The Didactic-Technology Challenges for Design of the Computer Supported Collaborative Teaching

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Abstract—A design of the Computer Supported Collaborative Learning (CSCL) represents a big challenge from an informatics point of view. In general, any computer support of teaching requires existing didactic algorithms for design of the informatics algorithms and writing programming codes. In comparison with technical processes, which are well-standardized, due to the complexity of teaching processes, such algorithms are missing. Moreover, the computer support of collaborative activities requires using the virtual spaces of servers, networks and clouds. Additionally, the lifetime of software and hardware is too short for supporting long-life learning. Contextually, a complex, didactic-technology approach is not researched enough within the fields such as technology-enhanced learning (TEL) or educational technology. This paper presents the authors' didactic-informatics approach related to these challenges. It is based on developing the in-house education-specific software, knowledge representation, personalized IT infrastructure, and a specific way of solving the knowledge transmission between off-line and online environments to support collaborative activities of teachers and researchers. This complex personalized approach seems to be beyond the state-of-the-art (e.g., a utility model is used).

Keywords—computer supported collaborative learning, long-life learning, technology-enhanced learning, educational technology, knowledge transmission

1 Introduction

The integration of ICT into education represents a very complex problem – despite the great progress in digital technology. Specific challenges related to digital technology, TEL or educational technology can be found in [1, 2, 3, 4], for example. Key trends accelerating technology adoption and important developments in educational technology for higher education are discussed in [5]. In the HoTEL report [6], it was analyzed which technologies are being researched in TEL (where they were classified in three types: reviews of existing technologies, identification of new trends, and forecasting reports). The report contains a list of reviewed FP6 and FP7 projects. Especially realistic is the TEL monography [1], which is still useful, because many actual problems were predicted there. For example, it is mentioned that professors "also need the support of their assistants, who in turn require institutional support to prepare courses, to model collaborative learning and perform evaluations jointly with the lead professor" or that "preparing a virtual course may require twice the time needed to prepare a traditional one and require a great deal of technological expertise." It is emphasized that "this can be a frustrating experience, at least in the beginning. That is why we find it necessary to have a design and technology team behind every professor, which assists with the design of Web pages, design of materials, design of visual aids, aesthetic enhancements, production (including pre and postproduction needs), and the technological platforms used for interaction." The issues mentioned above automatically relate to the issues of CSCL, which is a part of TEL. In comparison to the past, only collaborative activities are added, which technologically require the shared virtual spaces or clouds (Note, they did not exist at the time of publishing the TEL monography). The state-of-the-art in CSCL one can find e.g., in [7].

Relatively frequent is the critique of the lower level of the TEL, i.e., the computer support of teaching and learning (see e.g., [8]). For instance, it is stated in [9] that the "Higher Education-TEL" community has been just as ineffective as the school-level "ICT" community at delivering real improvements in education. As was presented on the Online EDUCA conference in Berlin, "the European Commission, which has funded a series of large academic research projects into TEL, explicitly recognized that there was a general 'absence of evidence' that the projects had achieved lasting impact" (at this time the London KnowledgeLab reported the premise that "evidence of digital technologies producing real transformation in learning and teaching remains elusive"). It is discussed in [9], as well, that the TEL acronym for Technology Enhanced Learning should be terminologically understood as (1) T: education-specific technology (2) E: by teaching students a technology-enhanced curriculum, and (3) L: Teaching (not learning) is what we do. Similarly, the attention was drawn to the tendency of a range of technologies to reduce pedagogical interactions to a series of data-field transactions of information [10]. Within the UK survey, which was focused on the TEL tools that are being used by institutions to support learning, teaching and assessment activities – mostly "global" VLEs (Virtual Learning Environments) – were evaluated as the key tools, (e.g., Moodle, Blackboard Learn) [11]. Surprisingly, only nine percent (9%) of the VLEs currently used were in the category "Other VLE developed in-house". The absence of education-specific personalized software for TEL was emphasized in the survey. The same is also stated in [3], i.e., that the suitable software in the field of TEL is still missing.

According to the authors, this criticism is related to the didactic - informational imbalance of existing approaches. The authors link these challenges to the absence of a knowledge-based approach. They emphasize the question of knowledge in their publications by arguing that teaching and learning are knowledge-based process. So, if one wants to computerize teaching processes, one must design the suitable knowledge representation and start from the didactic background. It is important because the automation of teaching is related to mental processes. From the existing learning theories, the constructivism or radical constructivism seems to be interesting because knowledge is considered as a mental representation. The learner is not a passive recipient of knowledge, but that knowledge is constructed by the learner. Such a constructivist approach to teaching – including linking cybernetics and the theory of knowledge – is presented, especially, by von Glasersfeld [12]. The authors' research on TEL is also linked to cybernetics regarding their model of the knowledge representation, which is discussed in this paper (see also [13]). In general, the design of the TEL or CSCL regarding the question of knowledge requires additional ontological and semantics approaches. Such issues with a focus on robotic education are discussed in [14, 15], or on cloud-based learning [16], soft computing [17], and teaching the blind students, respectively [18].

The authors' research started around ten years ago with a vision that knowledge workers (teachers, researchers) should be equipped with IT tools for the complex support of knowledge-based processes. So, the in-house education-specific database beta-software, BIKE(E), has been designed for performing the batch knowledge processing), which enables the teacher to automate his/her teaching based on the simulation of teachers' activities. The complex didactic-technology approach of the authors is briefly discussed in the paper, especially the principles of knowledge representation and processing; barriers of ICT integration into teaching; the IT support of STEM courses of study and enlarged IT support.

2 The Principle of Knowledge Representation and Processing

The authors' research approach is not designed to compare such didactic situations when one group uses computers and other one practices "traditional learning". Contrary to this, how the teacher develops his/her educational technology is up to him/her; this simulates cognitive functions of mental processes associated with the teacher's activities needs (the in-house beta-software BIKE(E)-Batch Information and Knowledge Editor and Environment). It provides the teacher with a personalized infrastructure (including VLE) within which the teacher's and students' knowledge are transmitted between online and off-line environments (e.g., between the teacher's personal computer and the cloud). The knowledge processing and transmission complement the traditional face-to-face teaching. The human-curriculum knowledge is processed by using a model of the virtual knowledge representation, which is both human-readable and machine-readable (where both the teacher and computer use the same knowledge). The BIKE(E) enables the teacher to process knowledge analogically to a calculating machine, which processes numbers. Because the virtual knowledge is only an empty data structure, it is crucial how users (teacher, researcher, students, and knowledge workers) design the inserting of their knowledge into this default structure. After that, ontology and semantics are automatically created, and the data becomes semi-structured. Then they can be better controlled by programming codes.

In general, engineering study requires more self-study activities than standard learning. Thus, the teacher does not have didactically enough time for each student, as it would be needed. Moreover, the amount of contextual information regarding each topic of courses of study is “huge”, so one should navigate in this vast amount of information. Therefore, it is a guiding role of the teacher to prepare teaching material of high quality that generalizes the topics of teaching. It is common that a university teacher constructs teaching and learning materials for lectures and exercises. In practice, these teachers only have a limited time for planning, e.g., minimally 50 minutes for the lecture or exercise. Moreover, within this limited time, the teacher must manage several topics. It is a paradox that only a minimal number of scientific papers deal with this time factor.

The authors’ research started with the idea, which was presented on the e-Learning brokerage event in Warszawa (2006) – that a teacher as a knowledge worker should be equipped with technology analogically as are a contemporary soldier. This was a driving factor within their research under the umbrella of TEL. One should be aware that computers were not invented for teaching. Thus, teachers need a suitable knowledge representation and many specific software or hardware tools to cover automation of teaching processes. Additionally, because the processes are knowledge-based, he/she must identify curriculum knowledge, processes, and steps, and design didactic algorithms (methodology) as a background to be able to write informatics algorithms and programming codes. The in-house software BIKE(S)/WPad as an all-in-one teaching support tool was also tested and developed continually for IT support of collaborative activities which requires knowledge exchange and managing. In this context, these categories of collaboration were implemented until now: Student–Student | Student–Teacher | Teacher–Students | Teacher–Teachers | Teacher–Researchers.

The research on the automation of teaching processes showed that design of the didactic issues or a "direct" computer support for collaborative teaching is potentially solvable [19]. Contrary to this, in order to solve the adaptation of the in-house software to digital technology (e.g., to Windows, networks), or to overcome the incompatibility of software and hardware on the market, it is complicated and very time-consuming. From the automation point of view, it is the weakest point of the automation. Moreover, a short lifetime of digital technology was found as an important technological barrier for developing long-term education computer support. Despite this fact, several case studies resulted as outcomes from the implemented computer support of teaching (ca 2000 bachelors students participated during the long-term authors' research). The preliminary outcomes showed that the research on CSCL requires the teacher to solve both didactics solutions (to indicate and define didactic algorithms), and software and hardware solutions (– especially, to solve the knowledge transmission between off-line and online environments). The long-term suitability of the operatively-developed in-house software was achieved thanks to the approach on how to solve the unstructured data transmission (i.e., the knowledge transmission). The related utility model is registered on the Slovak patent office [20]. Consequently, another patented solution is worked out in relation to a vision of an educational robot (Note: As for the in-house software, it is not possible to patent software in the European Union).

In terms of learning outcomes, tens of contribution to the conferences and journals were continually published by authors, including the ICL Conferences (2012-2017). The publications content was targeted to: (1) the empirical participatory action research, when the teacher designs his/her own educational technology in parallel (as the technology-driven or educationally-driven computer support, and active learning); (2) building the personalized Virtual Learning Environment by using the in-house software and associated IT infrastructure; and (3) the computer-supported collaborative teaching (CSCL) for solving the collaborative activities of students and researchers. Presently, e.g., the collaborative activities are tested on the IBM BOX-cloud by the V4+AcaRD Consortium of six academic subjects that was initiated within ICL 17. The authors' approach resulted in many added didactic and informatics values, which are briefly summarized in Table 1.

Table 1. Added didactics and informatics values within tens of case studies (basic, CSCL)

Added didactic values	**Added informatics values**
Identification of didactic algorithms for lectures, exercises, self-study	Developed informatic algorithms associated with didactic algorithms
Production of the extended teaching, study and self-study materials	Tailored personalized ICT infrastructure with communication channels (combination of off-line and online)
Shortening teacher's time for preparation of the teaching and constructing study materials (lectures, exercises, self-study)	The Utility model used for transmission of knowledge and files (feedback, shared activities)
Elimination of passivity of students and minimizing plagiarism when using WPad	Shared virtual spaces for collaboration and knowledge exchange on faculty's cloud and IBM cloud (international team)
Model of the elimination of passivity and absence of students within distance learning	Educational software WPad installed on each computer in classroom used for several courses of study
Enabling feedback (not possible without communication channels)	Educational software for cloud and virtual environments (client-server)
Knowledge exchange – the international collaboration of V4 teachers	Apps – Database applications for research, teaching, learning and self-study
Audio additions of English language into the course of study "Background of environmental protection"	Personalized research on technology-enhanced learning, Digital libraries (scientific heritage), Learning analytics
Models of collaborative activities (collaborative writing of semester works and study material for chemistry student-	Visualization tutorials and computing support for chemistry, language support for self-study and academic writing

created content for students)	
Extended assessment variations (summative and formative assessment), support of diploma and bachelor’s works	Research areas within FP7/Horizon: Technology-enhanced learning, Learning Analytics, HLT, CSCL
Automation of associated teacher’s activities (research, publishing, information and knowledge management, administrative activities)	Universal - personalized all-in-one multipurpose software/system that does not exist in the market
Creation of knowledge base of C++ programming codes by students/teacher	Modelling visualization and natural marking for STEM support

3 Barriers of ICT Integration into Teaching

As for the integration of digital technology into education, in contrast to long-term teaching needs, the life-cycle of technological tools is shorter. In general, in the case of an ICT support of teaching, computers work reliably commonly for three to five years. After that period, they work slower and slower. This fact is rarely discussed in scientific literature. It is automatically supposed that any computer support of teaching functions perfectly. However, it is not true from the point of view of the teacher who needs sustainable, long-term personalized support. In [21], these issues are discussed by authors in more detail. There, the obstacles related to the barriers of ICT integration into teaching are divided into several categories:

- Internet Browsers
- Changes of Hardware and Software
- Servers and Networks
- Students and the Human Factor

It must be once more emphasized that computers were not invented for teaching. Therefore, this gap stemming from ICT state-of-the-art tools can be considered as a standard situation. The authors' research has shown that the best solution to the problem of shorter life time of technology is to develop both their own educational software and personalized ICT infrastructure for educational data transmission. In the case of the all-in-one educational software application BIKE(E)/WPad, the life cycle is not ended even after around ten years of integration of ICT into engineering teaching within the author’s research on TEL. In addition, the sustainability for long-term teaching is automatically assured while operating system Windows continues to exist. Moreover, the principle of the approach is "evil" because of the lack of dependability of virtual knowledge representation from software and hardware. [The database application could be also written by using any other database platform.]

Another specific teaching and learning issue is the knowledge transfer. The issue of the educational data transmission (the content transfer) is less described in scientific literature than the content processing, despite the fact that it is very time consuming. It does not matter how many students have the teacher, the data transmission requires one to build a complex ICT infrastructure with paths for knowledge transfer (as the files in various formats) between off-line and online devices. In the case of CSCL, this issue can by crucial, i.e., how to transfer knowledge between tens of students or researchers. It is common as well that teachers use some computers and e-devices. Contextually, Fig. 1 illustrates the teacher's infrastructure used by the main author of this paper as a combination of home and work computers, clouds and online virtual spaces (– just the Windows 10 is already used presently).

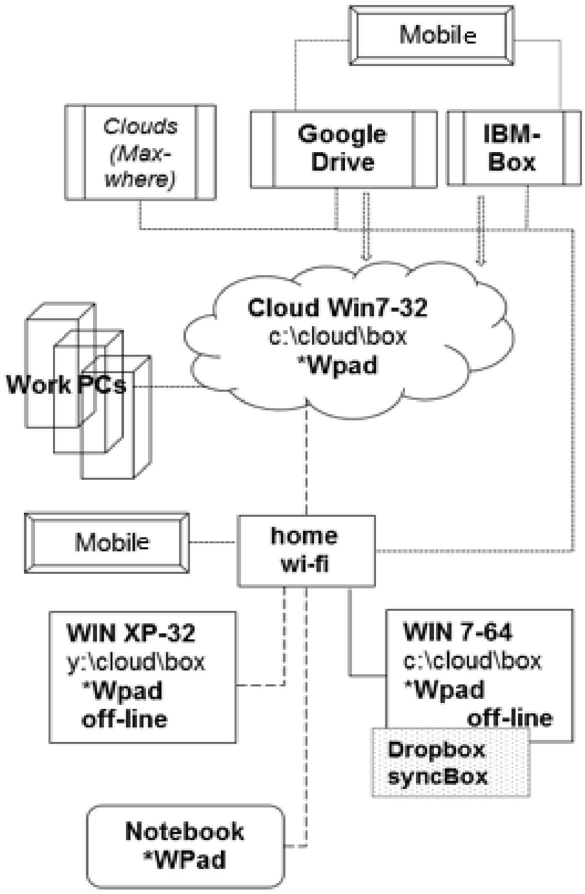

Fig. 1. Example of the personal teacher's off-line/online ICT infrastructure

It should be also emphasized that the computer time is very important since computer time is typically very important for the process of transmitting knowledge. In the case of online/off-line transmission of files or folders, it requires the user to take minutes – even tens of minutes (especially when using at-home WIFI with a weak signal or when copying giga-bytes of files between computers, networks and e-devices).

4 The IT support of STEM courses of study

Within around ten years of the authors' research on TEL-support of bachelor's-level teaching, several categories of courses of study were supported, e.g., Background of environmental protection, Programming languages, Occupational health and safety, Chemistry, Industrial management. The research showed that each of them required specific didactic approaches, so also different informatic approaches. This means that one course of study required e.g., more text formats than images, more working off-line than online, or more active or passive activities. For example, the IT support of STEM teaching required more visualization, which has, in general, a richer information content. A specific problem was how to solve chemical formulas and equations without using any specific software. The most effective method was using the paper and chalk and blackboard in the classroom. It could also be mentioned that PHP-programming codes were used for training in areas such as calculation of chemistry tasks, including writing a set of tutorials related to teaching photosynthesis.

4.1 Basic IT support - the design of educational packages

Because there was no educational technology which could cover such a large range of problems in teachin**g**, the education-specific application WPad was developed on the principle of simulation of teacher's or student's activities. [It is a selected part of the in-house software BIKE(E).] This means, that the programming codes were written based on didactics steps primarily, i.e., up to the teacher needs. The complex didactic-technology approach can be explained in the case of designing the IT support of STEM when solving the modelling and simulation tasks which require a higher level of visualization. Principally, the approach must be in compliance with the didactic goals and algorithms required by the teacher.

In this case, the teacher wants to design the online application aimed at the self-study of distance learning students, and a set of exercises when creating the simulation projects by individual students.

Specification of the teacher's requirements requires that the curriculum content should be created by using texts, images, videos and files in the native format of the Witness software, which is used for exercises, as follows:

- images and texts as the navigation elements
- videos as the motivation and teaching elements
- files in the native format of the simulator (*.mod) with access to Witness software - it should enable students' direct launching and browsing of the files

As for the specifications, she would consider as the ideal case when enabling students to relink the problem areas with the offer of manuals and scripts, i.e., to support students to solve the individual problem tasks by using:

- hypertext links for instructions, including the enlarged help-function
- keyword search in scripts of the course of study
- search in the knowledge base consisting of simulation models and instructional files.

Fig. 2 illustrates how to fulfill the teacher's requirements for IT support of the course of study. The in-house software BIKE(E)/WPad will work as a black box, which would join the inserted educational "big data" from the associated teaching resources. In the "black box", the educational packages will be constructed, which will be used by students and teachers within the exercises. The design of the educational packages is just being started with intention to also obtain model templates that could be useful for the planned design of the educational robot within the V4+AcaRD consortium (a project of academic subjects of so-called Visegrad countries).

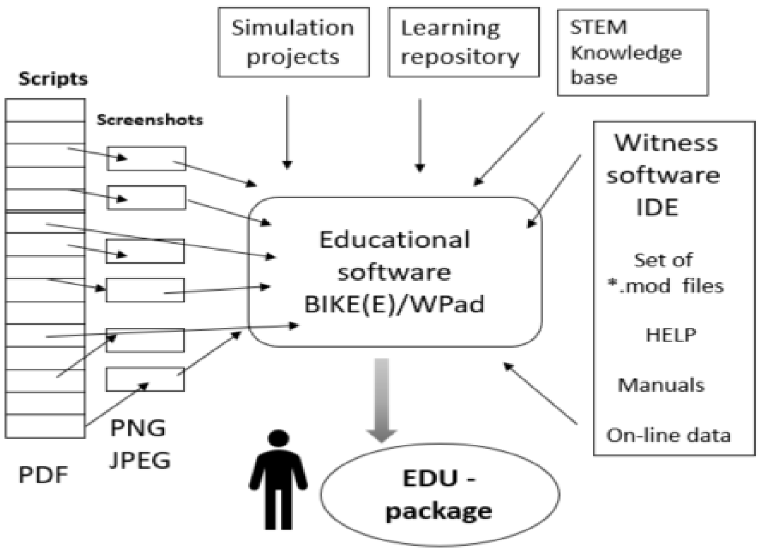

Fig. 2. Scheme of the design of educational packages

4.2 Enlarged IT support – the design of collaborative teaching and learning

Commonly, a general or global software and hardware are mechanically used; this is not automatically suitable already for the standard teaching. Mostly, it is tested by users to see whether or not it works; therefore, didactic aspects are not primary. Additionally, in comparison with the standard teaching, any collaborative teaching and learning requires a specific methodology for collaborative activities and enlarged IT support. Namely, "collaborative" means practically that a group of users needs to share virtual spaces for the collaborative work or larger number of files must be processed in a unified manner.

As it is apparent from the previous description of the design of educational packages, a teacher always must play the key role (not technology). Thus, he/she should formulate didactics goals and procedures (algorithms) which would be a background for writing the informatics algorithms and the design of suitable IT infrastructure. Because the collaborative activities are not a part of standard teaching, the additional methodology must be prepared before a design of any IT support. This is very rarely discussed in scientific papers because it is automatically supposed that the didactic algorithms exist. However, each teacher knows that if one wants to teach whatever subject collaboratively, it is relatively a hard issue. Moreover, from the informatics point of view, it requires very specific software and hardware for the shared information and knowledge exchange. The "knowledge exchange" practically means that the crucial problem is how to solve both knowledge transmission between off-line and online environments and how to share knowledge among many users (it requires shared virtual spaces or cloud environments). Knowledge transmission means that data or files are off-line or transmitted online between computers and networks. Another specific issue is that if one wants to automate teaching, one must additionally also solve the adaptation of one's programming to the Windows operating system. In other words, the teacher also must solve the personalized file management, i.e., write the analogical programming codes as are performed by the Windows Explorer, Internet Explorer, or Internet browsers, in general. The authors' research showed that this is the most time-consuming programming activity. Table 2 illustrates it on the example of data transfer/transmission.

Table 2. Examples of data transmission/transfer cases when teaching STEM

Data transmission/transfer cases from needed for the complex IT support	
Adoption to Windows: file management and conversion of formats (pdf, images)	Data transfer via WIFI and e-mail communication
FTP is needed (teacher's computers - virtual space of the institute) Data compatibility from other software outputs (ASCII unification)	Data transfer from the EU, national, local, and institutional resources and information systems (CORDIS, AIS)
Data transfer from other database platforms, Excel, text/audio editors Data transfer from the internet services, databases and repositories	Teacher's computers - Faculty's cloud Teacher's computers - Global clouds (e.g., Google Drive)
Data transfer from the internet browsers Data transfer from the USB and external discs	Data transfer from the mobiles, digital camera, e-carriers International networking (V4+ AcaRDC): Researchers' computers – IBM Box cloud

5 Conclusions

One of the authors' finding is that any IT support of the knowledge-based teaching processes, i.e., the simulation of mental processes, requires synchronized solving both didactics and technology issues. It means that any computerization of every didactic activity requires solving the didactics and technology simultaneously. The didactic-technology challenge is that any suitable education-specific technology does not exist. The author's approach is primarily based on the selection of the didactic situations that need to be computerized. This may be e.g., collaborative writing of semester works or scientific articles; a methodical procedure to eliminate plagiarism, a support of STEM; or the mass production of study materials. When the didactics algorithms are defined, they are processed by the education-specific in-house software BIKE(E)/WPad within the personalized off-line/online IT infrastructure. In comparison with the IT support of standard teaching, the design of the CSCL required solving the data (knowledge) transmission between off-line and online environments (virtual spaces, clouds, networks). This brings absolutely a new situation, especially from personalized point of view. Programming codes of the in-house software must also cover the adaptation to existing technology, especially how to transfer the didactic content of knowledge between online and off-line environments. This requires solving the compatibility issues and elimination of the above-mentioned technology barriers. Additionally, the specific approach is needed for solving the computer-mediated communication. [Until now, these communication levels were tested: man-machine, machine-machine, man-machine-machine-man, people-machine-machine-people.] As it was explained on examples from the teaching practice, this all requires the specific enlarged IT support which is complex and time-consuming. In this context, the future research will be aimed at the didactic-technology design of the educational packages and computer solutions for the knowledge transfer, including automation of teaching processes based on the idea of the educational robot which is being worked out.

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