, the digitized nature of e-learning makes it possible to measure and analyze a wide range of data during the learning process, fully automated, without subjectivity and human error – and this satisfies several of our requirements for measurement systems.

Another important benefit of the new measurement system is that with these measurements we can easily fine-tune or even completely rethink the e-learning educational material, for which there are only much more limited options in traditional classroom courses due to the lack of easily collectible and analyzable feedback present there that can be gathered with little energy.

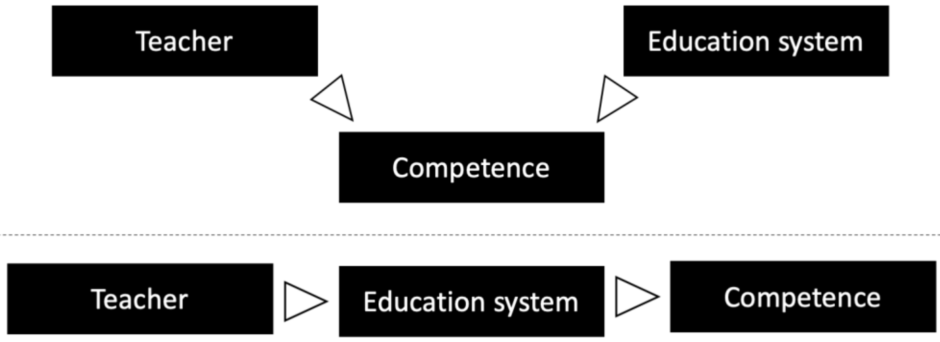
The primary measures of traditional education were either the results achieved by the student (the grade obtained) or the assessment of the tutor, but the latter is not feasible in the case of e-learning for obvious reasons (see the subsection on differences compared to traditional education) – for this reason alone, different metrics need to be developed for the e-learning form of education.

In e-learning systems, based on what has already been discussed, the person of the tutor is less important by nature. The personality and knowledge transfer technique of the tutor is still not negligible in the production, editing and presentation of the content, but the selection and involvement of the tutor is less prominent due to the system of recording and displaying the content.

In the case of the traditional form of education, knowledge transfer is directly influenced by two things: the tutor and the course system. The former transfers knowledge directly to the students, while the latter determines when, where, under what conditions knowledge is transferred.

In contrast, in the case of a purely e-learning form of education, the student does not come into direct contact with the tutor, as the tutor primarily participates in the professional development of the content. Therefore, the structure of competence building in the form of e-learning changes, in which the indirect role of the tutor is well illustrated in the following figure – and this change also affects the measurement system, as the teacher evaluation (SETE) is thus essentially removed from the measurement tool set.

13. figure: Changes in the role of the tutor in the e-learning ecosystem based on Duma & Nagy (2018)



The applicability of the HIPI principle mentioned in the previous subsection also changes greatly due to the specifics of the e-learning form of education, which makes the form of e-learning easier to evaluate. For example, the problem of heterogeneity is solved, as we are talking about fixed content, it does not change per consumer (per student). According to the UST theory, the goodness of the process and the goodness of the service cannot be separated (i.e. the quality is one-time and unchangeable), but this does not apply in the case of e-learning, because e-learning technology makes education repetitive and repeatable. E-learning also provides an answer to the problem of perishability.

However, within the framework of the previously mentioned UST, in addition to the summary word “mind” formulated by Sampson (2001), I suggest that the inputs should be broken down into other important factors when creating an e-learning measurement system.

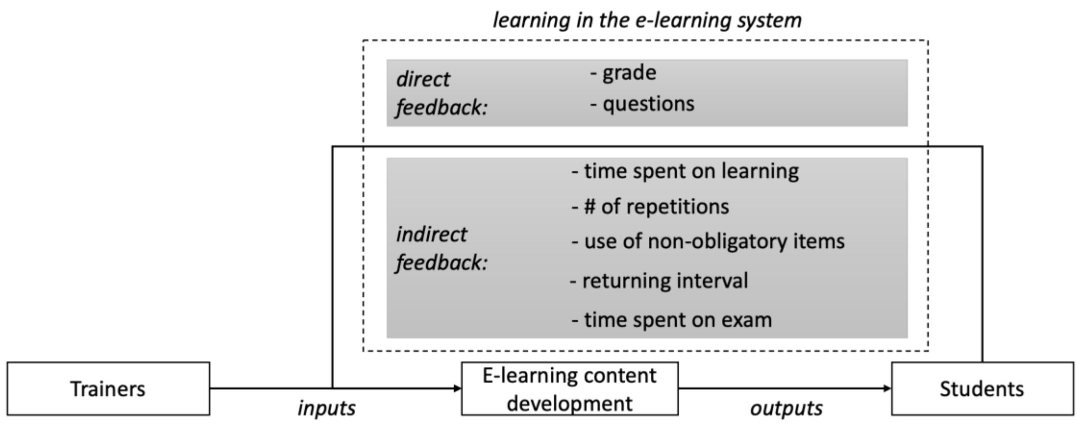
9. table: Proposition on the range of data to be included in the measurement of the education system (own creation)

Data to be measured	**Description and justification**
Mark	Points, results, etc., which remain the primary source of acquired knowledge.
Time spent in the course	A high value (differing substantially from the average) can indicate either slow comprehension or enjoyment of the course.
Average time between returning to the course	If the student only returns to the course after long intervals, we can conclude that he or she is unmotivated, that the content is unenjoyable; it is worth noting though, that it can also mean that the student purely no longer needs the content that can be acquired during the course.
Number of interruptions	In other words, how many times the student must return to the course before it is successfully completed; a high number of interruptions may indicate inadequate course fragmentation or lack of attention.
Frequency of using additional learning elements	In the subchapter discussing the content components of e-learning, additional learning elements are mentioned (e.g. glossary, case studies, reference list, etc.) that do not form the core of the professional content. The frequency of their use also characterizes their usefulness and their complementary role in learning.
Number of questions asked by students	Students also have the opportunity to ask questions through the e-learning interface, but this shows that the e-learning curriculum is not complete on its own, the knowledge transfer is not efficient enough.

Time allotted for taking the exam	It is worth treating this as a percentage (quotient) divided by the time allowed for the exam. If this ratio is high, close to 100%, then the exam is of sufficient difficulty, otherwise the sequence of tasks to be solved is proportionately easy.

In the following figure, I have summarized the place of insertion of the above elements into the UST based on Duma & Nagy (2018). Later, I will use these indicators to propose an efficiency measurement system.

14. figure: Student feedback through the e-learning interface integrated into the UST theory, based on Duma & Nagy (2018)



4.2.4 The proposed method of measuring efficiency

Comparing the required characteristics of the previously measured metric systems, the evaluation systems traditionally present in education, and the specificities and possibilities provided by e-learning, I propose to set up a specific metric system in this chapter. In approaching the evaluation of the e-learning form of education, I divided the measurement possibilities into three factors.

4.2.4.1 Narrowing the measurement aspects

From the three main measurement aspects identified in our previous research with my supervisor (Duma & Nagy, 2018), the aim of this dissertation is to develop a measurement system for the third aspect:

1. Curriculum;

2. The educational framework;

3. Transfer of knowledge.

The transfer of knowledge can be further broken down into the following sub-aspects:

1.1. Tutor evaluation

1.2. Assessment of the acquired knowledge (competence)

1.3. The course process and knowledge transfer

These three factors can't always be separated, assessment questions include examining all three factors at the same time (e.g., "was the education effective?"). Nonetheless, the separation of these is important, as we cannot measure directly beyond or without SETE, due to evaluation difficulties explained in previous chapters.

4.2.4.2 Theoretical background of the measurement method

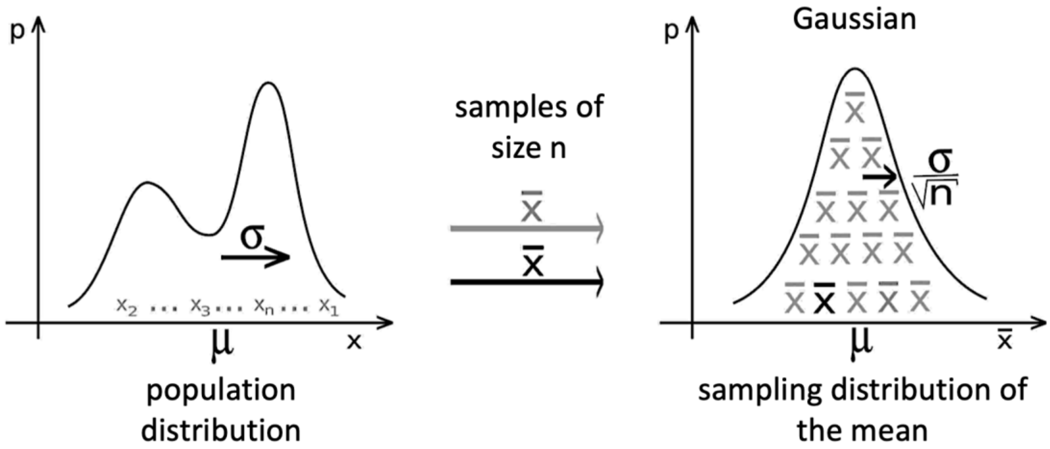
Due to the large number of courses in e-learning that can be considered homogeneous (see previously resolving the heterogeneity in e-learning along the lines of the refutation of the HIPI principle), statistical descriptive indicators can help us to draw indirect conclusions. In practice, I mainly recommend the use of different dispersion indicators, including deviation, skewness and kurtosis indicators, where we can draw conclusions about the goodness of the process through deviation revelation.

I will summarize the proposals for specific indicators in the next chapter. It is not by evaluating a course alone, but by the cumulative values of historical data generated during the repetition of the same course, that we can improve the descriptive goodness of deviation formation in relation to the base statistical population.

However, for the above, it is important to determine the nature of the distribution of the statistical population so that we get a clearer picture of the dispersion. The distribution of educational performance (effectiveness, i.e., points achieved) typically follows a normal distribution. The reason for this is that the distribution of marks is determined on one hand by the performance of the students and on the other hand by the grading system (assessment system).

Student performance (as a characteristic of countless other human factors) is normally distributed – the question is whether the evaluation system will also be normally distributed? Student performance depends on a number of independent variables, such as preparation, educational background, timing, intelligence, socio-economic background, and other specific factors that affect a student's (exam) day (relaxation, mental state, stress tolerance, hunger, etc.). Of these parameters, too, by their nature, many indicators will follow a normal distribution. Based on the central limit distribution theorem, the sum of independent random variables will always approach a normal distribution. Consequently, by supplementing student performance with an independent variable (the assessment system), we will continue to approach a normal distribution.

15. figure: Representation of the Central Limit Theorem (source: Rouaud, 2013)



Beyond all this, normal distribution is of great importance in education: grading on the bell curve has a long past and tradition – which was also met with a lot of criticism. (Bresee, 1976; Wall, 1987; Aviles, 2001; Kulick & Wright, 2008; Erickson, 2011) The essence of this method is that students should always be graded in such a way that their results approach normal distribution. That is, the majority of students receive a result close to the mean, and extreme cases become less and less common. Simply translating the analogy: the correct way to assign grades according to the theory is that the majority of the assigned grades (about 65%) are average, in addition a few (about 30%) are sufficient and good, and there are only one or two (5%) insufficient and excellent grades assigned.

Assuming that we get a normal distribution anyway, the question is why it can be used as an evaluation and measurement criterion? On one hand, the bell curve of the normal distribution will never have a perfect shape, and it is precisely this degree of imperfection, i.e. the degree of distortion, that should be examined. A good example of this is the study of Kronholz (2012), who examines the obliquity of the bell curve to the right (i.e., the improvement of results) in addition to the appropriate forms of education – he analyzes all this as an impact of the e-learning platform provided by Khan Academy, which suggests an improvement in knowledge transfer.

So basically, a perfect normal bell distribution is shown by a statistical population if it is completely random and no external interference occurs. In our case, the education (learning) is the interference itself, a deliberate act designed to give students the knowledge they need. If, after knowledge transfer, the distribution of students continues to show a bell curve, it shows that the interference was unsuccessful, i.e., the education process did not change anything. (Guskey, 2011)

Thus, the assumption of normality can be a good basis for measuring the e-learning system. The essence of my proposal is to apply this theory not only to learning outcomes (grades, points, marks) but also to other elements describing knowledge transfer. In practice, any deviation from the normal distribution correlates with the efficiency of the education system; in addition, the data to be adapted can be easily and automatically recorded and analyzed thanks to the digitized environment. I will test this in the empirical research of my dissertation (see later for more details) on the data of a university e-learning course I developed.

The fact that the process of education shows a normal distribution provides an opportunity to examine the efficiency of education. The basis of the proposal is that we can record, measure and quantify the activity of students and every moment of their participation in the course in e-learning courses. These data are separately expected to show different distributions. If any of the distributions doesn't follow a regular normal distribution (i.e., is distorted in some direction), it will indicate some kind of effect on the efficiency of knowledge transfer. So, testing and analyzing a simple normal distribution on each of these data can show the goodness of an e-learning course without having to compare it to some artificial or natural control group – in our case, the control group is the perfect normal distribution, so we study the deviation from that. It allows for further analysis if this course is repeated later and we compare the key indicators with each other by changing the content of the e-learning course somewhat in each phase.

4.2.4.3 Goodness of the measurement method

The examination of the deviation from the normal distribution satisfies the measurement requirements presented earlier, along the following logic.

10. table: Feedback of the developed measurement theory on the requirements for indicators (own creation)

Relevance	We can draw conclusions from the measurement, and arbitrary targets can be assigned to key indicators (e.g. degree of obliquity, etc.), so it is also suitable for motivational use, which can be continuously monitored and checked later.
Reliability	Data collection and measurement is digitized and automated, eliminating the risk of human error – in addition, they do not require large investments, their resource requirements are practically negligible.
Representative faithfulness	It takes into account all participants (students) of the courses, not just a subjectively or even randomly selected proportion of students.
Verifiability	Independent measurements give the same results as they follow the rules and laws of mathematics.
Neutrality	It is fulfilled due to the completeness of the data, i.e. that we take into account all students, we do not work from a sample.
Comparability	Comparability is achieved either in time or with other courses too.

Consistency	Assuming that the mathematical tool set remains unchanged, this condition is also met.
Understandability	The parameters and components of the educational process are clear and can be communicated to both students and educators, but even to lay people.

4.2.4.4 Concrete indicators

After presenting the theoretical background of the measurement method, as a last step, I will propose the specific metrics in which I see potential when performing the normality tests.

For the other two measurement aspects presented earlier (curriculum content and educational framework), I did not develop specific proposals in the framework of this dissertation, however, it is worth mentioning that this would include examining the usefulness of the curriculum as the most important concept, and measuring whether the curriculum is able to convey conceptual / procedural knowledge. Another aspect not currently discussed is the e-learning system, i.e. measuring the goodness of the support processes (administration, etc.): due to the methodological similarity, it is worth mentioning here that due to the assumption of normality, the number and proportion of individual, deviant, problematic cases related to the e-learning system can be an obvious indicator.

It is obvious and inevitable to apply SETE in the case of e-learning as well, as the student's assessments cannot be completely replaced by indirect calculations. By implication, in the form of e-learning education, SETE does not mean questions and evaluation regarding the tutor, but about the e-learning curriculum itself and the structure and goodness of the course. As I have deduced above, there is therefore a need for additional indicators in addition to SETE, which can be grouped into the following categories.

- **Indicators related to understandability** (treating this as an independent factor from the professional content of the subject):

    - Distribution and standard deviation of students' results (scores, grades, etc.);
    - Frequency of return to course elements;
    - Frequency of use of explanatory materials;
    - Number of clarifying, interpreting and explanatory questions asked by students.

- **Student satisfaction indicators** (as this is an important indicator of maintaining attention):
    - Percentage indicator of learning unit abandonment, i.e. at what percentage the first exit from the given module took place compared to the whole module;
    - Learning layout, i.e. how many times the student viewed the whole material in total;
    - Average return time per student (how many times later he / she re-entered after each exit).

- **Indicators of learnability** (both in terms of content and quantity):
    - Number of students who successfully complete the course, in proportion to a similar indicator for all courses (this indicator exceptionally requires the inclusion of additional courses);
    - Total time spent in the system while learning.

- **Indicators of goodness of tests** (availability, adequacy, evaluation):
    - Percentage distribution of correct answers to given questions;
    - Average time spent by students on answering given questions one by one;

- Representativeness of the exam questions in relation to the entire body of knowledge.

As mentioned earlier, it is worth adding SETE to the above list, i.e. to subjectively assess the process of e-learning knowledge transfer with students. However, if this assessment method is included, the question arises as to how well the students are able to separate the assessment aspects from the interest, usefulness and obligatory nature of the course. In the case of the above SETE-independent indicators, i.e. the difference and standard deviation calculations, however, such a potentially misleading correlation will not exist, as we analyze student behavior from direct data, not from answers to questions.

Overall, therefore, the normality tests and the analysis of the dispersion of these indicators may provide an answer to the question of measuring the effectiveness of e-learning knowledge transfer. With this, I developed a relatively simple, easy-to-implement assessment method that can also serve as feedback in future e-learning course planning and development.

4.2.4.5 Statistical tools to be used for measurement

After presenting the measurement method, I will briefly outline the applicable statistical solutions. A number of statistical tools are available to examine the existence of normality and to determine the extent of deviation from it. I will forgo a detailed statistical description and will suggest which normality tests to use to examine the metrics presented above. In these cases, we can talk about two main approaches: tests based on calculation or graphical appearance.

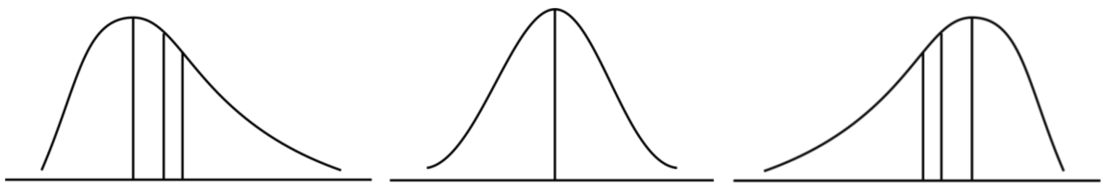
The advantage of the graphical method is that we can quickly determine whether a distribution shows a distribution close to normal, but this always provides us with a subjective result, we can decide only along non-objectively evaluable metrics. Visual appearance is informative in itself, as it immediately shows the direction in which our distribution deviates from the normal distribution (e.g. oblique to the right or left), but does not show the exact extent of this. It is typically used to decide whether a calculation-based normality test is worthwhile (or if it is so far away from the normal distribution that it would be completely unnecessary). It can also serve as sort of a controlling function, as we can perform a calculation that provides us with specific expectations about the degree of normality and skewness, so we can notice any computational errors if the two contradict each other - this of course requires practice and routine.

In contrast, normality tests based on calculations provide us with objective results that can be regarded with a level of significance, on the basis of which we can make a clear decision about the normality of a distribution. However, in the case of samples with a small number of elements, these models are sometimes not sensitive enough, and in the case of samples that are too large, they may be too sensitive, so they may show distorted results. (Thode, 2002)

Commonly used normality tests include the Kolmogorov-Smirnov and Shapiro-Wilk tests. The former is recommended for samples larger than 50 elements and the latter for samples smaller than 50 elements. Both statistical tests determine whether the distribution is normal at a 95% confidence level. (Razali & Wah, 2011)

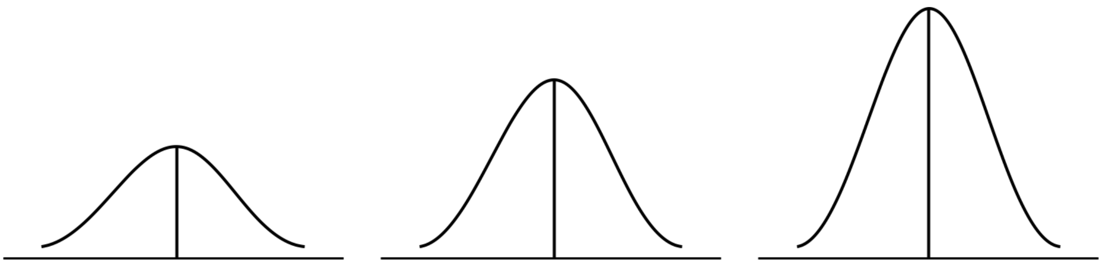
The skewness and kurtosis of normal distributions can be examined with simple descriptive statistical indicators, for which popular statistical software, like the normality test, are also suitable. In case of deviation from the symmetry of the normal distribution, the index of asymmetry (e.g. α_3 or Pearson index) will not be 0: in case of a positive number we get a left oblique (extending to the right) distribution, in case of a negative number we get an oblique to the right (extending to the left) distribution. For skews greater than 1, the distribution is no longer generally considered a normal distribution. (Mardia, 1974)

16. figure: In order: left oblique; symmetrical; right oblique normal distributions (own creation)



Kurtosis (i.e., how much the data is grouped around the center, around the mean) works on a very similar principle to the skew index (a kurtosis index, for example, is α_4): 0 is for normal distribution; in the case of a positive value we can see a flatter distribution, which is more grouped to the edges, while in the case of a negative value it is a more peaked distribution, i.e. it is more grouped around the center.

17. figure: In order: flat; normal; peaked normal distributions (own creation)



4.3 Results-based measurement methodology

In the previous subchapter, I examined the process of knowledge transfer, and developed and proposed a measurement method for it. However, the specific indicators formulated there are often not or only partially part of e-learning courses, or are not available due to the lack of an appropriate e-learning framework, or their extraction may be too much of a task for a quick analysis.

This subchapter offers a simpler alternative that does not examine the individual elements of the knowledge transfer process, but focuses on the students' "end state", i.e., using test tools from classical knowledge measurement methods to examine test results. It is important to note that this type of method also requires preparation, as the final test of a course alone does not provide us with a real picture of the effectiveness of learning. Recalling the previously presented difference between efficiency and effectiveness (the former examines the minimization of losses, while the latter examines the fact of realization), we can use this method to highlight the success of learning: whether the student has successfully acquired the desired knowledge. However, the method provides us with more information than that, as by not only analyzing the results of the final exam, cause and effect connections can be inferred using the additional variables involved.

The essence of the method presented here is to draw conclusions on the success of the knowledge transfer, taking into account the following three measurable results of students.

1. **Knowledge assessment test:** assessing the students' knowledge before or at the beginning of the course with the help of a test that has the same difficulty and level of knowledge as the final test of the course.

2. **Inter-course activity:** examining how active the student was during the e-learning course. The measure of this can be of several types, I suggest to create it from some weighted summary of the following:

   i. total or average time spent on studying the e-learning materials,

   ii. how many e-learning units the student successfully completed,

   iii. how many questions the student asked in the discussion forum,

   iv. what test results the student achieved,

   v. how many times did the student try the practice tasks, etc.

   Its definition always depends on the structure of the given course - in the empirical analysis of my dissertation I will provide a suggestion based on the example of the e-learning course I have analyzed.

3. **Final test:** the exam at the end of the course; it is vital for good comparability that this tests knowledge of the same difficulty and level as the knowledge assessment test.

Thus, the relationship between the above variables measures only the success (effectiveness) of the knowledge transfer rather its efficiency, facts about efficiency could only be formulated with predictions or by requesting additional data. However, the simple feasibility of the method can help to determine the quality and usefulness of the selected and analyzed e-learning course in many cases.

Next, I will present a methodology based on two types of statistical analysis, which both examines the effectiveness of e-learning education, but from a different approach. The first is a measurement methodology based on linear regression, while the second is based on cluster analysis procedures.

4.3.1 Measurement methodology based on linear regression

The first method therefore uses the toolbox of linear regression to determine effectiveness. According to this principle, using the three indicators presented above (knowledge assessment test, inter-course activity, final test) as variables, we build a regression model and analyze its parameters. Prior to the regression calculation, we examine the closeness of the relationship between the three indicators by correlation calculation.

Based on the learning process, the student has an initial starting knowledge, which I assume can be expanded with as much activity as possible in the course, and finally will possess a final knowledge at the end of the course. Continuing this logic, therefore, the success of knowledge transfer is determined by the score of the final test, and this will be chosen as the outcome variable (dependent variable); the initial knowledge and the inter-course activity will be the explanatory variables (independent variables) that determine the knowledge at the end of the course (with some certainty).

So, my assumption is that by adding the acquired knowledge to the initial knowledge, we get the final knowledge. Starting from this additive approach, I chose the linear type of regression. Further proof of this hypothesis, i.e. whether linear regression is what best describes knowledge expansion, may be an interesting topic for further study.

4.3.1.1 About regression analysis in general

My dissertation does not aim to present and explain in detail the operation and theoretical background of linear regression – there are numerous professional literature sources available for this, that can convey and make understand this knowledge much more precisely and satisfactorily than me. Nevertheless, for the proper use of its application, I consider it important to highlight some of its features.

With regression analysis – of which, in our case, we apply multivariate regression analysis with respect to the number of variables – we basically get an equation that determines with what coefficient (multiplier) each explanatory variable gets to contribute to the value of the result variable based on the elements of the sample. (Using a general example: the price of an apartment as a result variable can have two possible explanatory variables, the year of construction and the size of the apartment in square meters.) According to the general form of linear regression:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k +,$$

where y denotes the outcome variable, β_0 denotes the constant, $x_{1..k}$ denotes the explanatory variables, $\beta_{1..k}$ denotes their coefficients, and ε denotes the random factor.

In the specific case of measuring e-learning education, y will be the result of the final test, x_1 is the input test, x_2 is the mid-year activity variable, β_1 and β_2 are their coefficients, which determine that by ceteris paribus increasing the given explanatory variable by one unit how much will the value of the result variable grow (or decrease in case of a negative sign). β_0 can be interpreted somewhat in the abstract, this number symbolizes the end-of-year result that students can achieve with zero input knowledge and zero mid-year activity - we expect this to be generally not significantly different from zero. (Seber & Lee, 2012; Neter et al., 1996)

$$y_{\text{final test}} = \beta_0 + \beta_{\text{knowledge assessment test}} x_{\text{knowledge assessment test}} + \beta_{\text{activity}} x_{\text{activity}} + \varepsilon$$

4.3.1.2 Methods for selecting variables

In the case of multivariate linear regression, the statistical software running it allows the analyst to specify the way in which the explanatory variables are included in the model. (Pasha, 2002)

11. table: Possible methods for including variables in multivariate linear regression (own creation)

Method	**Description**
Enter	All variables are automatically included in the model.
Remove	After all variables are included, the software automatically removes those that do not contribute significantly to the outcome variable.
Forward	Step by step, the variables are included as long as we remain below the maximum error value (defined by the analyst).

Backward	Initially it includes all variables in the model, and then step by step removes from the model the one with the smallest partial correlation up to the threshold specified by the analyst.
Stepwise	A procedure similar to the forward method with the addition of step-by-step checking of previously involved variables and, like the backward method, removing them afterwards when the threshold is reached.

For the analysis of the e-learning course - as we work with only two explanatory variables - I propose the "enter" method, and we have to determine the goodness of the model and the explanatory variables ourselves, which also determines the original purpose of our analysis.

4.3.1.3 Application to an e-learning course - step by step

In the following segment I will present the steps needed to perform the correlation and regression calculation on the data extracted from the e-learning course.

After collecting the appropriate data and importing it into a statistical program (e.g. SPSS), we should run a correlation analysis. As a result, we obtain the correlation matrix, which shows how close the relationship is between the three variables. This shows the strength of the relationship between the variables on a scale of 0-1 in the form of a 3x3 matrix. According to the rule of thumb, a value between 0-0.3 shows a weak, a value between 0.3-0.7 shows a medium, and a value between 0.7-1 shows a strong relationship. (Goodwin & Leech, 2006) My hypothesis is that during a good e-learning course, the inter-course activity should be strongly related to the result of the final test, which would thus prove the goodness of the e-learning course.

After the correlation calculation, lets run a linear regression with the following parameters:

- the outcome variable is the score of the final test;

- the two explanatory variables are the score of the knowledge assessment test and the measure of the inter-course activity;

- the method of selecting and incorporating the variables into the model: “enter”.

As a result, we first obtain a table for the model showing the multiple correlation (r), the multiple coefficient of determination (r^2), its corrected value, and the standard error of our model. The most important of these for us is r^2, which shows to what percentage the combination of the knowledge assessment test and the inter-course activity explains the result of the final test, i.e. the knowledge in the student's possession after completing the course.

Another output of running the regression model is the so-called ANOVA table. In the case of linear regression, we can test the goodness of the model, in which case our null hypothesis is that the explanatory variables in the model are independent of the outcome variable. If we can reject this hypothesis based on the F-test in the ANOVA table, then the independent variables are suitable for explaining the outcome variable, so our model is “workable”. This is usually tested with 95% reliability (confidence level). (Kutner et al., 2005)

We can also see the values of the coefficients (β) of the model and the statistical value of the *t*-tests for each explanatory variable and the corresponding *p* value (i.e., significance level) among the outputs. From these, we can determine separately for each independent variable whether they have significant explanatory power in the model (this is true if the *p* value is less than 0.05), i.e. whether they really contribute to the result of the final test.

4.3.2 Measurement methodology based on cluster analysis

The other method seeks to answer the extent to which the e-learning course has contributed to the effective tutoring of the student and thus to the acquisition of the necessary knowledge by grouping along the similarities between the students’ results. We will use the same three variables here that we used when constructing the regression model, but here the three variables are used as equal parties, without distinction (i.e., no explanatory and outcome variables, or any other categorization).

I justify the use of cluster analysis on the basis that by grouping the students, the size and "quality" of the group of students who write a final test with a good score after a weak input test and high course activity will be visible. The more students there are in a cluster with such parameters, the more effective the knowledge transfer of the e-learning course is; and inversely, the existence of a cluster where there is no difference between the initial and final tests of the students and their course activity is low also supports the existence of an effective e-learning course. In contrast, an e-learning course that can form a large cluster of students in which the results between the initial and final tests do not show a significant difference with high course activity is ineffective.

4.3.2.1 About cluster analysis in general

In similar manner to regression analysis, I would like to clarify that it is not my aim to present and explain in detail the operation and theoretical background of cluster analysis - but I will say a few words about the essence of its operation here.

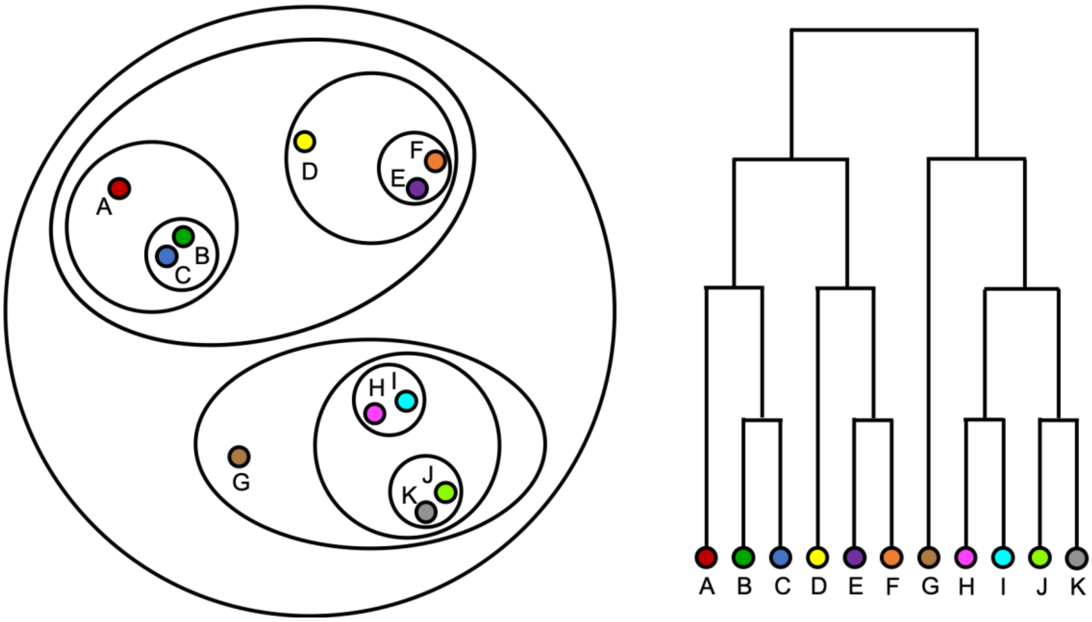
Cluster analysis is an element of multivariate statistical methods that helps to form groups with similar values (behavior) along different variables. (Sprinthall & Fisk, 1990)

In our case, this consists of the three variables presented earlier (knowledge assessment and final test and inter-course activity). Thus, we will examine what groups we can form from students whose scores for different variables are similar to each other, and then draw our conclusions by analyzing the cardinality of these clusters.

Cluster analysis uses a so-called dendrogram (tree diagram) to visualize the formation of groups, which shows, by iteration, which students are considered similar (close to each other) along the values of their variables and their combined distance.

As a first step, each student represents a separate cluster, and they are compared to each other by the procedure. In the next step, it examines the similarity between the clusters formed in the first step (according to different procedures, see the next subsection), until in the last iteration the remaining clusters are transformed into a single large cluster. (Kettenring, 2006) It is important to add that we can limit the number of iterations, it is not necessary to run the model until the last step.

18. figure: An example of clustering iterations based on point distances (own creation)



4.3.2.2 Cluster analysis procedures

Among the cluster analysis methods, hierarchical and k-means methods are used most often.

- **Hierarchical cluster analysis:** a three-step procedure. First, the distances between the individual elements (or already clusters) are calculated, then they are connected, and finally the appropriate number of clusters are selected.

  With this type, we can choose from a variety of methods (e.g., nearest and farthest neighbor, Ward method, etc.), including numerous distance determinations (e.g., squared Euclidean distance, Pearson correlation, Chebyshev, etc.), all of which influence the clustering process – that is, on what basis the model determines similar students and their clusters in each iteration.

- **K-mean cluster analysis:** in contrast to the previous method, here the elements in each cluster change continuously after each iteration (i.e. new and old elements can be added to and from each cluster in each iteration). In the first iteration, the model forms practically random clusters, and then determines the elements closest to it by determining their middle (average). The procedure then recalculates the means and proceeds as long as there is no longer a difference between two iterations, i.e. the elements in the clusters do not change.

Another difference from the hierarchical procedure is that here the analyst has to determine the number of clusters to be formed – this makes the model run faster, so it can be used on large data sets and to compare cases of different cluster numbers.

In the case of cluster analysis, it is recommended to perform and examine several methods, and then to draw the conclusions from the combined results of several similar models. Commonly used methods include "group relationship" with squared Euclidean distance, "Ward method" and "farthest neighbor" within the hierarchical analysis, and k-means cluster analysis in the cases already mentioned above.

4.3.2.3 Application to an e-learning course - step by step

In the following segment I will present the steps of cluster analysis on the data extracted from the e-learning course. After collecting the relevant data and importing them into a statistical program, the first step in cluster analysis is usually to standardize the variables so that it is easier to compare their deviations from the mean later on, and in this way all variables contribute equally to the distance measurement. If we want to give a variable a higher weight to determine the distances, we can multiply the standardized values of that variable by the desired weight. After standardization, we can run a cluster analysis procedure on the three standardized variables we want to include. (Milligan & Cooper, 1988)

In the case of a hierarchical clustering procedure, select the desired method and distance measurement logic. Set up the program to visualize the dendrogram for us, from which we can read and interpret the clusters.

For quick analysis on the dendrogram, find the point where you find a large protrusion (in practice: a long line) between the clusters according to the rule of thumb. Next, we randomly examine the results, scores and activity indicators of the students belonging to the given clusters - these should mostly show similar values that are close to each other. Based on this, we finally formulate the properties of each formed cluster based on their data content. (Clifford & Williams, 1973)

In the case of k-means clustering, it is recommended to choose the number of clusters established in the hierarchical clustering and thus perform the analysis. The only difference is in the iteration procedure, the interpretation of the data and the dendrogram is identical to the hierarchical cluster analysis. (Kodinariya & Makwana, 2013)

4.4 Comparison of the two methods

In my opinion, the most information is provided by the combined application and analysis of the two statistical methods - correlation calculation with linear regression and cluster analysis - as by each other's complements they provide us with completely different conclusions. The two analyzes may even yield conflicting results, which also carry information.

Correlation calculation and regression calculation help to give an objective measure of how the variables are related to each other, to what extent the result variable is explained by the independent variables; cluster analysis helps to identify typical groups that represent behavior and knowledge in an e-learning course in a homogeneous way.

Given that we interpret cluster analysis on the basis of subjective judgment - that is, we look for the jumping point where students can already be considered to belong to a cluster along the rule of thumb, not along boundary-bound metrics – and considering the order of the two analyzes, it is more practical to start with regression and correlation calculations, as the results obtained there can help to properly define and interpret the clusters.

4.5 Confirmation of the characteristics of a good metric

In the table below, I have summarized how the above statistical methods meet the requirements for good metrics set out in the previous chapter.

12. table: Confirmation of the goodness of result-based measurement methods (own creation)

Relevance	They can be used to determine whether learning was due to the e-learning course and thus suitable for further decision-making (e.g. rewarding the course creator, further development of the course, etc.)
Reliability	Digital data acquisition and computer-generated results rule out factors resulting from human error.
Representative faithfulness	Measurements projected onto the entire data set are accurate, not just inferred from a single sample.
Verifiability	Statistical methods based on mathematics will give the same result with analyzes performed independently from each other on the same data.
Neutrality	It is satisfied through the utilization of all the data, i.e. there is no subjective selection.
Comparability	The analyzes given by correlation and regression can be easily compared, while the sizes of the clusters derived from the cluster analysis can also be compared with the same analyzes on different data sets.
Consistency	It is satisfied assuming that standard statistical methods remain unchanged.
Understandability	It provides easy-to-interpret results even without a deeper knowledge of the mathematical background.

5 DEVELOPING THE CALCULATION OF THE BREAK-EVEN POINT

In the previous chapter, I focused on developing efficiency and effectiveness measurement methods during the e-learning learning process that focus on knowledge transfer. In this chapter of the dissertation, I aim at developing a method of calculating the break-even point: I am looking for a method by processing professional literature and synthesizing my 10 years of e-learning implementation work experience, with which the cost system of a classroom and an e-learning training can be compared, and it will be clear which is it more profitable to finance in the long run from an economic point of view, and what is the timeframe in which investing in e-learning can pay off. By developing this model, I will provide a decision support tool for personas facing an e-learning investment.

It is a generally accepted fact (see, e.g., Strother, 2002; Wild, Griggs & Downing, 2002; Vilaseca & Castillo, 2008) that e-learning is a profitable financial investment as a substitute for classroom training – however, in my opinion, this is not a general truth, it is necessary to examine all such investments and decide on their economics.

To examine this, I will first review the characteristics of e-learning implementation projects, from which I will derive the cost element characteristics of them. I declared the average costs of traditional classroom education primarily through experiential values. Finally, taking these cost elements into account, I will develop the most suitable break-even point model for comparing the two forms of education.

5.1 E-learning implementation projects

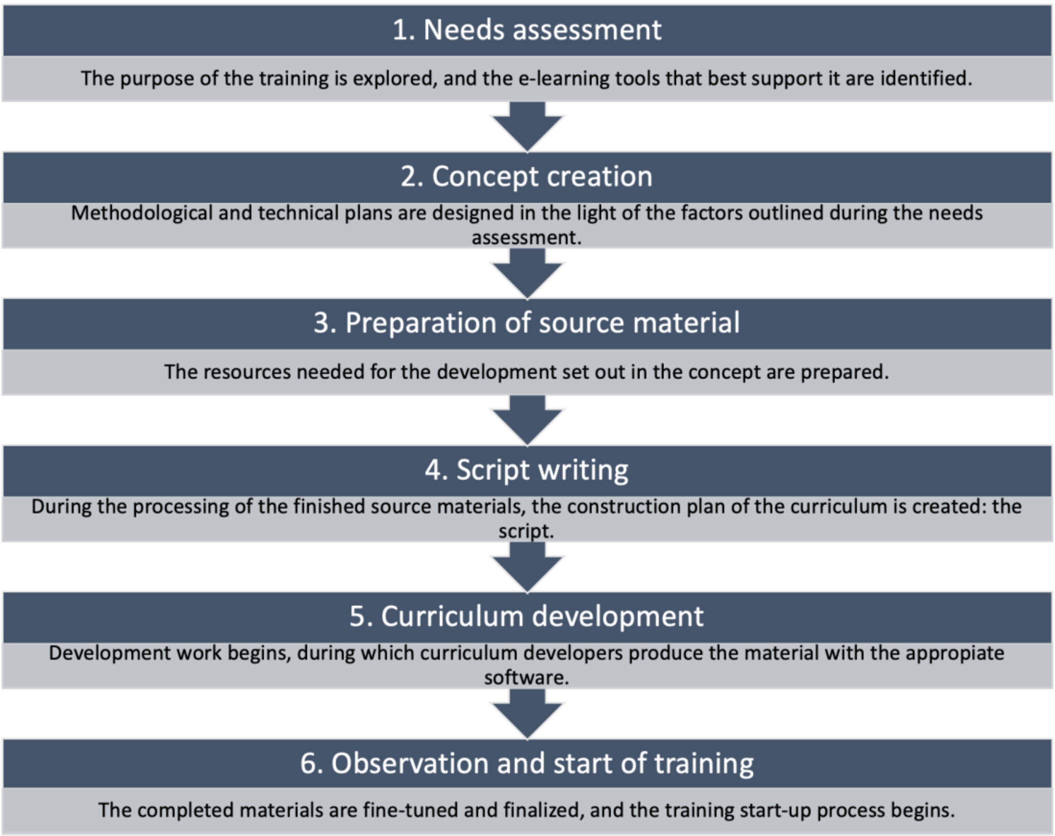
When describing the implementation of e-learning solutions, I will use my personal work experience of 10 years to formulate its most important factors and components. As well as in the case of projects in general, e-learning implementations can sometimes differ in terms of risks, challenges and results too. (Lynch & Roecker, 2007)

5.1.1 The project process

Comprehensive e-learning implementation projects cover both system and curriculum development work. The **e-learning framework implementation sub-**

process of the project has a classically IT approach, the implementation of which can be executed either along the classical waterfall or the more modern agile methods, but a model specifically created for the development of e-learning platforms has also been described in professional literature. (Axinte, Petrica & Barbu, 2017) In the following figure, I will outline the six steps that cover the e-learning curriculum development sub-process of the project, from the assessment of the training need to the start of the training.

19. figure: Presentation of the e-learning curriculum development process (own creation)



5.1.2 Stakeholders

The complexity of e-learning implementation projects is well illustrated by how many additional participants besides the e-learning personas presented in the previous chapter characterize the planning, implementation and monitoring phases of e-learning projects, i.e. participants cover a wide range in such projects. As in project management in general, the proper management of stakeholders is of paramount importance in e-learning implementation projects, for which the work of Roeder (2013) provides a good basis.

In the following segment, I will present the tasks and interests of each participant, as well as their general field of expertise. Stakeholders of the project include both those who raise the demand, those who carry out the operational implementation, and the personas responsible for its sustainability.

- **Project level participants:** this includes those participants who have a role in the formulation of the project need and in making financial decisions, and also, from a financial point of view, it is primarily their interest for the project to be successful and to break even. (Newcombe, 2003)
    - **Project owner** (training department, HR, specialization manager): project managers are the stakeholders who formulate the need for the implementation of the e-learning curriculum development project and the management of the given training in the form of e-learning.
    - **Project leader** (project management office): classic project management role, not necessarily skilled in the field of e-learning. Its task is to complete the e-learning curriculum development on time, in the right quality and within budget.
    - **Management** (leader): its goal is for the cost allocated to e-learning development to generate profit growth over a period of time (either through more efficient knowledge transfer and thus more productive employees, or through training cost reductions). They can also be project owners. They typically do not participate in the project directly.
- **Participants in the operational implementation of the development** (one-time task): this includes those involved in the project who are responsible for the implementation of the curriculum development at each stage of the process. (Krašna, Bratina & Kaučič, 2009)

- **Training manager, expert, tutor** (learning center): The training manager, or simply the expert or tutor is the person in possession of the professional knowledge (typically he/she teaches the training in the attendance form of education) that the project wants to convert to e-learning. His/her task is to transfer the professional knowledge to the learning & development (L&D) team (see the following subsections) so that they can incorporate all the knowledge into the e-learning curriculum. He/she is also the person who approves the completed e-learning curriculum from the content side.

- **Course planner** (L&D department): the methodological expert who determines the best-fitting concept related to the given course; i.e. what e-learning methodology should be used for the knowledge transfer.

- **Screenwriter** (L&D department): writes the script of the e-learning curriculum according to the e-learning methodology defined by the course planner, which is practically the textual excerpt of the interactive and multimedia elements to be developed. Depending on the size of the organization, the course planner and screenwriter are often one person.

- **Curriculum developer** (L&D department): based on the script of the e-learning curriculum written by the screenwriter, he/she develops it with the help of appropriate software and IT tools, and later improves and updates the e-learning curriculum based on feedback.

- **Tester** (L&D department): as an IT end product, testing the e-learning curriculum is also an essential task. The tester reports his/her comments to the curriculum developer, who corrects the errors accordingly.

- **Participants responsible for maintaining the e-learning course** (ongoing task): this includes those personas who are not directly involved in the development of the curriculum, but are involved in its systematic operation after the start of the course.

- **Operator** (IT department): The e-learning system responsible for running the e-learning materials can be accessed from an IT infrastructure, the continuous availability of which is essential - the operator is responsible for ensuring this.

- **Helpdesk/support** (IT department or course organization): the helpdesk or support staff guarantees a problem-free learning experience (as much as possible) for the students from a technical point of view. Students turn to them if they encounter any errors, problems or technical difficulties in the e-learning system or curriculum.

- **Course organizer** (learning center): the person responsible for the ongoing organization and follow-up of the e-learning and attendance trainings in the organization. His/her task is to integrate the e-learning course into the training structure of the organization, and to ensure that the developed curricula reaches the right students at the right time.

- **Training manager, expert, tutor** (learning center): I have previously introduced this person among the participants in the operational implementation, but it also has an important function in this category: he/she needs to periodically review the professional content of the e-learning curriculum and formulate any needed changes.

The personas presented above detailed the participants of a general, typical e-learning implementation project. It is worth noting that depending on the nature of the curriculum, the number of participants may increase with a number of additional personas: in the case of video teaching materials, for example, actors and a full filming staff are also required; in the case of custom-developed teaching materials that cannot be implemented with the available software toolkit, programmers may be required, and the list can go on further – however, all these personas can be categorized as "participants in the operational implementation of the development" and their one-time (non-recurring, continuous) task arises during the implementation of the project, so they don't appear among the personas during the training.

5.2 Incurred costs

After identifying the process and personas of e-learning development and implementation projects, we can examine what costs may be incurred during such a project. These costs can be divided into two categories: costs that can be measured in money (i.e. explicit) and those that are difficult to quantify in money (implicit). (Stiglitz & Rosengard, 2015) I see the former as easy to integrate into the measurement model, in the latter there are several risks, which I will cover later.

5.2.1 Explicit costs measurable in money

Among the costs that can be measured in money, I have included the elements that, even if based on some generalization calculations, are monetized. I will examine the cost structure of e-learning implementation projects separately, and then the typical costs of classroom trainings. In both cases, we can talk about one-off, ad hoc costs and long-term, continuous expenses.

5.2.1.1 E-learning training costs

In the case of e-learning trainings, just as I did when detailing the concepts and definitions, we have to separate costs regarding the development of curricula and the costs of the e-learning framework (LMS). The cost of the system implementation shall only be taken into account, if it has not been realized within the framework of a previous investment at the organization. It is also important to differentiate between one-off investment costs and future continuous (usually monthly or annual) expenditures, which are necessary to maintain the entire e-learning ecosystem. (Briciu, 2008)

In the following matrix, I have collected the possible costs grouped along the dimensions of the curriculum/system and the one-time/continuous occurrence.

13. table: Matrix of cost elements of e-learning investments (own creation)

	One time		Continuous
Framework (LMS)	Introduction of framework (human cost of IT investment)		Framework version upgrade
	One-time application fee	(or)	License fee (can be free)
	Server investment	(or)	Hosting service
	-		Support / helpdesk function
Curriculum (content)	Curriculum development (human cost of investment)		Curriculum maintenance (content update)
	One-time software cost		License fee
	-		(Professional support for students)

First of all, the framework has an implementation cost (here we first calculate it separately only including human costs, as IT related costs are not necessarily one-time, so it is recommended to manage them separately), and it is worth considering its future regular update and maintenance costs. The e-learning framework has to be operated on some kind of infrastructure (server park), which can mean a one-time investment cost or can be rented as a regular service. The situation is similar with the license cost, which can be - instead of a one-time fee - free of charge, depending on the use of it, but an annual cost is more typical, which depends on the extent of use (e.g. number of users). We must also not forget the support / helpdesk function required for maintenance, as someone must constantly ensure that students' questions and issues are addressed.

In the case of study materials, we can also talk about a one-time development cost and then subsequent maintenance costs, and as well as in the case of license fees there are similar constructions: it is possible to purchase a one-time boxed product or use an application with a monthly / annual license. It is important not to forget the professional support of students, as e-learning courses can be accompanied by professional support that requires tutor intervention (of course, this is only an optional element).

5.2.1.2 Costs of classroom (attendance) courses

The costs of classroom (attendance) education is somewhat easier to list. This can be made up of three main factors (Bartley & Golek, 2004):

- the cost of the tutor (including salary, travel, accommodation, meals, if financed);
- infrastructure costs, such as classroom rental and maintenance, projector, parking space, etc. (or from some internal organizational cost accounting);
- costs incurred during examinations (tests, exams) (treated as a separate category, as examination is not always necessarily included in the education);
- a possible coverage of other expenses of the students (like travel, accommodation and meals similarly to the tutor; but this includes various teaching aids such as printed publications, textbooks, etc.).

I did not include the development of professional content in the model (neither here nor for the costs of e-learning), because in the case of a completely new course it has almost the same time and cost requirements for both forms of education. In the case of the transfer of an existing attendance education to e-learning, the development of professional content is also not an additional task, and thus not a cost either - it does not affect the break-even point.

5.2.2 Non-monetary, implicit cost sources

In addition to the costs listed above, there are a number of other factors that may be difficult to quantify. These could only be incorporated into the model in a very subjective, forced way, which could easily distort the accuracy of the measurement. Nevertheless, I consider it important to at least mention and list these types of (potential) costs:

- **Cancellation:** the constraints of classroom education include the person of the tutor, who due to some force majeure situation may not be able to hold the education. In this situation, the students acquire the knowledge later on, thus the classroom remains unused, or the situation can may be resolved by involving a replacement tutor at an additional cost.

- **Failure:** fitting it into the above analogy, the e-learning system or the curriculum in it can also fail, the restoration of which can generate unexpected expenses - or merely hinder the acquisition of knowledge for some time.

- **The need for education ceases:** the education in question may become redundant (for example, as a result of a change in legislation). In this case, the development of the e-learning curriculum becomes a lost cost, or classroom instructions that have already been held unnecessarily in the recent period are also lost costs.

- **Lost cost due to fluctuation:** an unnecessary lost cost is also the per capita training cost of a student who leaves the organization in the post-training period (until he / she has not been able to make substantial use of what he / she has learned).

- **Labor costs due to efficiency:** one of the central topics of my dissertation is the question of efficiency - according to which can one form of education pass on a unit of knowledge to the students with less or more time – can also be accounted as a cost, since if e.g. the hourly wage cost of an employee working for a company is included in the training time, we can get serious differences in the costs of the two forms of training.

Overall, we can conclude that some of the above elements can be interpreted to the e-learning form, while some to the attendance form of education, and their probability and impact vary widely. Although it would be an easy and convenient statement to say that referring to the law of large numbers, the above elements affect the costs of both forms of education equally, I do not dare to put this statement on paper – however, the observation and quantification of these can be an interesting research topic, which I will not undertake in the framework of this dissertation. As a general suggestion, the sporadicity and volatility of these costs can be addressed and incorporated into the model by introducing simple correction factors, such as empirical estimates.

5.3 Method of calculating return

After identifying the costs, lets draw the first conclusions. It can be seen in advance that a classroom education does not have a one-time investment cost, rather costs per training (annualized). In contrast, e-learning has a higher investment need in the beginning, but its subsequent maintenance costs are not human resource-oriented, so they are presumably lower, therefore the investment is expected to pay off over time, and in the long run the e-learning form of education will be the one with lower costs. I will look for the intersection of the two time series budget lines, which will ultimately give us the time of the break-even point calculated from the beginning.

5.3.1 Cost summary table

In order to automate the calculations, I created a general template, which, in addition to the costs mentioned earlier, can also be used to record a few other pieces of information so that we can find the break-even point. The following table shows the scope and interpretation of the data required for this. In connection with the presentation of the calculation, I also coded the individual items for easy identification, later I will describe the formulas and equations to be solved for the return calculation by referencing them.

14. table: Data required to calculate economy (own creation)

Code	**Data**	**Unit**
General data		
GCount	How many e-learning courses (person * course) are implemented per year?	”courses of *x* persons”/year
GBudget	What is the budget for e-learning curriculum development in the given year?	HUF/year

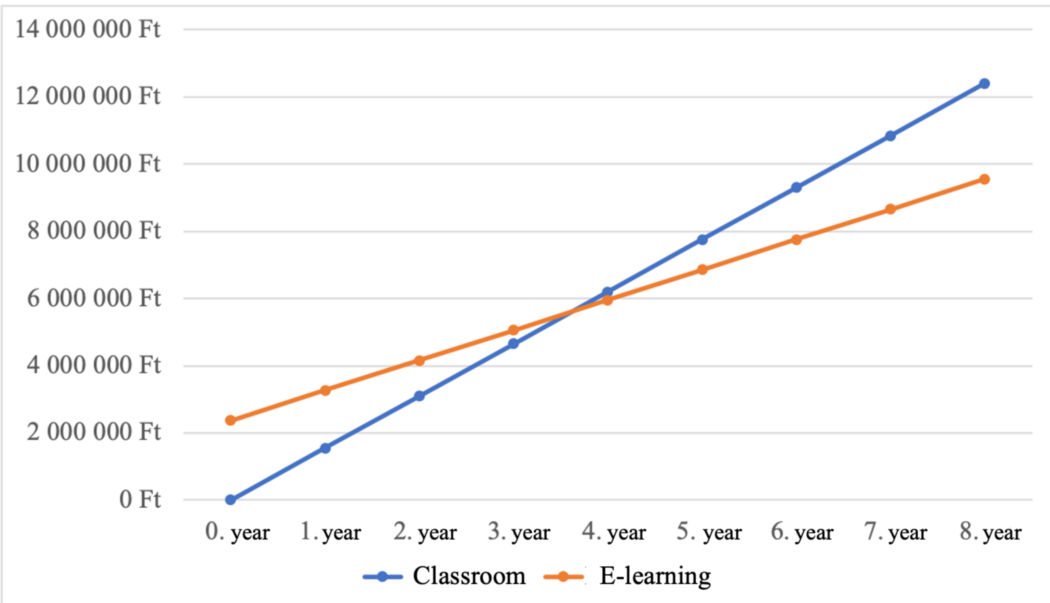
GFreq	How often is this course started?	pcs/year
Face-to-face data		
FCapita	Number of participants in a course	persons/course
FTeachCost	Tutor cost (can also be calculated by internal cost accounting)	HUF/course
FTeachOther	Other tutor expenses (accommodation, meals, travel insurance)	HUF/course
FRoom	Classroom rental cost (can also be calculated by internal cost accounting)	HUF/course
FExam	Cost of examinations	HUF/course
FStuCost	The average costs of other costs per capita (accommodation, meals, travel for students)	HUF/person
LMS Data		
LCost	Cost of implementing an e-learning system (0 in case of an existing system)	HUF (one-time)
LMaint	Cost of updating the e-learning system	HUF/year
LLic	License cost of the e-learning system	HUF/year
LServ	Hosting fee of the server (0 in case of a single investment)	HUF/year
LHdesk	Helpdesk costs	HUF/year
E-learning content data		

CCost	One-time cost of curriculum development	HUF (one-time)
CChange	How much does the content of the curriculum change each year?	%
CLic	License cost of the e-learning development software	HUF/year
CTutor	To what extent is it needed to supplement learning time with personal professional support?	%

5.3.2 The process of calculating return

In the following I will present how to calculate the break-even point of an e-learning investment (if it has one) using the data provided in the table above. The purpose of the calculation is to obtain a forint amount for both classroom and e-learning education, which shows the annual cost of the given training; in addition, the e-learning education will be accompanied by an initial investment amount. Placing the two next to each other, we will cumulatively annually get a date from which the total cost of e-learning training (orange) will be lower than classroom training (blue).

20. figure: A possible example of a return on investment for e-learning (own creation)



The calculations presented in the following subsections can, of course, be done in an Excel spreadsheet in an extremely short time - the itemized presentation below helps to explain the calculation process. In practice, a pre-designed Excel spreadsheet greatly speeds up the break-even point calculation time.

5.3.2.1 Cost of classroom education

There is therefore no one-off, distinctive (therefore such that is not part of e-learning costs) investment cost for classroom education. The annual cost is obtained from the following calculation:

1. First, we calculate the **fixed cost of a classroom course**, that is, we add the variables related to classroom rental, tutor costs, and examinations:

   $$FTeachCost + FTeachOther + FRoom + FExam$$

2. We then calculate **the variable cost per classroom course** by multiplying the number of participants in one course by the unit cost per student:

   $$FCapita * FStuCost$$

3. From the sum of the two, we get the **total cost of a classroom course**:

   $$[1] + [2]$$

4. Finally, we multiply this by the number of courses held per year, so we get the **total annual cost of the given classroom course** (hereinafter: FTotal):

   $$[3] * GFreq$$

5.3.2.2 Cost of e-learning education

Next, let’s look at the cost of e-learning education. As an auxiliary data, it is necessary to calculate **the ratio of the e-learning course** (hereinafter: LRate) in relation to the total number of e-learning courses of the organization. To do this, we increase the whole-year e-learning “courses of *x* persons” with the total number of participants in the new courses, and then proportion it to the number of those to be trained with the new course.

$$LRate = (GFreq * Facpita) / [(GFreq * Facpita) + GCount]$$

In the case of e-learning courses, there is the new factor of an initial investment, which consists of the sum of three elements:

1. The **one-time cost of curriculum development**:

$$CCost$$

2. The **cost of implementing the e-learning framework in proportion to the given course**:

$$Lcost * LRate$$

3. The **e-learning license cost in proportion to the given course** in proportion to the annual budget planned for e-learning:

$$CLic * (CCost / GBudget)$$

4. From the sum of the three data we get the **cost of the initial investment in e-learning** (hereinafter: *CInitial*):

$$[1] + [2] + [3]$$

Next, calculate the annual cost of the e-learning course, which also consists of several elements:

1. First, multiply the amount of the annual costs of the e-learning system (cost of updating the e-learning system, license cost, cost of server rental, helpdesk cost) by the previously introduced LRate ratio, so we obtain **the amount of framework-type expenditures proportional to the given e-learning course's headcount**:

$$(LMaint + LLic + LServ + LHdesk) * LRate$$

2. Calculate the annual cost of updating the curriculum as the product of the initial investment cost of the curriculum and the expected annual change in the curriculum (in percentage):

$$CCost * CChange$$

3. Finally, let's calculate the **cost of e-learning tutor support** as a product of the tutor's classroom tuition, the annual number of courses, and the percentage of complementary to the e-learning learning time:

$$FTeachCost * GFreq * CTutor$$

4. From these three amounts we get the **total annual cost of the e-learning course** (hereinafter *CTotal*):

$$[1] + [2] + [3]$$

5.3.2.3 Calculating the point of intersection of the two lines

In the previous two points, we calculated the three bits of necessary data (FTotal - total annual cost of classroom education; CInitial - initial cost of e-learning education; CTotal - annual total cost of e-learning education), which is needed to determine the intersection of the cost lines of classroom and e-learning education. The left side of the following equation shows the cumulative cost of classroom education incurred up to a given point in time (measured in years, hereafter: *n*), while the right side shows the same for e-learning. Equalizing the two sides thus determines their point of intersection for *n:*

$$0 + FTotal * n = CInitial + CTotal * n$$

After some mathematical rearrangement, we express the variable that determines the year, i.e., *n*:

$$n = CInitial / (FTotal – CTotal)$$

The result obtained is expected to be a fraction, for example 3.4 for the sake of clarity of further explanation (thus also reflecting on the image depicting previous lines). This number means that in the 3.4. year (meaning: in the three-point-fourth year) the tides turn and the e-learning form of education becomes the cumulatively cheaper form of education. As the model is not sensitive to the distribution of inter-year education, in practice this number should always be rounded up, so staying with the example, we can say that from the 4th year after its introduction the e-learning form of education brought back the initial investment and in terms of total cost it is the cheaper form of education.

5.4 Calculation example

It is important to note that the developed model can only be considered viable and applicable in practice, if we consider the issue of knowledge transfer efficiency, which is one of the previously indicated elements that is difficult to quantify in money, to be the same between the form of attendance and the form of e-learning education, that is, we assume that the two forms of education are able to pass on the same amount of knowledge in a unit of time - or vice versa: it is able to pass on a unit of knowledge to students in the same amount of time.

In the following table I will illustrate the application and operation of the above indicator system with an example illustrated with concrete numbers (taken from a fictitious example). To do this, first see the table that is already filled with data. (I will not provide further explanation for the data here.)

15. table: A table filled with example numbers to illustrate the break-even point (own creation)

Code	**Data**	**Unit**
General data		
GCount	How many e-learning courses (person * course) are implemented per year?	”courses of 3000 persons”/year
GBudget	What is the budget for e-learning curriculum development in the given year?	15 000 000 HUF/year
GFreq	How often is this course started?	5 pcs/year
Face-to-face data		
FCapita	Number of participants in a course	25 persons/course
FTeachCost	Tutor cost (can also be calculated by internal cost accounting)	50 000 HUF/course

FTeachOther	Other tutor expenses (accommodation, meals, travel insurance)	10 000 HUF/course
FRoom	Classroom rental cost (can also be calculated by internal cost accounting)	30 000 HUF/course
FExam	Cost of examinations	20 000 HUF/course
FStuCost	The average costs of other costs per capita (accommodation, meals, travel for students)	10 000 HUF/person
LMS Data		
LCost	Cost of implementing an e-learning system (0 in case of an existing system)	10 000 000 HUF (one-time)
LMaint	Cost of updating the e-learning system	800 000 HUF/year
LLic	License cost of the e-learning system	3 000 000 HUF/year
LServ	Hosting fee of the server (0 in case of a single investment)	1 200 000 HUF/year
LHdesk	Helpdesk costs	3 600 000 HUF/year
E-learning content data		
CCost	One-time cost of curriculum development	3 000 000 HUF (one-time)
CChange	How much does the content of the curriculum change each year?	25%
CLic	License cost of the e-learning development software	400 000 HUF/year

CTutor	To what extent is it needed to supplement learning time with personal professional support?	20%

The following table summarizes the values calculated by sub-calculations.

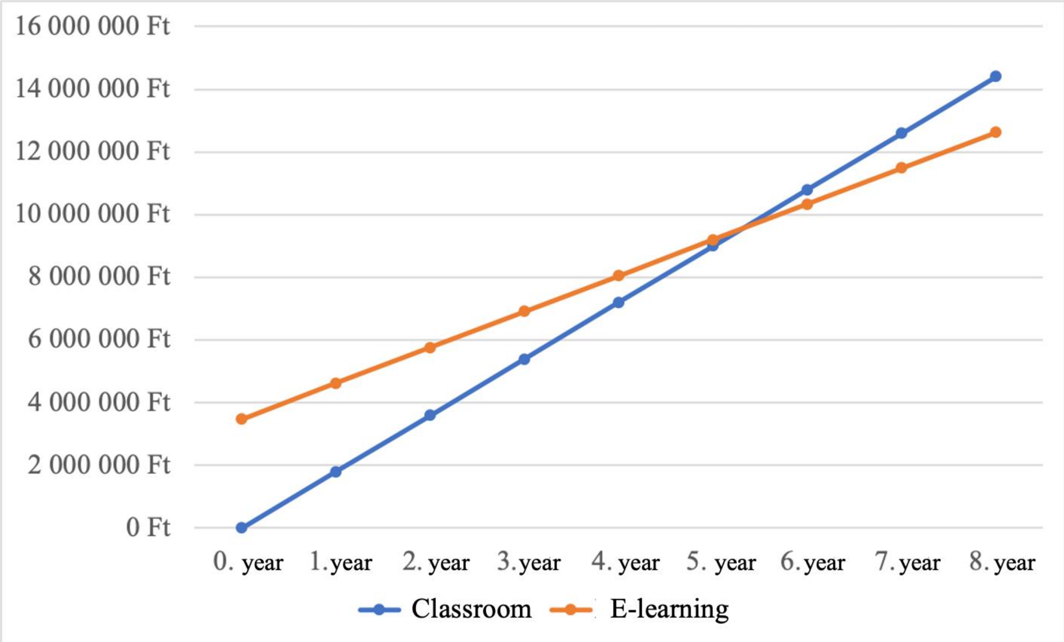
16. table: Results of partial calculations and calculation of break-even date based on example data (own creation)

Code	**Item**	**Formula**	**Result**
[1]	Fixed cost of a classroom course	*FTeachCost + FTeachOther + FRoom + FExam*	110 000 HUF
[2]	Variable cost per classroom course	*FCapita * FStuCost*	250 000 HUF
[3]	The total cost of a classroom course	[1] + [2]	360 000 HUF
FTotal	**Total annual cost of a classroom course**	**[3] * *GFreq***	**1 800 000 HUF**
LRate	Rate of e-learning course	*(GFreq * Facpita) / [(GFreq * Facpita) + GCount]*	4,00%
[1]	One-time cost of curriculum development	*CCost*	3 000 000 HUF
[2]	The cost of implementing the e-learning framework in proportion to the given course	*Lcost * LRate*	400 000 HUF

[3]	E-learning license fee in proportion to the given course	*CLic * (CCost / GBudget)*	80 000 HUF
CInitial	**The cost of the initial investment in e-learning**	**[1] + [2] + [3]**	**3 480 000 HUF**
[1]	The amount of framework-type expenditure in proportion to the number of e-learning course participants	*(LMaint + LLic + LServ + LHdesk) * LRate*	344 000 HUF
[2]	Annual curriculum update cost	*CCost * CChange*	750 000 HUF
[3]	Cost of tutor support for an e-learning course	*FTeachCost * GFreq * CTutor*	50 000 HUF
CTotal	**Total annual cost of an e-learning course**	**[1] + [2] + [3]**	**1 144 000 HUF**
n	**Break.even date (year)**	***CInitial / (FTotal – CTotal)***	**5,30**

The interpretation of the result obtained is therefore as follows: based on the comparison of the above parameters, the initial investment in e-learning education will pay off from the 6th year onwards. The two budget lines and their intersections are shown in the diagram below.

21. figure: Representation of the intersection of the budget lines, i.e. the break-even point (own creation)



In conclusion, I consider it important to note that this simplified model ignores a number of economic and financial circumstances that may affect the break-even date, which shortcoming is mainly due to the comparative nature of the calculation. Some of these parameters may be, including but not limited to, the changes in wage costs over the years (in some cases simply due to changes in the tax system), changes in curriculum development and framework license fees, or even inflation (i.e., excluding net present value calculation). By discounting future cash flows, the model can be made more accurate - especially that the present value calculation can be used to properly manage the elementary difference in the two cost structures (the difference between the initial investment and the amount of ongoing costs). The above-mentioned factors may even significantly affect the result, so the model should only be used with caution and discretion, taking into account the above limitations when applying it to real market situation.

6 EMPIRICAL RESEARCH

The next step is to test the developed knowledge transfer measurement methods with data. For this, I will use the mandatory E-business course from the University that affects hundreds of students every year. I have developed the measurement method as a general-purpose tool, i.e. it should be suitable for measuring any course, regardless of the topic.

6.1 Characteristics of the revised course

The participants of the above-mentioned course selected for analysis – the E-business course - consist of third-year students majoring in economics and management from the Corvinus University of Budapest, who complete the subject as a compulsory element of their program curriculum. Due to the number of participants (approx. 200 people / semester), I can obtain statistically relevant and representative results and can help highlight possible weak points of the measurement methods and the elements to be developed.

From a technical (IT) point of view, I also had to find a course suitable to test the method: as a tutor of the subject, I also had the opportunity to prepare the subject appropriately from a methodological and digital technological standpoint. As a result of a collaboration with my other two colleagues who also taught the subject, we were able to prepare the course to include the e-learning form of education with its necessary content elements. Thus, I could extract the data regarding the learning process of the students taking the course in the University's Moodle system and apply it to the previously developed and presented measurement methods.

6.1.1 Course content structure

The primary aspect of the methodological rethinking of the course is the inclusion of e-learning educational elements in the content and structure of the course, keeping in mind the range of data to be measured, i.e. that I would like to record every action in the e-learning course executed by the students.

The course was expanded using the following elements:

1. **Input test:** a test of the same level of difficulty as the final exam, which students must complete before the first lesson. The test does not count

towards the final grading of the subject (thus preventing preparation for the test), but as a means of encouraging completion, points can be obtained for completing it. The aim of this is to fit it into the result-based calculation method of e-learning efficiency, and to compare it with the results at the end of the course, from which the degree of the acquired knowledge surplus can be determined.

2. A Moodle-embeddable, pageable version of the **slide shows of the weekly attendance lectures**, where we can keep track of when, how often, which parts of these static (non-interactive) resources students viewed.

3. **Weekly e-learning materials:** uploading additional professional content (about 30 minutes per fortnight) as e-learning material that does not appear in the lecture.

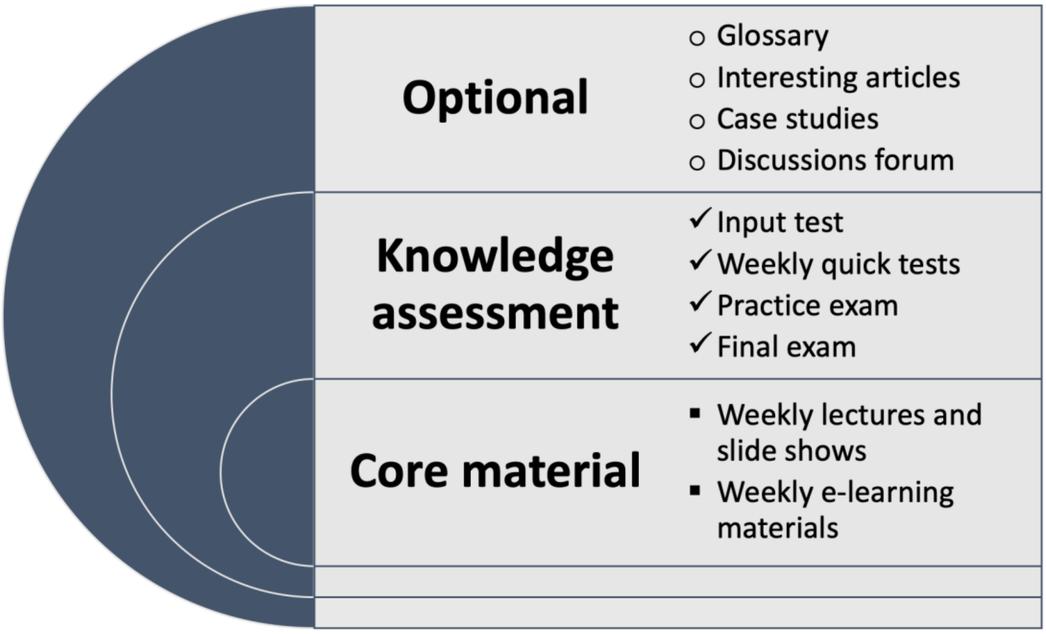
4. **Weekly short tests:** preparation of separate tests on the knowledge elements given in the lecture and from the e-learning materials.

5. **Additional non-compulsory learning elements:** Uploading glossary, collection of links and references, and interesting (relevant) articles to the course site.

6. **Discussions forum:** which provides a questioning interface for students (students can also answer the questions asked).

7. **Test exam:** the test at the end of the semester, its difficulty is the same as the input and practice tests.

22. figure: Components of the E-business course revised for e-learning measurement (own creation)



6.2 Structure of the empirical research

An essential feature of the University's Moodle e-learning system is that it records and saves all user activities and this is accessible to faculty. Thus, after the proper compilation and parameterization of the course, the data is recorded automatically, no user intervention was required during the course – although, in practice, I tested the proper operation of these and the formal correctness of the data, within the framework of a pilot "mini-course", so that they would be suitable for analysis, even if at the cost of some post-production.

6.2.1 Data recording

Although data acquisition is done automatically, the raw data that can be extracted from Moodle is not suitable in itself for running the desired measurements. As a result, two types of data sets can be downloaded from the system.

1. **The scoreboard and results of the online tests (and other scoring tasks)** to be completed during the course. This can be saved as a dataset that contains students in the rows and Moodle activities in the columns, where they can gain points. At the intersection of the two are the points earned by the students.

2. A **report containing the students' course activity**, also in Excel format. This is a time-series dataset that typically includes tens of thousands of records for a course of this size (in our case, about 83,000 rows), which includes the activities of each student in each course, including (but not limited to): entering the course, viewing study materials, completing a test, viewing additional learning elements (glossary, etc.), downloading lecture notes, etc.. In each case, these records include a name (which identifies the student), a categorization (e.g., viewing curriculum, course entry), an event description that includes specific identifiers (which includes the subject in which the activity took place), and a timestamp that records the date of the activity.

6.2.2 Data preparation

The first data table containing points and test results did not require any special systematization work, after formal standardization it could be practically loaded one by one into the appropriate statistical software, it is suitable for data analysis. However, in the latter report, which included the students' course activity, it was necessary to make manual corrections in order to be able to perform normality tests on them, as described below.

- The *number of entries into the course* and the number of views of course modules could be determined with a simple Excel function (“COUNTIFS”) student by student.

- In the case of indicators for different times (*time spent in the course, average time spent between course visits*), I obtained the appropriate data set using the difference of the consecutive time stamps of the same activities, and then by using the average function.

- I calculated the *average return time of the students* (i.e. how much time elapsed between each course-level exit-entry) from the average number of days missed between two entries per individual. For this, I arranged the students and the days of the course in tabular form (students in rows, the 96 days of the course in columns), and in the sections I examined whether students entered the course on a given day (yes / no). Finally, using a VBA function I wrote, I calculated the number of "idle" days between each course entry, which I divided by the number of all such omission periods.

- I also define a unique indicator (*course activity*) consisting of the weighted average of the standard normalized indicators listed below. When determining the weights, in my subjective opinion I tried to give more weight to the elements that, in my opinion, well represent the activities and behaviors that contribute the most to the increase of knowledge in the course.
    - Number of active days spent in the course (25%)
    - Number of views of course curriculum elements (10%)
    - Frequency of return to the course, i.e. the total number of course entries (5%)
    - Average return time of students, or average number of idle days between two active days; calculated with the reciprocal of the indicator, so more is better for this indicator as well (20%)
    - Results of mid-year tests (5 x 8% = 40%)

The data sets prepared according to the above, separated by indicators, can now be loaded into the appropriate statistical software, and the necessary normality tests and dispersion tests can be performed. Due to this unique data processing, an interesting and useful IT development could be the automated integration of the above post-production into the Moodle system, with the online implementation of the measurement methods and their graphical and numerical visualization within the system tool set as a next step.

6.2.3 Measurements to be run

With the help of the E-business course, I will test the following measurement methods I have developed using the SPSS statistical analysis program. I will first deal with the knowledge transfer-centric efficiency test, in the framework of which I will perform normality, skewness and kurtosis tests on the following indicators:

17. table: Indicators involved in the analysis of knowledge transfer-centric efficiency testing (own creation)

Name of the indicator	**Code of the indicator**
Students' end-of-course scores	*course_score*
Frequency of return to the course (number of course entries)	*course_entering*
The number of views of curriculum elements in the course	*module_view*
Average return time of students (average number of idle days between two active days)	*passive_time*
Number of active days spent on the course	*active_days*
Course input test scores	*assessment_score*
Unique indicator of course activity	*activity_score*
Percentage distribution of correct answers to exam questions	*question_score*

I then continue the analysis with a result-based efficiency study, which I examine using two different methods:

a. **Measurement method based on linear regression:** examining the relationship between the results of the initial test (assessment_score) and the total score of the course (course_score) by correlation calculation, using the student activity observed week by week as an additional variable (activity_score); then performing a linear regression calculation on the above (as described in chapter 4.3);

b. **Measurement method based on cluster analysis:** just as the previous method, examining the relationship between the results of the initial test (assessment_score) and the total score of the course (course_score), and the individual indicator of the course activity (activity_score), however, here I use the toolkit of cluster analysis (with several methods and procedures) to examine the student groups that can be formed in this way and their common characteristics.

6.2.4 Result expectations

During the knowledge transfer-centric efficiency analysis, in a well-developed e-learning course, I expect right-oblique, left-extending bell curves from the analyzes of the individual metrics according to chapter 4.2.4.5, with normality tests giving positive results. With regard to the dispersion indicators, the lower the standard deviation of the calculations, the more it is true that for the student population, the course provided the necessary knowledge to everyone equally efficiently, i.e. the knowledge transfer was efficient. Highlighting one or two specific examples: students' end-of-course scores, number of course entries form a right-oblique bell curve; the number of views of additional curriculum elements is expected to approach a normal distribution due to different input competencies; the relative deviation of time indicators can be estimated to be average due to different student attitudes.

Values indicating the strength of the correlation between variables are important indicators in the regression-based measurement method. I expect that if the quality of e-learning content is adequate and knowledge transfer is effective, there should be a weak or moderate correlation between the initial test and course scores: although the students' input competence is somewhat predictive of their output competence, the determining parameter will be course activity, which represents the education. I hope that education as an intervention will significantly improve the final test results for those who initially achieved a weaker result, i.e. the knowledge of the two groups will be closer to each other. As a result, I expect a strong correlation between the variables of student activity and the total score of the course: the more active someone is during the e-learning course, the more knowledge they will acquire, so they will write a better test at the end of the semester and vice versa. Finally, in linear regression, these correlation relationships will also shape the relationships between the variables of the model, i.e. the coefficient β of course activity will be higher than that of the input test, and its *t*-test will also have a better *p*-value.

During the cluster analysis, if my expectations for the regression are correct and the effectiveness of the e-learning course is confirmed, I expect the formation of the following clusters:

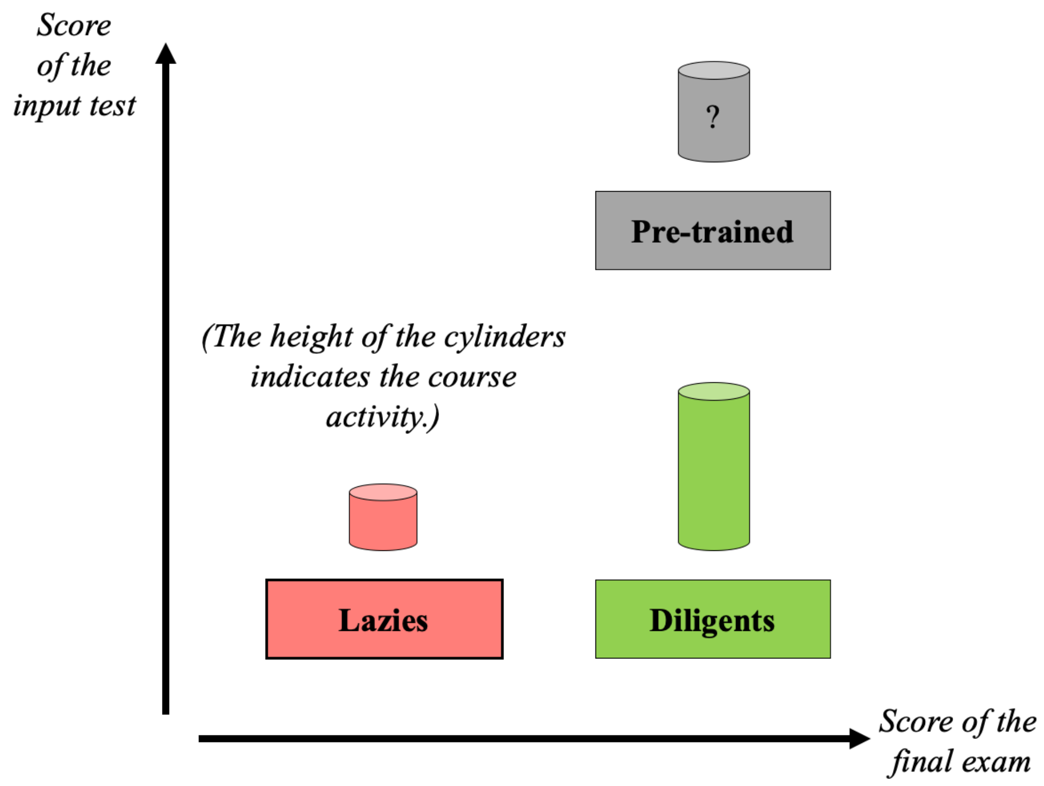
- **Pre-trained students:** students in this group are those who have good results in both the input test and the total course score, and their course activity is mixed, since it is essentially an independent factor (since they were already in possession of the necessary knowledge).

- **Diligent students:** the cluster that best characterizes the efficiency of knowledge transfer, in which the input test has a low score, and due to intensive course activity, the total score of the course is high.

- **Lazy students:** although somewhat inversely, the effectiveness of e-learning course knowledge transfer is further demonstrated by the group of students who have a low-score input test and a low overall course score, coupled with fairly passive course activity — that is, they do not acquire new knowledge without proper learning. This can only prove the effectiveness of the course if the previous cluster is present.

- **Stand out cases:** of course, so-called outlier students are also expected, who cannot be classified in any of the above clusters, who prove to be exceptions.

23. figure: Visualization of my expectations for the outcome of the cluster analysis (own creation; the height of the cylinders indicates course activity)



6.3 Knowledge transfer-centric efficiency study

As the first step of the analysis, I performed a normality test on the variables described in the previous chapter, the results of which are summarized in the table extracted from SPSS below.

18. table: Results of normality tests (own creation, SPSS)

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
assessment_score	0,110	147	0,000	0,882	147	0,000
activity_score	0,074	147	0,047	0,975	147	0,009
course_score	0,212	147	0,000	0,725	147	0,000
question_score	0,159	200	0,000	0,842	200	0,000
course_entering	0,144	147	0,000	0,869	147	0,000
module_view	0,100	147	0,001	0,920	147	0,000
active_days	0,120	147	0,000	0,923	147	0,000
passive_time	0,120	147	0,000	0,909	147	0,000

Due to the size of the sample (less than 200), I took into account the results of the Shapiro-Wilk test among the normality tests - but the Kolmogorov-Smirnov test also shows the same results. The null hypothesis of the test is that the tested sample has a normal distribution, which is acceptable above the significance level of 0.05. It can be concluded from the analysis that none of the examined indicators can be considered as normally distributed. The only indicator where we get a value other than 0 in the third decimal place is the unique indicator of inter-course activity (*activity_score*).

In order to get a closer picture of the examined indicators and their deviation from the normal distribution, it is worth examining the histograms drawn by the indicators, as well as the dispersion, skewness and kurtosis indicators in addition to the descriptive statistical indicators. For ease of transparency, I will divide the 8 indicators into two logical units: first, I analyze **scoring indicators** (mainly based on testing) (*assessment_score*, *activity_score*, *course_score*, *question_score*), then I move on to **activity-specific** (mostly behavior-based) **indicators** (*course_entering*, *module_view*, *active_days*, *passive_time*).

Beyond the clearly readable and interpretable indicators (mean, deviation), it is worth examining the skewness and kurtosis indicators. For skewness indicators, the negative value shows a distribution that extends to the left (i.e. apex to the right): in our case, such is the inter-course activity, the total score at the end of the course, and the indicator of test questions; in contrast, the skewness indicator of the input test score is positive, i.e., extending to the right (apex to the left). For kurtosis indicators, a positive value indicates a more grouped (peaked) distribution at the extreme values compared to normal, and a negative value indicates a more grouped (flattened) distribution than at the middle values of the bell curve. In our case, all 4 of our indicators are characterized by a positive value, i.e. a more peaked distribution.

19. table: Descriptive statistics and dispersion indicators – scoring indicators (own creation, SPSS)

		assessment_ score	activity_ score	course_ score	question_ score
N	Valid	147	190	190	200
	Missing	43	0	0	0

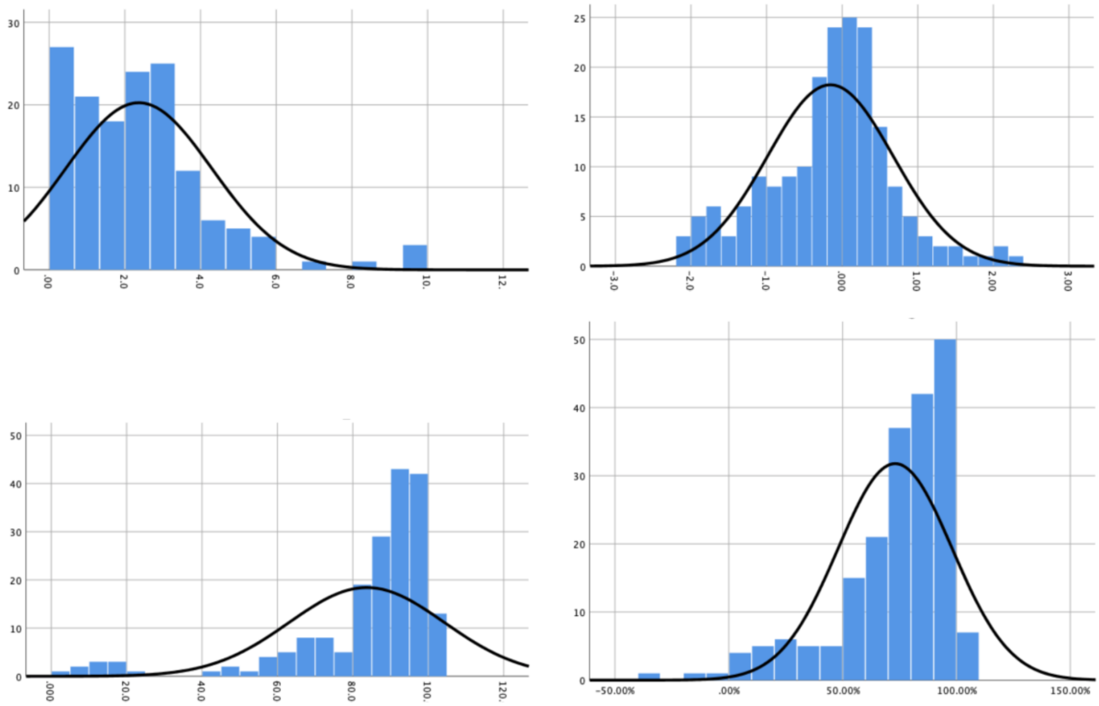
Mean	2,37	-0,16	83,68	73,06%
Std. Deviation	1,93	0,83	20,58	25,11%
Skewness	1,517	-0,140	-2,279	-1,571
Std. Error of Skewness	0,200	0,176	0,176	0,172
Kurtosis	3,711	0,448	5,201	2,378
Std. Error of Kurtosis	0,397	0,351	0,351	0,342
Range	10	4,40	100,91	130,30%
Minimum	0	-2,19	2,17	-30,30%
Maximum	10	2,20	103,08	100,00%

The results of the skewness indicators are also confirmed by the histograms drawn by the indicators. The significant shift between the input test and the total score at the end of the course can be explained by the fact that at the beginning of the course the students did not have any prior knowledge of the subject, and by the end of the course, probably due to the success of the education (knowledge transfer), the achieved results will be grouped around the better grades. However, the actual cause and effect relationship is examined only in later analyzes (based on regression and cluster analysis).

Two kinds of conclusions can be drawn from the right-tipped curves of the results obtained from the tests. A better average response rate compared to the normal distribution may mean that the questions given to the students are too easy, or we may assume acquired knowledge just as above. However, in order to decide which of the two is true, it is necessary to examine the correctness of the answers to the questions first at the beginning of the course (input test) and then separately at the end of the course (final test) – unfortunately, based on the available data, this is currently not possible, since only summary statistics can be retrieved from the system.

Based on both the indicators and visual appearance, the individually weighted measure of course activity (course_activity) is the closest to the normal distribution. This fact is not surprising, since based on the central limit theorem discussed in the previous chapter, when examining several variables together, its distribution will begin to approach normal distribution.

24. figure: Histograms of the variables assessment_score (top left), activity_score (top right), course_score (bottom left) and question_score (bottom right) compared to the normal distribution curve (own creation, SPSS)



Continuing the analysis, I also examined the indicators characterizing the activity. As in the case of the previous 4 indicators, these distributions are one by one more peaked than the normal distribution - the values of the kurtosis indicator are positive. Regarding the skewness indicators, all the examined indicators give a positive value, so we can see left-peaked, right-flattened distributions of these measures.

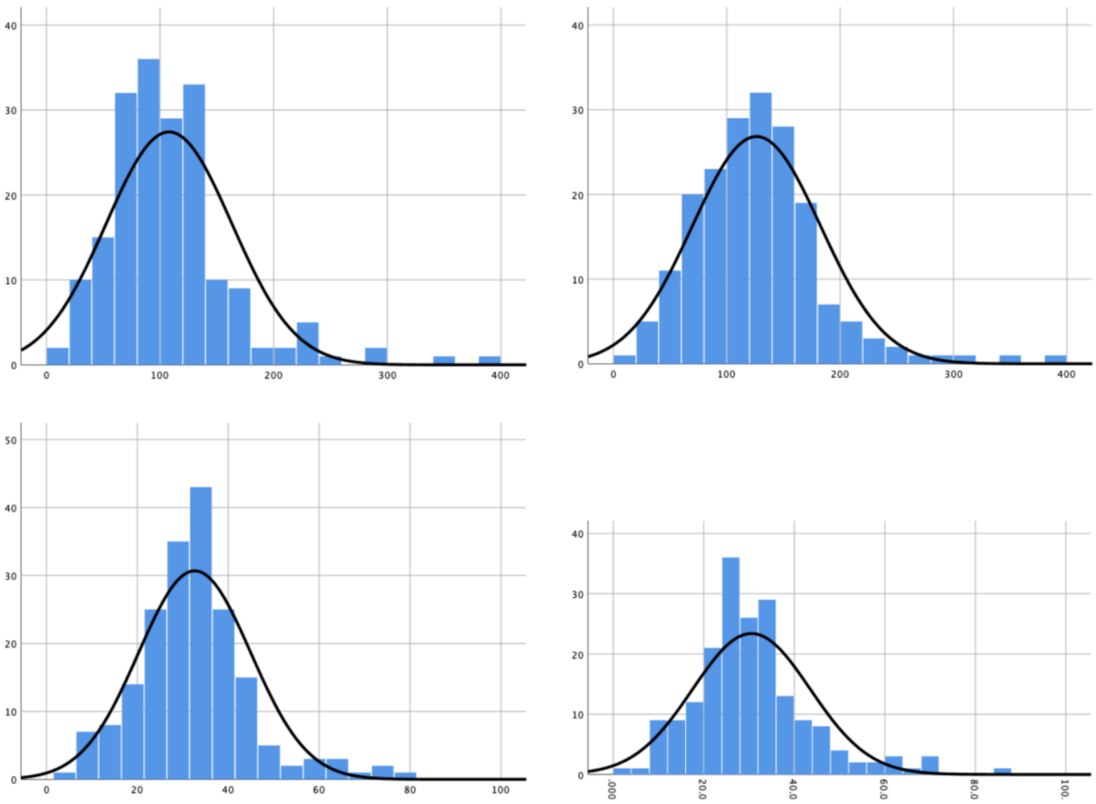
20. table: Descriptive statistics and dispersion indicators – activity indicators (own creation, SPSS)

		course_ entering	module_ view	active_ days	passive_ time
N	Valid	190	190	190	190
	Missing	0	0	0	0
Mean		107,92	126,26	32,62	30,54
Std. Deviation		55,29	56,50	12,35	12,96
Skewness		1,713	1,182	0,744	1,060
Std. Error of Skewness		0,176	0,176	0,176	0,176

Kurtosis	5,183	3,318	1,756	2,210
Std. Error of Kurtosis	0,351	0,351	0,351	0,351
Range	368	370	74	81,92
Minimum	17	16	4	3,26
Maximum	385	386	78	85,19

Examining the histograms of the distributions, it can be seen that each of its shapes are quite close to that of normal distribution. Given that the examined indicators are bounded from the bottom one by one (starting from zero) but not from the top (they go to infinity theoretically), the distributions peaking to the left are not of any surprise at all. With the exception of the protruding extreme cases, I might have been able to obtain samples with a normal distribution from the examined sample, but I also considered these values to be relevant. Although these metrics are from different approaches, they both measure the behavior of students in relation to the e-learning course, neither remarkably well nor remarkably poorly, as we do not experience extreme distortion in the indicators of kurtosis and skewness.

25. ábra: Histograms of course_entering (top left), module_view (top right), active_days (bottom left), and passive_time (bottom right) compared to the normal distribution curve (own creation, SPSS)



Summarizing the results so far, it can be seen that although the e-learning course is of average quality (the number of course visits gives peak distributions on the left), the students' knowledge at the beginning of the course was significantly increased by the end of the course. For further analysis of this, it is also worth performing regression-based calculations for the cause and effect study.

6.4 Result-based efficiency analysis - regression calculation

The variables to be included in the regression calculation model according to the preliminary plans are as follows:

- Dependent variable: end-of-course score (*course_score*)
- Independent variables: input test score (assessment_score), unique measure of course activity (activity_score)

Before building the regression model, it is worth examining the correlation between the dependent and independent variables. Based on the number of elements in the sample, I calculated the Pearson's correlation coefficient using SPSS. The analysis shows that there is a statistically significant relationship between the total score at the end of the course, and the input test and activity score - although this relationship is rather weak (both is around 0.25). However, there is no significant relationship between the input test of the course and the activity, so they will be included in the linear regression as truly independent variables.

21. table: Analysis of the correlation between the variables (own creation, SPSS)

		assessment_score	activity_score	course_score
assessment_score	Pearson Correlation	1	0,205	0,245
	Sig. (2-tailed)		0,014	0,003
	N	144	144	144
activity_score	Pearson Correlation	0,205	1	0,264
	Sig. (2-tailed)	0,014		0,001
	N	144	144	144
course_score	Pearson Correlation	0,245	0,264	1
	Sig. (2-tailed)	0,003	0,001	
	N	144	144	144

After examining the correlation between the variables, I performed the regression analysis, which is summarized in the following table. One of the most important indicators in the analysis is R^2, according to which the explanatory variables included in the linear regression explain together the value of the outcome variable to about 11%.

22. table: Summary analysis of the linear regression model (own creation, SPSS)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,329	0,108	0,095	10,132465121308174

Although the explanatory power of the model is not very high, its significance is still decisive. In several previous points of my dissertation and research, I have established that the efficiency of knowledge transfer depends on many factors, the measurement of which pushes the boundaries of the impossible. The significance of the model is confirmed by the ANOVA table of linear regression, in which the F-test examines whether the whole model can be considered significant – in our case, at a significance level of 95%, it can be stated with complete certainty that the model is significant. The R^2 indicator can also be well perceived from the ANOVA table, since the sum of squares of the regression is about one tenth of the sum of squares of the residuals.

23. table: ANOVA table of the linear regression model (own creation, SPSS)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1751,769	2	875,884	8,531	0,000
	Residual	14476,026	141	102,667		
	Total	16227,795	143			

Finally, as the last step of the linear regression calculation, we examine the coefficients of the regression model, their individual significance, and we also interpret the coefficients. According to the model, both the input test and the course activity metrics appear as significant parameters in the model (with a value significantly lower than 0.05) - of the two, the course activity point can be considered the more significant. According to the interpretation of the coefficient B of the input test, leaving all other conditions unchanged, an input test higher by 1 point results in an average end-of-course score higher by 1.094 points on average. In contrast, increasing the individual (standard normalized) score of the course activity by one (and leaving all other conditions unchanged) gives an end-of-course score higher by 3.409.

24. table: Coefficients of the linear regression model (own creation, SPSS)

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	86,931	1,341		64,816	0,000

	assessment_score	1,094	0,446	0,199	2,453	0,015
	activity_score	3,409	1,239	0,224	2,750	0,007

Based on the above, therefore, our linear regression model looks as follows:

$$y_{\text{total course score}} = \beta_0 + \beta_{\text{input test}} x_{\text{input test}} + \beta_{\text{activity}} x_{\text{activity}} + \varepsilon$$

$$y_{\text{total course score}} = 86{,}931 + 1{,}094 x_{\text{input test}} + 3{,}409 x_{\text{activity}} + \varepsilon$$

Overall, I have successfully fitted a linear regression to the total course score, the input test and course activity metrics. Although the explanatory power of the model was low, its significant nature is unquestionable. Based on the above, no clear conclusion can be drawn regarding the goodness of the e-learning course – in any case, it seems that compared to the input knowledge, the activity measured in the course has an explanatory power of about 1.15 times in relation to the final result of the course, i.e. the e-learning course definitely contributes to the knowledge transfer.

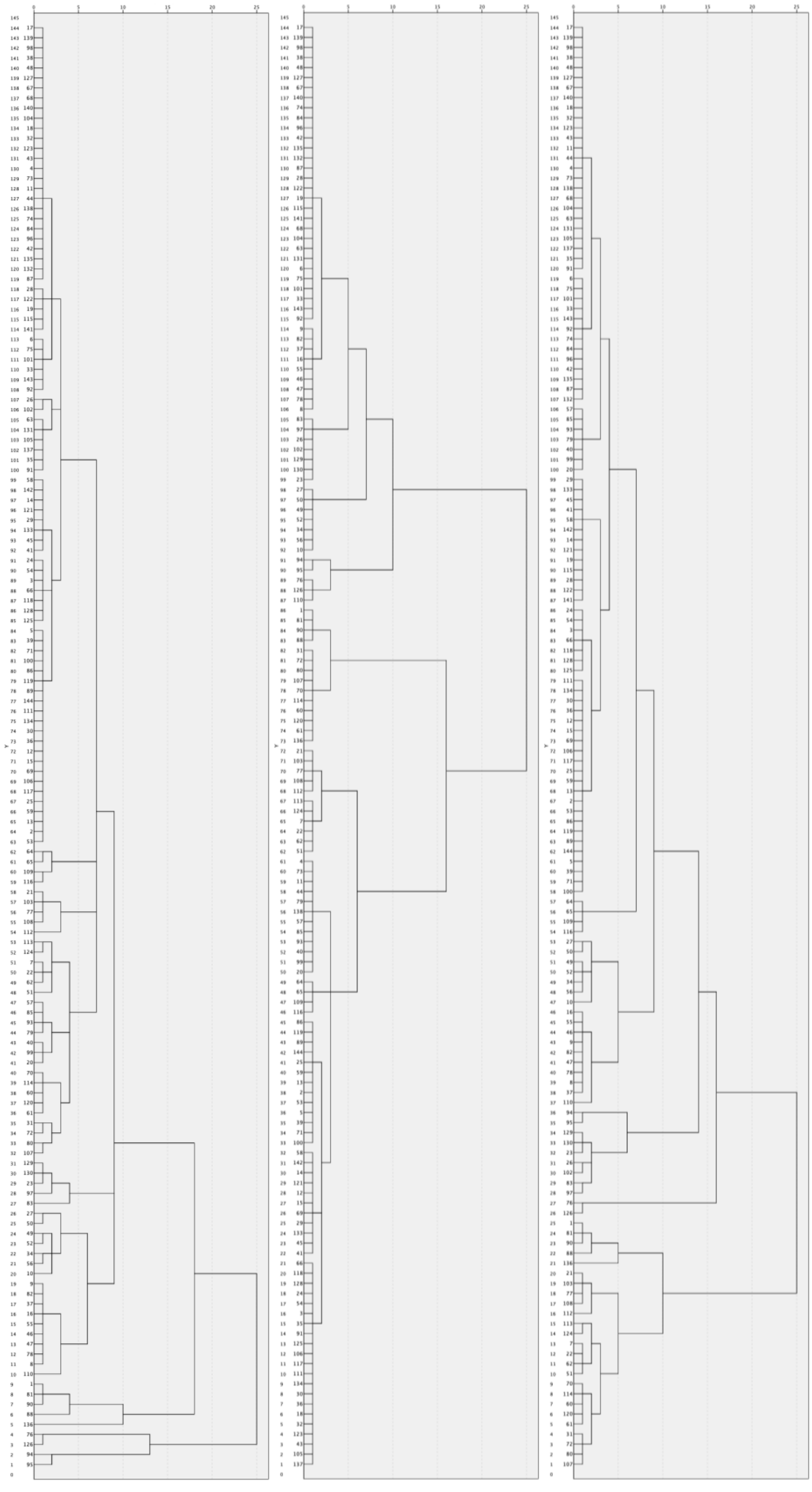
6.5 Result-based efficiency analysis - cluster analysis

As a result of the regression calculation performed in the previous chapter, I determined that the input test of the course and the inter-course activity of the students play a decisive factor in the total score of the students at the end of the course. In order to be able to evaluate this relationship from another dimension, I will use the tool of cluster analysis to classify the students of the course into different groups. For stable and reliable results, I will perform the cluster analysis using both hierarchical and k-means methods, using 3 different clustering methods in the case of the former.

6.5.1 Hierarchical cluster analysis

First, I will perform the hierarchical clustering, the 3 dendrograms of which are shown in the following figure. I will present their analysis and interpretation following the figure.

26. figure: Dendrograms of hierarchical cluster analysis procedures (from the left: between groups linkage, Ward's method, farthest neighbor) (own creation, SPSS)



Before performing the cluster analyzes, I standardized the 3 variables to be included with the help of SPSS, so I already worked with the variables Zscore (assessment_score), Zscore (activity_score) and Zscore (course_score) in the analysis. First, I performed an analysis according to the method between groups (between groups linkage). According to the rule of thumb, when determining the number of clusters, I took into account the larger stand out points, so I finally classified the students into three clusters. The first 4-item cluster included students whose input test, course activity, and year-end score were all outstandingly high. The second, 5-item cluster included students who had low input and final scores and average activity. The last cluster of 135 elements includes everybody. I do not consider this procedure to be effective, as instead of creating real clusters, it only filtered out overly extreme cases.

The second cluster analysis type, the Ward's method proves to be more effective, since the number of elements of the clusters shows a more even distribution:

- In the first, 14-item cluster, particularly poor students were included with low input and final scores and lower-than-average course activity.
- In the second, 58-item cluster, students with good final results and a higher-than-average course activity scores were included. Their input tests were mixed, not showing a clear pattern.
- All other students were placed in the third cluster of 72 items, typically with a good year-end score, but their course activity and input score show mixed results.

We have obtained clearly better clusters using Ward's method, which is in line with our regression analysis: in the majority of cases, students' inter-course activity explains the year-end score, but in most cases, there is no close relationship between the two metrics. (As a reminder, according to the regression analysis, the two independent variables together explained the outcome variable in 11%.).

Finally, I used the farthest neighbor method, which is somewhere between the previous two in terms of usability. As a result, bad students were also separated, forming a 25-item cluster. In addition to students with extremely poor overall scores, this procedure also included those who were not significantly worse than average. This is followed by a group that has not yet been included: 32 students with completely average course activity, a stronger-than-average input test and a good total end-of-course score. We can call them “pre-trained” students who already had some knowledge at the beginning of the course. The last cluster of 87 people typically included students with a good overall score, with completely mixed input test score and course activity.

Overall, the cluster analysis provided a somewhat subjective tool compared to the previous statistical tools, and we were able to find somewhat distinct groups of students with different procedural methods.

6.5.2 K-means cluster analysis

Since the analyst determines the desired number of clusters in the case of the k-means cluster analysis, I will select and give the number of clusters in the case of the k-means analysis, which can be determined from the hierarchical analysis. As a result of hierarchical cluster analyzes, we can see that even when working along different methods, the typical cluster number was 3, so I also rendered 3 clusters in the model for the k-means cluster analysis. It is worth examining the ANOVA table first, in which the significance of the F-tests shows that all three involved variables should be used in the cluster analysis.

25. table: ANOVA table of k-means cluster analysis (own creation, SPSS)

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
Zscore (assessment_score)	27,977	2	0,617	141	45,319	0,000
Zscore (activity_score)	25,027	2	0,659	141	37,967	0,000
Zscore (course_score)	48,150	2	0,331	141	145,380	0,000

The number of groups created during the k-means cluster analysis is very similar to the number of items determined by the third hierarchical cluster analysis. The number of clusters is shown in the table below, extracted from SPSS: 26 in the first, 25 in the second and 93 in the third.

26. table: Element numbers of clusters in k-means cluster analysis (own creation, SPSS)

Cluster	1	26
	2	25
	3	93
Valid		144
Missing		0

The most important output of the k-means cluster analysis is the table where we can see the means in each cluster as measured by the standardized scores. In our case, the analysis created the following groups:

- The 26 students of the first cluster achieved lower-than-average results (in addition, particularly low in the case of the total course score) for all three metrics. This group therefore represents **the unskilled and lazy** students who had little prior knowledge, were not active, and this is reflected in their final score.

- The 25 students of the second cluster represent **the educated and hard-working** group: with a significantly higher than average input score and outstanding activity, they achieved a high total end-of-course score.

- The third cluster of 93 includes **the average students**, whose neither pre-education nor inter-course activity is outstanding, but they have achieved nice, slightly higher than average results by the end of the course.

27. table: The final cluster means of the k-means cluster analysis (own creation, SPSS)

	Cluster		
	1	2	3
Zscore(assessment_score)	-0,401	1,355	-0,252
Zscore(activity_score)	-0,803	1,143	-0,083
Zscore(course_score)	-1,723	0,638	0,310

Comparing the results of the 4 clustering procedures, we can report a result that is broadly in line with expectations. The group of lazy, poorly performing students I hypothesized was indeed included in virtually all clustering procedures. However, contrary to my expectations, several clustering procedures grouped pre-trained and hard-working students into one group, who ultimately achieved good results – on the other hand, there was never a significant group in which good results could be achieved throughout the course with high activity following a low input score (i.e. lack of pre-existing knowledge).

6.6 Evaluation of the developed measurement methods

The aim of my dissertation was to set up a measurement method that alone (without comparison or a control group) is suitable for drawing conclusions about the goodness of an e-learning course. The hypothesis I set up was as follows:

The unique measurement method I have created is suitable for drawing conclusions for the given e-learning course in terms of efficiency and effectiveness.

In the empirical phase of the research, I fitted the data set of a university course in which we used the tools of e-learning to the method I developed. To evaluate a measurement method for e-learning efficiency, I need to ask three important questions:

1. Can the developed measurement tools **be fitted to the data** extracted (and prepared) from the e-learning system?

2. **Can conclusions be drawn** about the efficiency of the e-learning course?

3. **What simplification and development opportunities** are available in the developed e-learning measurement method?

The **first question** is perhaps the easiest to answer, as here only the technical feasibility needs to be confirmed. I state that the data set of a properly prepared e-learning course can be fitted to the developed e-learning measurement method. Given that the measurement method builds on long-standing, tried and tested mathematical and statistical models, their usability is beyond question. Here, however, it is important to highlight that the range of data generated and recorded by each e-learning system varies in quantity, quality, and format. Consequently, it is not possible to make a general statement that data from *any* e-learning course can be fitted to the measurement model. Nevertheless, the course I tested was extracted from the currently most common open source Moodle e-learning system, so the measurement toolkit becomes widely applicable. Hopefully the range of data recorded by Moodle will be further expanded in the future (e.g. by recording exits from the course), thus facilitating even better utilization of the measurement method.

The **second question**, whether conclusions can be drawn about the efficiency of the e-learning course, is a bit more complex. During the empirical research of my dissertation, I constantly tried to formulate both mathematically and statistically substantiated statements along the guidelines of the measurement method for the evaluated e-learning course. It is important to emphasize that the measurement method contains elements based on subjective judgment. With the wide range of tools provided by the measurement method, it is possible to draw as accurate and correct conclusions as possible if we examine them not in isolation, but in connection with each other – and this provides the greatest lesson for the practical implementation of empirical research. The interpretation of the dispersion, skewness and kurtosis indicators alone can be very misleading when measuring the e-learning course, but by comparing and merging them with the results of correlation calculation, regression modeling and cluster analysis we can draw well-founded conclusions for the given e-learning course. Thus, **besides the full use of the measurement method, it is suitable to draw conclusions regarding the efficiency and effectiveness of the examined e-learning course.**

The **third question** examines the possibilities for further development of the measurement method. In this regard, I make the following suggestions:

- Elaboration of a general proposal for an indicator measuring the activity of the course: i.e. including what parameters with what weight can be ideal to determine this (e.g. by correlation calculation).

- Inclusion of additional variables in the linear regression model, which can further increase the explanatory power and significance of the model.

- Inclusion of another variable in the cluster analysis procedures, thus opening the possibility to form even more precise groups.

- Narrow down cluster analysis procedures to a narrower circle that can generally give good results for analyzing e-learning courses. This can be done after testing a number of courses.

- It can also help the analyst if the measurement method also formulates specific value limits and rules of thumb for the interpretation of the obtained results. (For example, above what value of the skewness indicator do we consider e-learning to be slightly, moderately or very efficient.) This will, of course, require benchmark data.

I consider the formulation of further proposals realistic after the measurement method has been performed on several (maybe even a couple 100) different courses. Following the completion of this research, a number of additional practical and theoretical advices may emerge, which may make subsequent research shorter, faster, and simpler in time.

7 SUMMARY

At the beginning of my doctoral studies, I chose e-learning as my field of research. More than 5 years later, enriched by numerous researches, work, teaching and practical experiences, I have arrived at the last chapter of my dissertation. I consider the goals set at the beginning of the dissertation to have been achieved, and my experiences and thoughts accumulated during the research can hopefully provide a useful point of reference for many in the world of e-learning. In the following, I will summarize the results obtained during the creation of the dissertation and look at further research opportunities, which were partly formulated in me during the writing of the dissertation.

7.1 Results of the dissertation

In this chapter, I will present the most important results of the dissertation, which can be summarized by focusing on four main areas:

1. Conceptual clarification of the e-learning ecosystem both at the international level and taking into account the peculiarities of the Hungarian language, in the framework of an extensive literature review.

2. Development of a new measurement method for the efficiency and effectiveness of e-learning knowledge transfer.

3. Development of a new measurement method to calculate the break-even point of the e-learning form of education.

4. Testing and evaluation of the measurement method developed in the third point through real practical examples and empirical research.

In the spirit of transparency and easy interpretation, I summarized the central result of the dissertation in one paragraph:

In the dissertation I set up a metric (measurement system) based on the characteristics of e-learning, and I also validated it within the framework of the dissertation. My goal was to give the field of e-learning a tool to evaluate the effectiveness and efficiency of this form of education. The aim of the empirical research carried out in the dissertation was to examine the applicability of the

method in a real environment, which shed light on its limitations and possibilities for expansion and further development.

7.1.1 Conceptual clarification, literature review

Due to the novelty of e-learning, I consider it important to form a comprehensive picture of the e-learning ecosystem as the first step of my research: I examined the current trends in the e-learning market and elaborated some of the approaches of professional literature to define the concept of e-learning. Using this experience, I also attempted to formulate my own definition of e-learning

As a next step, one step away from the specific definition of e-learning, I examined its components and constituents: the e-learning system, the e-learning content and the personas of e-learning. In addition to the conceptual definitions, I plotted their points of connection and detailed the role of the e-learning components in the e-learning ecosystem.

As a final step to get an even broader and more accurate picture of the e-learning ecosystem, I examined additional concepts and expressions that are related to the world of e-learning in some form, and drew the network and connections of these additional concepts. Finally, I made a thorough comparison with the surrogate and complementary service of e-learning: attendance education.

7.1.2 Development of an e-learning knowledge transfer measurement method

The primary goal of my research was to find a measurement method that is suitable for measuring the efficiency of e-learning courses in terms of knowledge transfer without being able to compare them to any control group. As such a measurement method did not yet exist, I first examined the expectations and requirements for good measurement methods in general, and then I examined the measurement tools used in classroom (attendance) training as good practice and as a starting point – and I also expressed my criticisms of them, which were mainly about its subjectivity and tutor-centredness.

Based on these experiences, I developed a method based on mathematical and statistical methods, which, thanks to the IT background provided by e-learning, make use of the possibilities provided by automated and digital data recording. I provided tools from two approaches to calculate the efficiency and effectiveness of the e-learning form of education:

1. Knowledge transfer-centric measurement method;
2. Result-based measurement method.

The knowledge transfer-centric measurement method primarily analyzes the behavior of e-learning users with dispersion, kurtosis and skewness indicators. My basic assumption according to the measurement method is based on the central limit theorem, according to which observations depending on many factors typically approach a normal distribution. Based on this, I assumed that participation in a completely average e-learning course to be normally distributed, and I examined the nature of the deviations from it with the indicators above.

The result-based measurement method compares the results of the students' input knowledge assessment test and the final result at the end of the e-learning course, and characterizes the knowledge transfer between the two with an individual activity indicator. Analyzing the correlations between these three variables with correlation and regression calculations and clustering procedures, and the joint interpretation of these studies, we can also get an idea of the goodness of the e-learning course.

7.1.3 Development of the e-learning break-even point calculation

In order to be able to fully evaluate an e-learning course, in addition to knowledge transfer, I also found it necessary to examine its material and financial implications. It is no use if an e-learning course is extremely effective in transferring knowledge if the cost of producing the course far exceeds the cost of a classroom training with the same professional content. People facing such decisions will need both sets of information, so I also developed a method for calculating the e-learning break-even point.

For this, I first examined the specifics and cost structure of e-learning development projects (chapter 5), which I paralleled with the typical expenditures of attendance education. The main conclusion of this is that attendance training has uniformly distributed, even expenses with the tutor and classroom rental costs, while e-learning has a significantly lower maintenance cost after the initial investment.

Along this, I set up a method for calculating the break-even point, which determines the break-even point of the investment in e-learning, measured in years. I did not examine this method with empirical data, but I demonstrated its applicability in practice through the example of a fictitious case generated by me.

7.1.4 Testing and evaluation of the method of measuring knowledge transfer

The hypothesis formulated in my dissertation was that the method I developed, which measures the efficiency and effectiveness of knowledge transfer, is suitable for drawing conclusions about the goodness of e-learning. To prove this, we converted one of the subjects of the Corvinus University of Budapest to e-learning form, and I fitted the data generated and collected in the Moodle e-learning system of the University to the measurement methods.

I divided the evaluation of the measurement method into 3 phases: first I examined whether the data fitted properly, then I examined the usefulness of the conclusions that can be drawn from the measurement methods, and thirdly I formulated remarks, criticisms and suggestions for further development. After proper preparation and cleansing of the data, I successfully fitted them to both the knowledge transfer-based and result-based measurement methods. I managed to draw interpretable and usable conclusions about the e-learning course, so I considered the developed measurement method to be suitable and my hypothesis to be justified. Finally, the suggestions and critiques formulated in the last step make the measurement method suitable for fine-tuning and further development.

7.2 Further research opportunities

Arriving at the end of my research, I still see a lot of potential in the topic, in formulating and later on elaborating further research questions. In the following segment, I will propose another research on the topic of the present dissertation, that may continue the line of thought outlined here, and which, although is not part of my present dissertation, I consider to be an opportunity for a possible next step after the defense of the dissertation.

7.2.1 Extending the empirical research

I applied the e-learning measurement tools developed in this dissertation to a single e-learning-supported course in the framework of my empirical research, with which I primarily tested the measurement methods. The results of this research provide an answer as to the effectiveness and efficiency of a given course; however, no general conclusions can be drawn about the effectiveness and efficiency of e-learning education.

As a further research topic, I propose to use the same measurement tools in many different e-learning courses. By summarizing these results, a large number of samples can be formed, with which, with appropriate assumptions and reservations, we can even infer the whole population by hypothesis testing. In this way, we can formulate general statements about the efficiency and effectiveness of the e-learning form of education.

7.2.2 Examining student freedom at an individual level

How a student experiences the learning process can be a key factor in e-learning at the individual level. Although we can determine the efficiency and effectiveness of knowledge transfer with different indicator systems, i.e. that it is worthwhile and profitable to choose the e-learning form of education, e-learning will not be a sustainable and attractive learning method if the students' experiences are worse compared to a traditional attendance training.

The arguments in favor of e-learning (independence from time and place, individually paced, selectable pace of learning, etc.) are manifested primarily in the forms of freedom that emerge in different dimensions. A possible further research question could therefore be "**what does student freedom mean in e-learning**".

By answering this question, we may get closer to this cause and effect relationship that whether this freedom contributes more, or perhaps hinders effective learning. Although people generally prefer freedom, there some who can achieve greater success in a more cohesive and controlled setting. Thus, if we analyze how students experience the freedom provided by e-learning, it may also shed light on its effects that may increase or inhibit its efficiency and effectiveness.

7.2.3 Comparison with the results of the dissertation

Following the logic presented earlier, as a result of the qualitative research presented in the previous chapter, it is possible to study in depth and hopefully understand how the student experiences the freedom provided by e-learning. A comparison of the above qualitative and the quantitative, empirical research to be carried out in the present dissertation may raise another research question: what effect does the freedom provided by e-learning have on the efficiency of learning? If e-learning is indeed an effective and efficient form of education, is it due to the freedom it provides? If some individuals do not consider it sufficiently effective and efficient (while others do), did they experience this freedom factor differently (if they did experience it at all)? If, however, the form of e-learning education is not effective and efficient, can this be caused by the freedom inherent in it, and can it hinder the student from learning effectively and efficiently? Is there a cause and effect relationship between the two factors at all - freedom and efficiency / effectiveness? After defending my dissertation, I would like to find answers to these questions.

7.2.4 Empirical research on return calculation

Another exciting research topic could be testing the model developed to calculate the break-even point on real data. I also propose two approaches to this:

1. We determine the average costs of e-learning and attendance forms by utilizing a large sample, and then, by fitting these results to the return calculation model, we can draw general conclusions about the economics of the e-learning form of education.

2. We examine the forms of e-learning and attendance education in pairs, calculate their break-even points in pairs, and then we perform a hypothesis test on this sample and draw a general conclusion about the economics of the form of e-learning education.

The aim of both approaches is therefore to make general statements about the expected value of the break-even point of the e-learning form of education. The difference between the two approaches is in the placement of the cumulative procedure: that is, to summarize the costs separately (by form of education) and then calculate the average point of return; or on the contrary, we derive the expected value of the break-even point from the calculation of many break-even points.

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