

## DIGITAL AGE DIDACTICS: FROM TEACHING TO ENGINEERING OF LEARNING PART 1\*

M. A. Tchoshanov<sup>1</sup>

<sup>1</sup> University of Texas at El Paso, El Paso, Texas, USA

EDU612, 500 W. University Avenue, El Paso, TX 79968, United States

### Abstract

The digital age demands re-thinking of traditional teaching and learning. Rapidly growing technological innovations in education force a paradigm shift from traditional teaching to engineering of learning. Thus, the main focus of the article is on the design, development, and implementation of effective learning environments through the use of Information and Communication Technologies in various formats: face-to-face, blended, and distance education. Engineering of learning requires new understanding and reconceptualization of traditional didactics toward e-Didactics in order to effectively design and skillfully align learning objectives, content, and assessment in the digital age classroom.

**Keywords:** didactical engineering, digital age, teacher-engineer, effective learning environment.

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### About the author

**Mourat A. Tchoshanov**, Advanced Doctor in Pedagogical Sciences, Professor, Professor of Mathematics Education at the Departments of Mathematical Sciences and Teacher Education, Division of STEM Education, University of Texas at El Paso, El Paso, Texas, USA; mouratt@utep.edu

## Introduction

Since 2000 the author has been studying the approaches to the use of Information and Communication Technologies (ICT) in education and distance learning. In 2001, he developed an open access web site “Visual Mathematics” ([http://mourat.utep.edu/vis\\_math/visuala.html](http://mourat.utep.edu/vis_math/visuala.html)) and used dynamic cognitive visualization to represent solutions to mathematical problems and proofs. The website is used by the author in mathematics methods and mathematics classes at the University of Texas at El Paso, USA. During the recent years the author has been developing and teaching hybrid/blended (partially online) and distance (online) courses for pre-service and in-service training of secondary school teachers of mathematics. Analysis, modeling and designing of distance learning courses convinced the author that content and didactical knowledge are necessary but not sufficient for development of high-quality online courses. In addition, one needs to acquire a new type of knowledge that integrates content, didactics, and engineering. Application of engineering approaches to didactics is called *didactical engineering*.

In addition to teaching online, the author's enthusiasm about the efficiency of didactical engineering was supported by working with mathematics teachers in an urban public school in the southwest Texas attended by about 750 students. The school was equipped with computer labs; each mathematics classroom was

equipped with a computer for teachers and a few (three to five) computers for students to work on individual tasks and projects. Each classroom was also equipped with a projector and an interactive whiteboard. Mathematics classes were block-scheduled each day for 90 minutes. The Department of Mathematics employed 11 teachers whose teaching experience varied from one to 25 years. According to the results of the state standardized test, in 2003–2005 the average level of achievement in mathematics of the school pupils was around 41–46 %. Teachers explained the low rate by students' reluctance to learn. During summer 2005, a group of teachers invited the author to work together with the Department of Mathematics to improve academic performance of students. The analysis of the curriculum, interviews with teachers, students, and parents revealed that poor performance was due to teachers rather than students.

After a thorough analysis of the situation the author proposed to improve performance using the didactical engineering approach. The hypothesis was that the poor student performance was stipulated by the attitude of a teacher, his/ her teaching methodology and subject matter proficiency. ‘The vicious circle’ had to be broken, passive teacher behavior (as teacher-technician) had to be changed to an active one (as teacher-engineer). The author designed a professional development plan in cooperation with the teachers. Starting from the fall 2005, every two weeks he

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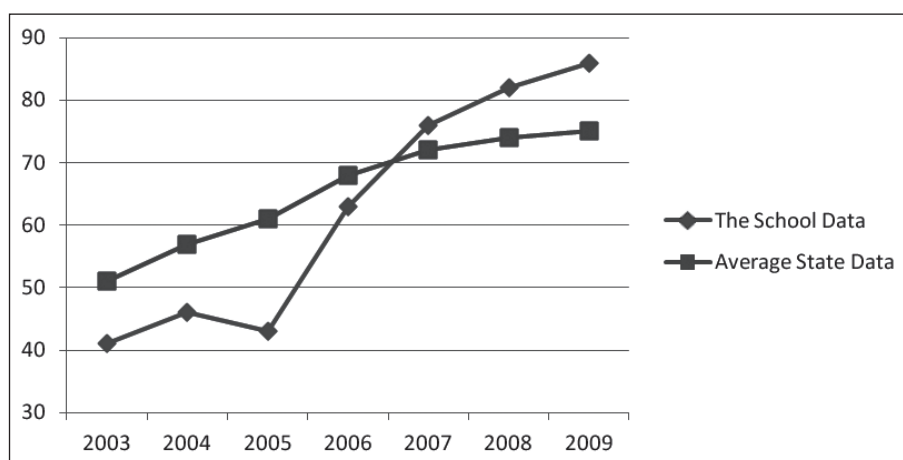


Fig. 1. Dynamics of student achievements in 2005–2009 academic years

conducted didactical engineering seminars (one and a half hour sessions) for teachers. In total, during the academic year, about 20 seminars were held, which included but were not limited to the following diverse activities: 1) analysis and development of learning objectives and expected outcomes for Mathematics topics in the curriculum; 2) detailed analysis of the content and teaching methods; 3) selection and design of tasks, problems, projects and activities for the development of students' mathematical proficiency; 4) design of lesson plans and didactical approaches to the development of students' abilities to reason and solve problems; 5) classroom observations by peers followed by analysis; 6) analysis of student work to identify and address common students' misconceptions; 7) analysis of video records of mathematics classes, etc.

The study continued during four academic years in 2005–2009. The critical point of the study was the first year (2005–2006), when teachers' attitude started slowly changing from passive to neutral. In 2006–2007 academic year, student achievements began to improve and reached the average for the state. The performance measure used in the study was the students' rate in the state standardized test — TAKS (Texas Assessment of Knowledge and Skills). During 2007–2008 academic year the school pupil performance exceeded the average rate for the state of Texas. This year teachers' attitude changed radically. Teachers no longer blamed students and became more optimistic about the results of their work. During the next academic year (2008–2009) the student achievement exceeded the psychologically meaningful level for the school — 85 %. The dynamics of the school's student achievement results in mathematics compared with the state average for the period of the study is shown in Figure 1.

## e-Didactics: Digital Age Didactics

**Origins of Didactics.** People often have limited understanding of didactics; its misinterpretation as teacher-directed learning occurs in some English-speaking countries [1, 2]. Didactics plays an important role in defining the main construct of this article — engineering of learning — via the following theoretical

chain: didactics — didactical engineering — engineering of learning. Thus, let us define didactics through the historical analysis of its origins.

There is a saying "Didactics is as old as times". It is clear that the need to learn and transmit the experience of previous generations to the next generation is a necessary condition for the development of society. Generally speaking, when one person teaches another person, this situation already suggests didactics. For example, for the case when in the most ancient times senior members of a tribe instructed young fellows in hunting mammoths, using the modern language of didactics the roles can be assigned as follows: the senior — a teacher, the younger members — students, and hunting — the content of teaching and learning. The triangle "teacher — learner — content" is called a didactical triangle. Moreover, the original meaning of the word "didactics" (from the Greek *didaskhein*) is "to teach" or "know how to teach". Let us make a brief excursion in the history of didactics in the context of the conceptual origin of didactics. Many scholars in the history of education claim that didactics was first proposed by Jan Amos Komensky (Comenius, 1592–1670) — the author of the famous "*Didactica Magna*". Not diminishing the invaluable contribution of Jan Amos Comenius to the formation of didactics as a science, let us try to restore historical justice. As noted above, the root of the word "didactics" ("*didaskhein*", "*didascalía*", "*didascalica*") is of Greek origin. The term was first used in relation to the choir rehearsals in Ancient Greece [3]. The term "*didaskaleion*" was used for the place where the music teacher conducted these rehearsals [4]. Five hundred (!) years prior to Comenius, in 1120, the French philosopher Hugo of St. Victor published a book called "*Didascalicon*" [5], which was recognized as an attempt to improve higher education in the Renaissance Era [6]. In his book, Hugh formulated the framework of educational planning at universities and suggested the rules of systematic teaching and learning using the methods of dialectics [2]. In ancient Rome and the Hellenistic era in Greece, there was a range of academic disciplines related to Fine Arts. According to the founder of the medieval encyclopedia Isidore of Seville, this set of disciplines included two cycles: the trivium (grammar, dialectic and rhetoric) and the

quadrivium (arithmetic, geometry, music, astronomy)\*. We must admit that since the Antiquity there was a kind of confrontation between the two classical fine arts: the dialectic and the rhetoric. In ancient Greece, dialectics was the method of philosophical inquiry. This method has gained worldwide recognition through the dialogues of Socrates. Rhetoric is the art of public speaking. In ancient Greece, and the more so in ancient Rome, preference was given to the rhetoric. Although Aristotle has called for “equal rights” for the dialectic and the rhetoric. However, during the Renaissance Era the dialectic “took revenge” over the rhetoric, which is reflected in “Didascalicon” by Hugh. This text was used as a basic manual in the European higher education institutions for the next three or four centuries. The dialectic has reached its dawn in the Middle Ages. Figuratively speaking, if the Antiquity is the golden age of the rhetoric, the Middle Ages is the golden age of the dialectics [7].

Attention to the problems of education has risen during the Renaissance era, which along with other great achievements was characterized by the rapid development of higher education: the number of universities and, respectively, the number of students in European countries increased considerably. By that time the society accumulated social experience and knowledge that had to be transmitted to the next generations but the lack of transmission mechanisms became an obstacle in the development of the society. In the 12<sup>th</sup> century, this contradiction, along with the development of higher education in the Renaissance era, to some extent, stimulated the interest in Hugh and his colleagues to study the problems of teaching and learning. In the 16<sup>th</sup> century, Pierre de la Ramee (Petrus Ramus), French philosopher and professor of the University of Paris, together with his fellow humanists Rodolphus Agricola and Philip Melanchthon continued the work of Hugh. Their contribution was extremely important for further formation of didactics: the ancient Greek concept of dialectics was gradually transformed into the art of teaching. Melanchthon considered dialectics as a method of teaching properly, orderly and understandably [8]. Ramee expressed this idea in a more succinct way: dialectics is an art of teaching. Ramee’s vision of the new nature and the role of dialectics in teaching was a kind of predecessor of didactics. In other words, with a certain degree of historical accuracy one can say that didactics emerged from dialectics. The progressive views of the 16<sup>th</sup>-century French humanists extended to the whole Europe [9] undoubtedly had a positive impact on the minds of other European scholars including Wolfgang Ratke. Due to the support of his colleagues Junge and Helwig, in 1612–1613 Ratke made a proposal for an initiative called “didactics as the new art of teaching”, which was supported by the Academic Council of the University of Giessen. Then, in the mid-17<sup>th</sup> century, Jan Amos Comenius, Czech educator, humanist, and intellectual, presented didactics as a system of knowledge, setting out the basic principles and rules of teaching in his seminal work “The Great Didactic” (1657). The history of didactics after Comenius is well documented in the educational literature.

As to the definition of didactics, it is most often defined as a theory of teaching and learning. Didactics addresses issues related to the main goals and guiding principles of learning and teaching, curriculum, content and methods of teaching and assessment, to name a few. Being asked whether didactics is a science or art of teaching and learning, most readers, based on the traditional definition of didactics, would answer “science”. Indeed, as a science, didactics has its categorical apparatus, methods of research, mechanisms to identify trends, its structure and logic. Thus, didactics evolved as a scientific discipline — the theory of teaching and learning. However, a theory without practice is blind. Didactics needs a teacher who would implement the theory into practice. Here comes “art” part, which plays the vital role in teacher professionalism, teacher personal qualities, culture and teaching style, creativity and talent, teaching philosophy, etc. We also cannot disregard the fact that the founders of the dialectic-didactics Hugh, Ramee, Ratke, and Comenius considered didactics, above all, as an art of teaching. Some scholars understand didactics as the theory, others — as the art of teaching and learning. Both groups are right, in their own way. As a part of pedagogy, didactics is not only the science but also the art of teaching and learning. The evolution of views on didactics is shown in Figure 2.

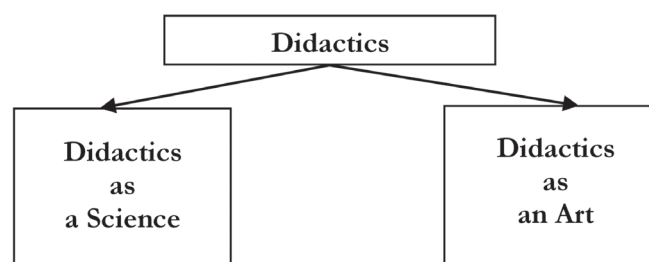


Fig. 2. The evolution of the concept of didactics

The two interpretations of didactics cannot exist separately; therefore, a question about a link between them arises naturally. The diagram does not show a “bridge” between the two components, though potentially this “bridge” should allow teachers to effectively use the didactics-science in the educational practice. To be able to teach effectively, a teacher needs to be able to conduct a comprehensive and meaningful analysis of the teaching processes and situations. S/he must also be able to select, design, and implement a variety of didactical products (e.g., learning objectives, content and learning activities, assessments, etc.). In addition to being science and art, didactics should also be considered as an engineering activity. Engineering is the process of analysis, design and construction of facilities/ mechanisms for practical purposes. Generally, the term “engineering” is applied to buildings and constructions. To build a house, one needs to make calculations for a construction site, economic analysis, including estimated cost of building materials, resources, and labor, etc.), then make the design (the drawing plan) and only then proceed to the construction. In the case of didactic engineering, we are talking about the analysis, design and construction of teaching products for learning. In other words,

\* Isidore of Seville is the patron saint of computers, computer users, and computer technicians.

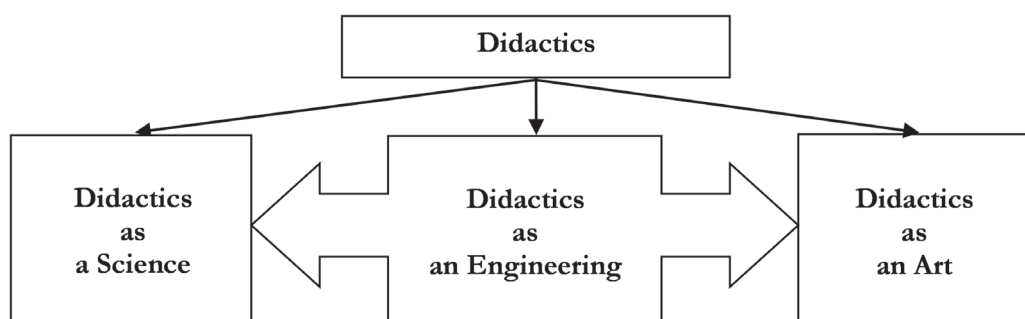


Fig. 3. Didactics as a science, engineering, and art of teaching and learning

in addition to science and art didactics should be an engineering of teaching and learning. Therefore, we propose to define *didactics as science, engineering and art of teaching and learning* (Figure 3).

**Traditional Didactics.** In a broader sense, a triangle “teacher — learner — content” including interactions among components of the trivium is called didactical (Figure 4). Originally, this construction appears in the work of Chevallard [10], Brousseau [11] et al. Chevallard introduces the construction of the didactical system which involves “three components — the teacher, the students, the knowledge taught — and the interactions between them” [10, p. 8]. Similar construction to represent the classroom culture system was proposed by Brousseau [11], which includes the teacher, the student and the *milieu* (e.g., learning tasks, instructional materials, and teaching strategies). Overall, “the didactic triangle in which the student, the teacher, and the content form the vertices (or nodes) of a triangle is the classical *trivium* used to conceptualize teaching and learning...” [12, p. 581].

Some scholars are concerned with the limitations of the classical view and suggest to consider the contextual factors (e.g., curriculum, assessment, and classroom culture) in the model. Schoenfeld [13] claims that “classrooms are cultural systems” (p. 598) and what occurs in mathematics classrooms “is indelibly a function of the cultural forces that shape them — e.g., how curricula are defined and which curricula are made available, how factors such as testing shape

teachers’ and students’ decision making within the classroom” (ibid: 598). The revised model of the didactical triangle including the context (as a broader notion incorporating curriculum, assessment, culture, etc.) is presented in Figure 5 below.

**Transformation of Didactics.** The beginning of the XXI century is characterized by the revolutionary changes associated with the intensive use of new technologies in education. The global web is increasingly impacting the daily lives of individuals and the society. Scholars started recognizing the transforming effect of technology on teaching and learning in the mid-1980-ies, as soon as computer software provided means to represent concepts in multiple ways including graphs, spreadsheets, dynamic visualization tools, etc. [14]. Due to the continuous intensive use of new technologies in the learning process, the beginning of the XXI century was marked by the attempts to revise the subject, the goals and objectives of didactics. Thus, “there have been various proposals to expand the heuristic device of the didactical triangle to form a didactical tetrahedron by adding the fourth vertex to acknowledge the significant role of technology in mediating relations between content, student and teacher” [15, p. 627] as shown in Figure 6.

Despite the fact that the didactical tetrahedron represents a whole, each of its faces reflects a specific relationship. For example, the face lying in the bottom of the tetrahedron shown in the figure above represents the traditional didactical triangle “teacher — learner —

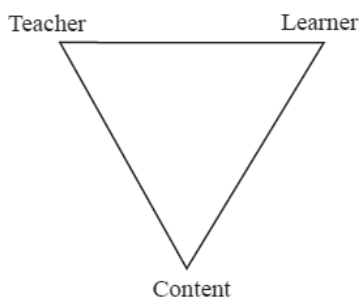


Fig. 4. The traditional didactical triangle

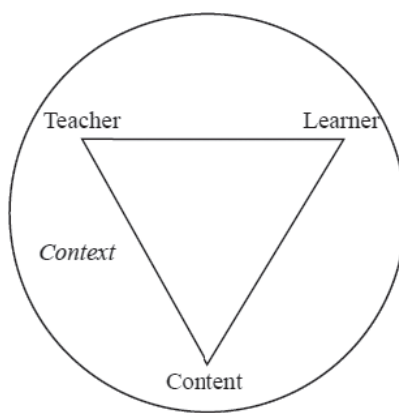


Fig. 5 The didactical triangle within the context

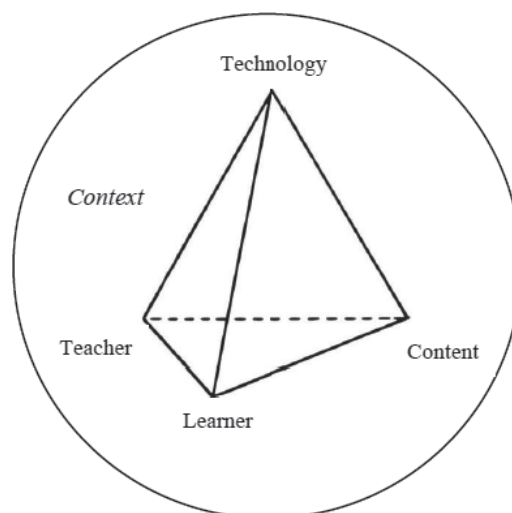


Fig. 6. The didactical tetrahedron



content". The face "learner — content — technology" reflects the interaction between the student, the content, and the technology that might be called *e-Learning*. This could also imply the 'flipped classroom' approach [16] and the self-organized learning model in a virtual environment [17]. The face "teacher — content — technology" coincides with the face of e-learning; the only difference is that a student is replaced by a teacher. That is why it is called *e-Teaching*. The next face "teacher — learner — technology" reflects an interaction between teachers and students beyond the subject domain via the use of ICT. An example of such interaction could be *e-Advising*. The didactical tetrahedron also depicts the integration of technological, pedagogical, and content knowledge, which is known as TPACK [18].

**e-Didactics and Didactical Engineering.** Reconceptualization of the traditional didactics is important in the light of rethinking its role in the digital age towards engineering of learning. New didactics of e-learning is called *e-Didactics* [19]. Broadly defined, e-Didactics is an ICT-integrated didactics. In order to identify its key characteristics, let us summarize the evolutionary development of didactics. As we mentioned earlier, didactics had several cornerstones in its development. We consider the following main stages in the conceptual evolution of didactics: Pre-didactics, Didactics-dialectics, Classic didactics, Digital age didactics.

The pre-didactics stage (IV BC — VII AD) began with Socratic Dialogues written by Plato (IV century BC), which later transformed to the well-known Socratic Method of Teaching. At this stage the classic Fine Arts curriculum was established, which included two major blocks of academic disciplines (e.g., trivium and quadrivium), described later by Isidore of Seville in "Etymologies" (VII AD). The didactics-dialectics stage (XII — XVI AD) began with the distinguished work of Hugh St. Victor "Didascalicon, or On the Study of Reading" (1120) and further continued with "Dialectique" (1555) by Ramee, where dialectics was considered as an art of teaching. At the next stage — classic (or traditional) didactics (XVII — mid-XX), we observe an important transition from the art to the

science of teaching and learning. The stage of classic didactics began with an initiative proposed by W. Ratke to call "didactics as new art of teaching" (1613) and further developed in "Didactica Magna" (1657) by J. A. Komensky, who outlined the didactical theory as a field of study of teaching and learning. This classic tradition continued to the XX century.

The stage of digital age didactics (late XX — present) began with reconceptualization of classic didactics in the era of Information and Communication Technologies. In 1991, M. Artique proposed didactical engineering as a research and development tool to study teaching and design effective learning. We consider didactical engineering as a turning point from the classic didactics to e-Didactics. In 2007, G. D'Angelo described an e-Didactics paradigm to address the phenomenon of e-Learning. The conceptual evolution of didactics is presented in Figure 7 below. Comparing the stages of pre-didactics and didactics-dialectics, one can see the emergence of the first teaching method (e.g., Socratic dialog) and curriculum (e.g., classic Fine Arts) as well as recognition of dialectics as an art of teaching. Comparing stages of didactics-dialectics and classic didactics, one can observe the emergence of didactics as a theory and field of teaching and learning study. The key distinction of digital age didactics from the classic didactics emerged in the late XX century through the development of its engineering/design characteristics.

Next, let us compare the key characteristics of classic/traditional and e-Didactics. Didactics still has its main goal on quality of teaching and learning through developing the desired level of students' competency and proficiency. Classic didactics and e-Didactics share similar theoretical foundation based on learning theory and its guiding principles of learning [20].

The main difference between classic/traditional didactics and e-Didactics is stipulated by a paradigm shift in the primary focus of didactics: from teaching to engineering of learning. This shift becomes more visible in online education where teaching in a traditional sense is limited by the structure of the format: if in traditional didactics primary delivery format is face-

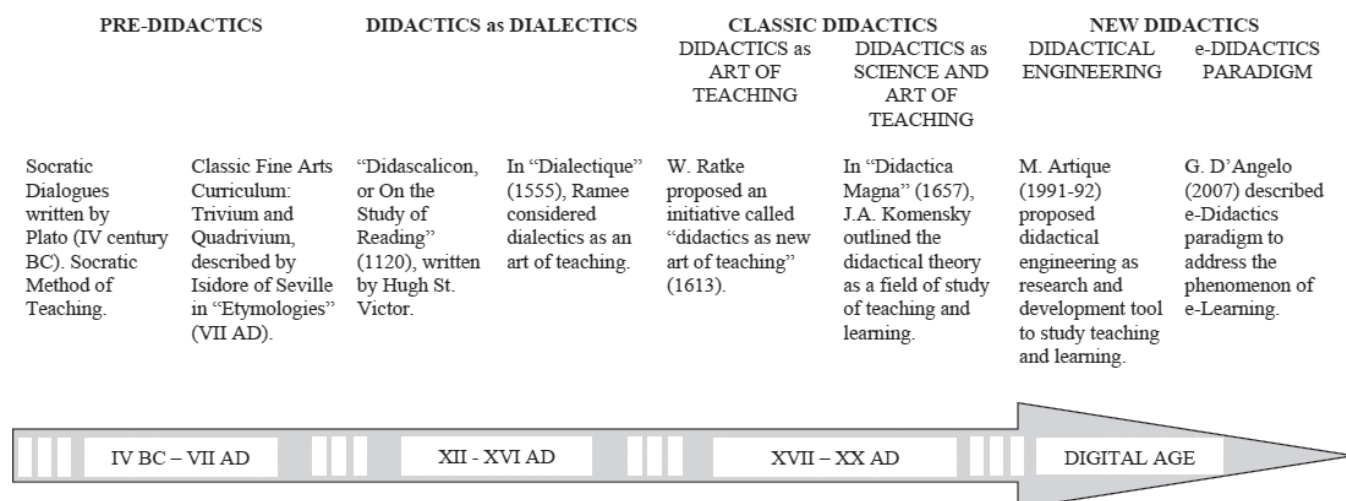


Fig. 7. Conceptual evolution of didactics

to-face (and hybrid, in some cases), in e-Didactics — it is mostly blended and online. Along with the changing delivery format, the learning and teaching space is changed: classroom is replaced by the virtual space represented by different learning management systems (LMS) and social networks. Moreover, there is a significant change in the role of a teacher in the digital age didactics: from a transmitter of knowledge to an engineer of student learning. In turn, transformation of teacher's role influences the change in student role: from an information receiver to a connected learner. Another critical difference could be observed in the primary mode of learning: passive learning transforms to more active and interactive discovery-type student engagement. This difference is impacted by the change in representation of instructional material among others: text and graphics in traditional teaching are replaced by hypertext and media in on-line education; instead of hardcopies, teachers and students get used to deal with softcopies of instructional materials; the principle of visualization in traditional didactics (e.g., mostly static and illustrative) is transformed to the principle of dynamic and interactive visualization in e-Didactics. The primary mode and means of classroom communication and assessment are also experiencing a significant change: from verbal to written; from oral classroom discourse to written exchange of ideas via online discussion, chats, and social networks; from traditional training and instruction to screencasting and videostreaming; from paper-and-pencil to e-assessment and e-folios, etc. Last but not least, there is a revolutionary change in information access: from access limited by a textbook and a teacher in traditional didactics to open access to knowledge unlimited by

ICT resources in e-Didactics. Table summarizes the results of comparative analysis between traditional and e-Didactics.

The table shows that e-Didactics has a number of characteristics that makes its position conceptually distinct from the classic didactics. The most important distinction is that ICT and engineering play critical role in e-Didactics. Therefore, *e-Didactics* could be defined as *ICT-integrated didactics with a focus on engineering of learning*. Within the framework of e-Didactics, we consider the following levels of ICT use: low, medium and high. The low level of ICT is characterized by the spontaneous use of some technological means such as calculators (including graphic calculators) or basic software (e.g., Word, Power Point, Excel). The medium level involves technology-enhanced learning with broad use of ICT and multimedia. The high level includes the use of Learning Management Systems to support the process of e-learning and e-teaching. The format of teaching and learning is divided into traditional (f2f = face-to-face), hybrid (or blended) and distance (online). The level of interactivity includes passive, active, and interactive learning environments. The interactive level is characterized by engaging students in constructive learning experiences [21]. If the zone of traditional didactics is the low level of technological tools usage in a predominantly f2f teaching and learning with primarily passive and some active learning, the zone of e-Didactics goes beyond the traditional boundaries of teaching and learning toward the virtual space using digital tools, interactive multimedia and systems of distance education with predominately interactive learning environments (Figure 8).

Table

### Comparing traditional didactics and e-Didactics

Characteristics	Traditional Didactics	e-Didactics
Dominating focus	Science and art of teaching	Engineering of learning
Primary goal	Quality of teaching and learning, students' competency and proficiency	
Theoretical basis	Research-based guiding principles of learning	
Delivery format	Face-to-face, hybrid	Hybrid, online, e-Learning
Primary teacher's role	Transmitter of knowledge	Engineer of learning
Primary student's role	Information receiver	Connected learner
Dominating mode of learning	Passive, active	Interactive
Primary learning and teaching space	Physical classroom, auditorium	Learning management systems, virtual space
Instructional material representation	Text, graphics	Hypertext, media
Instructional material format	Hardcopy	Softcopy
Use of graphics and visualization	Static and illustrative	Dynamic and interactive
Dominating mode of communication	Verbal	Written
Primary means of communication	Classroom discourse	Online discussion boards, chats, social networks
Information access	Limited by the textbook	Unlimited by ICT resources
Primary mode of scaffolding	Training, instructing	Screencasting, videostreaming
Dominating assessment format	Paper-and-pencil assessment	On-line assessment, e-Folio

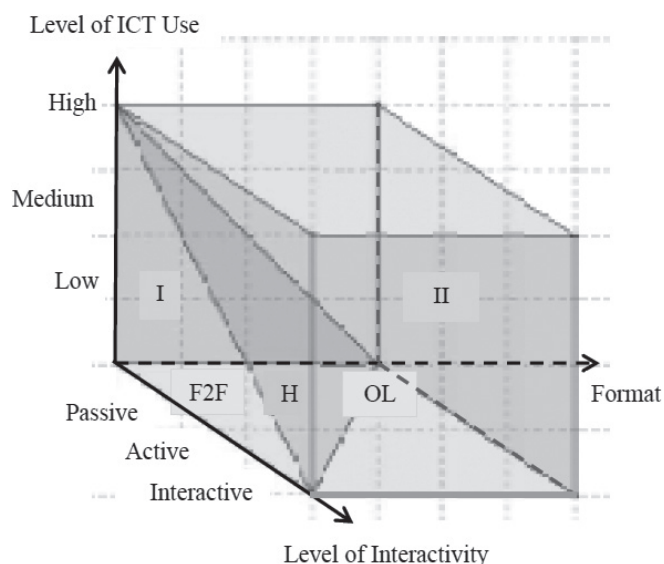


Fig. 8. The zones of traditional and e-Didactics:  
F2F — face-to-face; H — hybrid; OL — online;  
I — zone of traditional didactics; II — zone of e-Didactics

Engineering plays a significant role in the design of learning objectives, development of content, selection of teaching and learning means, and design of assessment in the structure of the e-Didactics.

## What is Didactical Engineering?

There are genetic engineering, computer engineering, or social engineering, to name a few. How these different 'engineerings' are defined? For example, genetic engineering is defined as a set of molecular biology and genetics techniques associated with the analysis, modeling, and design of new combinations of genes. Computer engineering is related to the analysis, software development and integration of software with a variety of computer platforms, hardware, and systems. Social engineering is defined as a design of activities for new social institutions as well as restructuring of existing social institutions by gradual reform and change. Each of the above cases

involves, to a certain extent, the following elements of engineering: analysis, design, modeling, construction, and development. In a broader sense, engineering is defined as analysis, design and/or construction of facilities for practical purposes. Consequently, engineering as a human activity may be applicable to various professions and it involves a wide range of activities from the analysis and design of facilities to their operation and maintenance. Therefore, didactical engineering is a kind of a generalized concept of the engineering approach to didactics.

Didactical engineering is a relatively new approach in modern education. That is why the number of publications in this area is low. First attempts to use an engineering approach in didactics took place in the 1990-ies [22–24]. Douady [24] defines didactical engineering as a series of teacher-engineer related didactical actions, which ensure the implementation of the learning project with a group of students. Ruthven [25] believes that “didactical engineering aims to develop highly precise designs that will be reproducible under suitably controlled classroom conditions, and to do so through systematic and exhaustive analysis of variables and strategies, framed in terms of an overarching didactical theory” (p. 586). Didactical engineering aims at using research-based practices and promotes the development of teaching design thinking. Didactical engineering also fosters the development of teachers’ analytic reasoning focused at the implementation of macro and micro analysis of didactical systems, processes and situations. Accordingly, didactical engineering (Figure 9) has its own subject domain that is characterized by the following main parameters: 1) analysis, design and construction of outcome-oriented teaching products (e.g., learning technologies); 2) application of a scientific method and design thinking to the analysis of didactical systems, processes and situations in order to create effective learning environments.

Didactical engineering has a dual nature: it is both a product and a process of an educational design activity. It is a product of didactical analysis and design as well as the process of applying an engineered teaching product to the learning environment. Thus,

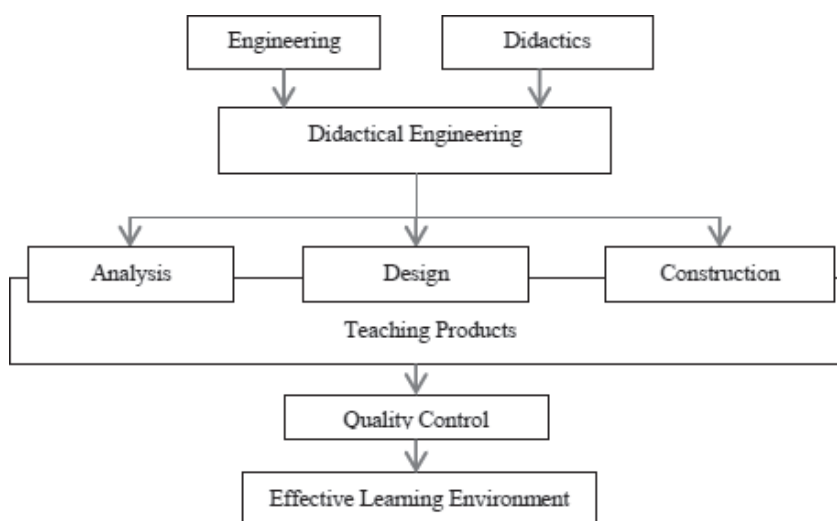


Fig. 9. Didactical engineering and design of effective learning environment

as an instructional activity, didactical engineering can be defined as a series of steps in analyzing, designing, and constructing of teaching products and their use in the instructional process in order to create effective learning environments and achieve desired learning outcomes.

## A Teacher in the Digital Age: Teacher-Engineer

The market of online educational services has been steadily growing. For example, in the Department of Teacher Education at the University of Texas at El Paso (USA) about 50 % of graduate courses are conducted in an online format. With the purpose of expanding online services, the leading universities create the MOOC consortia (e.g., Coursera, Udacity, edX) to initiate special programs for supporting the design and delivery of online courses as well as the development of new tools for online learning systems [26, 27]. However, some skeptics claim that massive open online courses are not a panacea. The Gallup/Inside Higher Ed conducted a survey of the presidents of several US universities involved in offering the MOOC. The major findings of this survey is that 54 % of the participants somewhat disagree or are not sure whether MOOC foster creative pedagogical strategies. Moreover, 83 % of the participants disagree or are not sure that the MOOC improves the learning of all students [28]. Some colleges such as the Duke University and the Amherst College rejected proposals to join the MOOC consortia because the faculty does not see the benefits of the MOOC in improving student learning, in particular at the undergraduate level. One of the faculty members expressed her concern about poorly designed online classes saying “students will watch recorded lectures and participate in sections via Webcam enjoying neither the advantages of self-paced learning nor the responsiveness of a professor who teaches to the passions and curiosities of students” [29]. The question is “how to make sense of this skepticism with the seemingly endless flurry of the MOOC-related announcements these days?” [28]. A possible answer may be that the speed at which colleges have embraced MOOCs has little to do with the readiness of the “MOOC industry” to offer high quality products. To do so a paradigm shift should occur: the shift from teaching to engineering of learning, which will foster creative pedagogical strategies to design and implement online courses. And, consequently, this shift develops an urgent need for training of “online” educators who are able to design and deliver effective distance education. This also creates a domino effect: along with the transfer of many university disciplines, including teacher education courses, to the online format, there is a need to revisit the training of school teachers themselves. Instead of traditional teacher training the focus is shifting toward the new type of teachers who can work effectively in the digital environment and satisfy high demands on teachers’ knowledge and ability to engineer online student learning. Moreover, in the digital era a teacher is not just an online tutor. The teacher becomes a kind of analyst and manager of informational resources, designer of courses, modules, lesson fragments using interactive multimedia tools.

In connection with the emerging changes in the role of a teacher, an important question raises: what kind of teacher is needed in the digital age? According to The National Educational Technology Standards (NETS) developed by the International Society for Technology in Education (ISTE), the advancement of digital age teaching is associated with the following standards: “(1) facilitate and inspire student learning and creativity; (2) design and develop digital age learning experiences and assessments; (3) model digital age work and learning; (4) promote and model digital citizenship and responsibility; and (5) engage in professional growth and leadership” [30]. The new set of standards was published by UNESCO [31]. The UNESCO ICT Competency Framework for Teachers emphasizes “that it is not enough for teachers to have ICT competencies... teachers need to be able to help students become collaborative, problem-solving, creative learners through using ICT” [31, p. 3]. This statement, in a way, echoes the above Duke University faculty’s concern on a lack of the MOOC’s support of students’ curiosity and creativity in online learning. The UNESCO Framework addresses the following teacher competencies in the digital age: “(1) understanding ICT in education; (2) curriculum and assessment; (3) pedagogy; (4) ICT; (5) organization and administration; (6) teacher professional learning” [31, p. 3]. The UNESCO Framework further expands the significance of integrating ICT and Pedagogy through the following teacher competences: (a) “integrate ICT into didactic knowledge acquisition and learning theory models; (b) create learning activities that use ICT resources to support specific educational outcomes; (c) apply ICT to “just in time” and “spontaneous” learning interactions; (d) design presentations that appropriately incorporate ICT resources” [31, p. 50–52]. Some of the above mentioned standards and competences expand the role of a teacher much beyond the traditional teaching. For instance, the UNESCO’s competency on integration of ICT and Pedagogy — “integrate ICT into didactic knowledge acquisition and learning theory models” — has a hidden call for the expansion of the role of a teacher to become a teacher-didactician — someone who is knowledgeable of the learning theory and research-based teaching. For a similar reason, Jaworsky [32] proposed an addition of an extra vertex to the traditional didactical triangle to include the didactician as an integral part of the system for teacher development. At the same time, the ISTE’s standard for teachers on “designing and developing digital age learning experiences and assessments” requires a teacher to extend his/ her role as an engineer — someone who knows and able to design and construct effective learning environments. In traditional education, the three roles mentioned above (a teacher, a didactician, an engineer) were isolated. Obviously, there is an emerging need to train a new teacher to face the challenges of the digital age, to be a teacher, who, to some extent, combines the competences of a didactician and an engineer. The digital age standards and competences demand “a push” for e-Teaching as an integration of the roles of a teacher, a didactician, and an engineer as presented in Figure 10.

The integration implies reconceptualization of the key role of a *teacher-engineer* in the digital



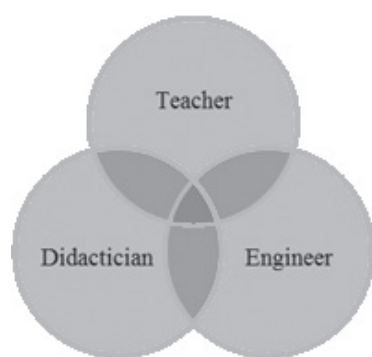


Fig. 10. Teacher-engineer

age: traditional teaching transforms toward the research-based engineering of student learning. This transformation requires a teacher-engineer to understand teaching theory and learning sciences [20, 33] in order to effectively design learning objectives, digital content and assessment, and as to make connections between the objectives, content, and assessment (Figure 11).

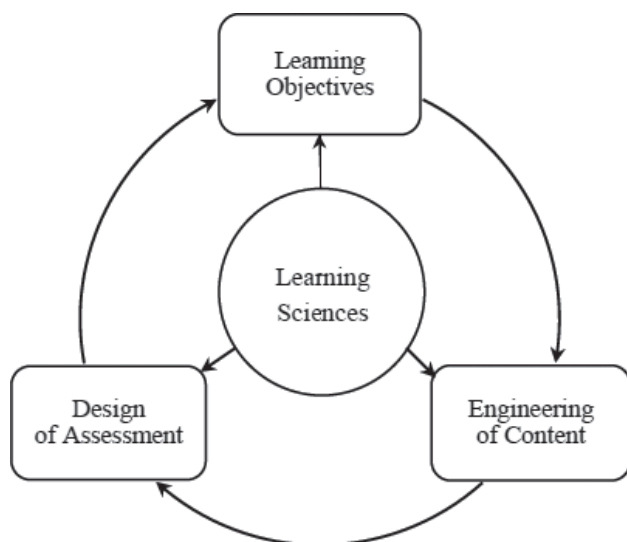


Fig. 11. Learning sciences and engineering of learning objectives, content, and assessment

The engineering of learning paradigm places a critical emphasis on the development of teachers' design thinking [34]. The development of teacher-engineer design thinking is a complex process based on the advancements of learning sciences. The teacher-engineer should acquire the following key competences: 1) design of learning objectives: create outcome-based, technology-enhanced learning environments that enable students to set their own learning objectives, monitor and assess their own learning progress; 2) engineering of content: develop interactive content and relevant learning experiences through selection and design of tasks, problems, projects, and activities that incorporates digital tools and ICT resources to promote student learning and creativity; 3) design of assessment: select and develop authentic assessments aligned with learning objectives and content; use assessment data to improve teaching and promote student learning.

## References

1. Hamilton D. The pedagogic paradox (or Why no didactics in England?). *Pedagogy, Culture and Society*, 1999, vol. 7 (1), p. 135–152.
2. Nordkvelle Y. T. Didactics: From classical rhetoric to kitchen-Latin. *Pedagogy, Culture & Society*, 2003, vol. 11 (3), p. 315–330.
3. Illich I. In the graveyard of the text: A commentary to Hugh's Didascalicon. Chicago: University of Chicago Press, 1995.
4. Myhre R. *Pedagogisk idehistorie fra oldtiden til 1860*. Oslo: Fabritius, 1976.
5. Hugh St Victor. *The Didascalicon*. Trans. by J. Taylor. NY: Columbia University Press, 1961.
6. Grabmann M. Hugh St Victor's Didascalicon: En hoyskolepedagogikk'for det 12 arhundre. *Agora*, 1998, no. 1, p. 39–46.
7. Fefner J. Tanke og Tale: Den Retoriske Tradisjon i Vesteuropa. Kobenhavn: C. A. Reitzels Forlag, 1982.
8. Ong W. Ramus: Method and the decay of dialogue. 2<sup>nd</sup> ed. New York: Octagon Books, 1974.
9. Hotson H. Philosophical pedagogy in reformed central Europe between Ramus and Comenius. *Samuel Hartlieb and universal reformation: Studies in intellectual communication* (M. Greengrass, M. Leslie, T. Raylor, eds.). Cambridge: Cambridge University Press, 1994, p. 29–50.
10. Chevallard Y. Sur l'ingénierie didactique, 1982. Preprint. Marseille: IREM d'Aix Marseille. Available at: [http://yves.chevallard.free.fr/spip/spip/article.php3?id\\_article=195](http://yves.chevallard.free.fr/spip/spip/article.php3?id_article=195)
11. Brousseau G. Theory of didactical situations in mathematics. Dordrecht, The Netherlands: Kluwer, 1997.
12. Goodchild S., Sriraman B. Revisiting the didactic triangle: From the particular to the general. *ZDM — The International Journal of Mathematics Education*, 2012, vol. 44 (5), p. 581–585.
13. Schoenfeld A. Problematizing the didactical triangle. *ZDM — The International Journal of Mathematics Education*, 2012, vol. 44 (5), p. 587–599.
14. Tall D., Vinner S. Concept image and concept definition in mathematics with particular reference to limits and continuity. *Educational Studies in Mathematics*, 1981, vol. 12 (20), p. 151–169.
15. Ruthven K. The didactical tetrahedron as a heuristic for analysing the incorporation of digital technologies into classroom practice in support of investigative approaches to teaching mathematics. *ZDM — The International Journal of Mathematics Education*, 2012, vol. 44 (5), p. 627–640.
16. Bergmann J., Sams A. Flip your classroom: Reach every student in every class every day. Alexandria: VA: ASCD, 2012.
17. Mitra S. Self-organising systems for mass computer literacy: Findings from the 'hole in the wall' experiments. *International Journal for Development Issues*, 2005, vol. 4 (1), p. 71–81.
18. Koehler M., Mishra P. What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, 2009, vol. 29 (4), p. 60–70.
19. D'Angelo G. From didactics to e-didactics: e-Learning paradigms, models and techniques. Napoli: Liguori, 2007.
20. Bransford J., Brown A., Cocking R., eds. How people learn: Brain, mind, experience, and school. Washington, DC: National Academy Press, 2000.
21. Bybee R., Taylor J. A., Gardner A., Van Scotter P., Carlson J., Westbrook A., Landes N. The BSCS 5E instructional model: Origins and effectiveness. Colorado Springs, CO: BSCS, 2006.
22. Artigue M., Perrin-Glorian M. Didactic engineering, research and development tool: Some theoretical problems linked to this duality. *For the Learning of Mathematics*, 1991, vol. 11, p. 13–17.

23. Artigue M. Didactic engineering. *Recherches en Didactique des Mathématiques*, Special book ICME VII, 1992.

24. Douady R. Didactic engineering. *Learning and teaching mathematics: An international perspective* (T. Nunes, P. Bryant, eds.). East Sussex: Psychology Press, 1997, p. 373–401.

25. Ruthven K. Linking researching with teaching: Towards synergy of scholarly and craft knowledge. *Handbook of International Research in Mathematics Education* (Lyn D. English, ed.). London: LEA, 2002, p. 581–598.

26. Greigner B. Introduction to MOOCs: Avalanche, illusion or augmentation? *Policy Brief*, July 2013. UNESCO IITE.

27. Yuan L., Powell S. MOOCs and Open Education: Implications for Higher Education. Available at: <http://publications.cetis.ac.uk/2013/667>

28. Jaschik S. MOOC skeptics at the top. *Inside Higher Ed*. May 02, 2013. Available at: <http://www.insidehighered.com/news/2013/05/02/survey-finds-presidents-are-skeptical-moocs>

29. Kolowich S. Duke U.'s undergraduate faculty derails plan for online courses for credit. *The Chronicle of Higher Education*. April 30, 2013. Available at: [http://chronicle.com/article/Duke-Us-Undergraduate/138895/?cid=at&utm\\_source=at&utm\\_medium=en](http://chronicle.com/article/Duke-Us-Undergraduate/138895/?cid=at&utm_source=at&utm_medium=en)

30. Information society for technology in education. *The National Educational Technology Standards for Teachers*. ISTE, 2008. Available at: <http://www.iste.org/standards/nets-for-teachers/>

31. UNESCO ICT Competency Framework for Teachers. UNESCO, 2011. Available at: <http://www.unesco.org/new/en/unesco/themes/icts/teacher-education/unesco-ict-competency-framework-for-teachers/>

32. Jaworsky B. Mathematics teaching development as a human practice: Identifying and drawing the threads. *ZDM — The International Journal of Mathematics Education*, 2012, vol. 44 (5). DOI: 10.1007/s11858-012-0437-7

33. Sawyer K., ed. The Cambridge handbook of the learning sciences. Cambridge: Cambridge University Press, 2006.

34. Dym C., Agogino A., Eris O., Frey D., Leifer L. Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, 2005, vol. 94 (1), p. 103–120.

## ДИДАКТИКА ЦИФРОВОЙ ЭПОХИ: ОТ ПРЕПОДАВАНИЯ К ИНЖЕНЕРИИ УЧЕНИЯ ЧАСТЬ 1

М. А. Чошанов<sup>1</sup>

<sup>1</sup> *Техасский университет в Эль-Пасо, Техас, США*

EDU612, 500 W. University Avenue, El Paso, TX 79968, United States

### Аннотация

Цифровая эпоха требует пересмотра традиционного преподавания и учения. Быстро растущие технологические инновации в образовании обуславливают смену парадигмы от традиционного преподавания к инженерии учения. Таким образом, основное внимание в статье уделено разработке и внедрению эффективных учебных сред на основе использования информационных и коммуникационных технологий в различных форматах: очное обучение, смешанное и дистанционное. Инженерия учения требует нового понимания и переосмысления традиционной дидактики в направлении е-дидактики (электронной дидактики), чтобы эффективно проектировать и умело согласовывать цели учения, его содержание и систему оценивания в цифровую эпоху.

**Ключевые слова:** дидактическая инженерия, цифровая эпоха, учитель-инженер, эффективная учебная среда.

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### Сведения об авторе

Чошанов Мурат Аширович, доктор пед. наук, профессор, профессор кафедры математических наук и подготовки учителей Техасского университета в Эль-Пасо, Техас, США; [mouratt@utep.edu](mailto:mouratt@utep.edu)