The ICT Design for Modern Education Technology and Applications

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Abstract. The current trend towards automation and data exchange in manufacturing technologies, known as Industry 4.0, has also an impact on engineering education. This has a significant influence on the field of research on information communication technology (ICT) for education. It means that the digitalization of teaching processes requires not only suitable supporting software tools but also a suitable infrastructure for managing the flow and transmission of educational knowledge within this infrastructure (clouds, remote desktops, virtual spaces, personal computers). In this context, the authors aim to fill a gap in universal ICT support for teaching, and the state of the art in ICT in general. This gap involves reassessing the actual issues in modern education technology and applications, and requires a more universal approach, because global software or cloud and Web services are not automatically suitable solutions for use in personalized teaching situations where the key players are teachers, i.e. individuals. an approach (also supported within the international research Consortium V4+ACARDC), is illustrated by examples such as testing clouds (cloud content management), virtual spaces, and the development of educational packages and supporting software for visually impaired people.

Keywords: Technology-enhanced learning, Education technology, Education 4.0, Digitalization of teaching processes, Educational knowledge management, Educational packages, Supporting software for visually impaired people, Computer supported collaborative learning

1 Introduction

Despite the great progress in digital technology, the integration of ICT into education represents a complex problem. In this view, the technology-enhanced learning monograph [1] is still useful because many of the current problems were already predicted there. It has been emphasized that ICT design should not be driven by technology “but by the painstaking analysis of human learning processes and of the requirements of a particular task”. According to the authors of [2], this problem relates to the fact that “technology is treated as if it will cause learning - and when it does not, there is no clear explanation of why”. In [3], more details regarding the teaching of students via a technology-enhanced curriculum can be found, and in [4] regarding the avoidance of technology-enhanced “non-learning”. Within a UK survey, which was focused on TEL tools, the absence of education-specific personalized software for technology-enhanced learning (TEL) was emphasized [5]. This was also stated in [6], in a study which argued that suitable software and models in the field of TEL are still missing. Similarly, the importance of the non-reducibility of pedagogy in information transactions was highlighted in [7]. Some barriers to the integration of ICT into teaching and the sustainability of digital technology for long-term teaching were also discussed in [8, 9], especially in relation to the short lifecycle of software and hardware. It was emphasized that any integration of ICT into education should consider teaching and learning processes as knowledge-based processes in which knowledge should be both human- and machine-readable. In this context, the cloud computing for education (CCE) literature was examined in [10] and was analyzed to determine whether research is developing in a scientific way with adequate empirical validation. A “systematic mapping study” was carried out that found that “the scope of interest in CCE computing for education is only partially covered; with empirical research being very shallow”.

This paper describes the progress that has been made in research on the ICT support for teaching processes, as presented in previous ICL conferences [9, 11], with a particular focus on the development of the personalized educational software WPad and the design of a CSCL approach within STEM education, including the associated didactic-technological challenges. Six European partners from the so-called Visegrad countries (Poland, Czech and Slovak Republics and Hungary) and Ukraine have formed the “V4+ Academic Research Consortium for the integration of databases, robotics and language technologies”, and have started to build a regional research network using the Box cloud, a global service for cloud content management. The goal of this effort is to model and test shared activities and project management, including modifying the in-house software WPadV4 to model the transmission of educational knowledge. This knowledge transmission, which involves sharing the partners’ educational expertise (as a flow of files and heterogeneous educational data between offline and online environments), requires the Consortium to build a suitable tailor-made virtual infrastructure, and to model informatics applications for technical and engineering education in general. In this context, this research covers all of the educational categories that form the topics of the ICL 2019 conference. The focus is principally on the categories of "21st Learning Century" and "Modern Education Technology and Applications", and involves modeling a new generation of educational packages, starting with the design of an educational robot, and including specific issues such as IT support for visually impaired people and multi-language IT support for teachers and researchers (5+1 languages). Modeling of educational packages as a set of heterogeneous unstructured data is supported by the registered utility model [12].

2 The Research Approach and Methodology

Any IT support for education should generally reflect the fact that teaching and learning processes are typically knowledge-based processes, and that any knowledge is related to the mental processes involved. Thus, from an informatics point of view, it is crucial to solve the problem of how computers understand human knowledge. In our case, a model of the virtual knowledge unit is used that enables individuals to insert their information and knowledge into this structure in their natural language; however, a computer understands this as an informatics element, so such human-readable knowledge is also machine-readable. This allows us to personalize educational knowledge processes and reach the abovementioned goals of this work. In other words, it is possible to write source codes, programming instructions and applications that are tailor-made to the level of each individual (e.g. teachers, researchers, students or visually impaired people).

Such approach seems to be new in the field of computer science and has been registered with the Slovak patent office as part of a utility model. In this context, due to its high compatibility with the Windows operating system, cloud services and web tools in general, it enables us to combine heterogeneous types of data and to model various multimedia outputs. This is very important in the field of education, as it enables us to better visualize educational content, including its handling and transmission within a tailor-made infrastructure, i.e. between notebooks, computers and clouds and virtual learning spaces, even in a collaborative way.

The authors' approach to research on ICT support for education is based on methodological steps that are tailored to education. It is particularly based on parallel and synchronized educational-informatics research that is related to three methodological pillars: (i) identification of "teaching and learning" algorithms or other processes associated with education; (ii) modeling "informatics" algorithms and applications; and (iii) the "adaptation" of WPadV4 software for Windows, web programming and cloud computing. In our case, the synchronization of these three inter-disciplinary pillars is specifically focused on the educational expertise of the V4+ACARDC project partners, i.e. on integrating databases, robotics and language technologies, including testing of the outputs of the model in educational practice. These technologies form the core of the modern design of educational technologies or technology-enhanced learning approaches. In this work, an educational system is developed using the authors' own in-house software that is customized for individuals, and this allows teachers not only to design their own educational materials (including e-learning packages) but also to transfer educational content via a combined online/offline infrastructure. It is also in compliance with the trend towards digitalization within the framework of Industry 4.0. Figure 1 illustrates the project infrastructure, which uses the Box cloud service for cloud content management.

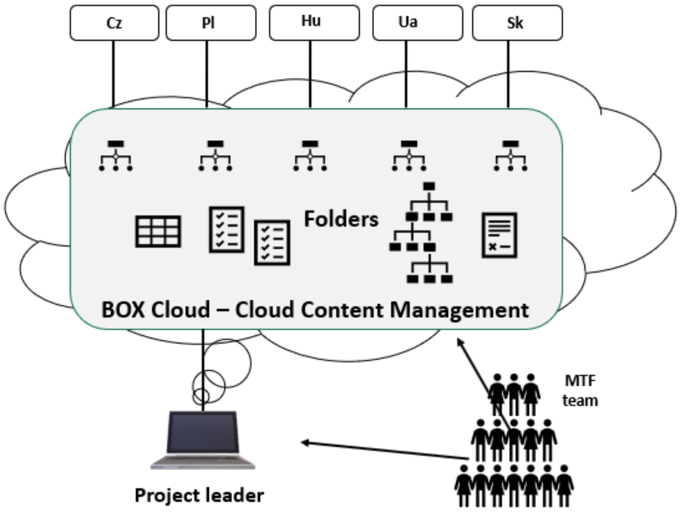


Fig. 1. The Box cloud collaboration scheme of the V4+ACARDC Project Consortium

3 The Actual and Anticipated Outcomes

In view of the background context and the approach used here, there are many potential problems that need to be solved within a timescale of days or months. Some of these are solved via the V4+ACARD project, which is divided into five work-packages (partner search; mobility; the online/offline infrastructure; the design of educational packages and language support; and the educational robot/personalized memory system), and these are continually solved by the international team of researchers and teachers of the Consortium. Some of the current outcomes, including papers published in Springer books or scientific journals, include the following:

- Partner search events for Horizon 2020 (e.g. a workshop at the university)
- An online/offline ICT infrastructure consisting of the BOX cloud and the faculty's remote desktop with Windows 10, involving around 20 teachers, researchers and doctoral candidates from five countries;
- The design of the multi-purpose WPadV4 beta software application;
- Modification of the WPadV4 for visually impaired people (based on using keyboard shortcuts);
- The design of a cloud content management system on the BOX cloud, consisting of more than a thousand files contained in tens of folders and subfolders; and
- Beta application modules such as V4+Educational packages, Writer, V4+Library and V4+R&D service, which were developed with the intention of designing a semi-automatic visualization for educational content, support

for a multi-lingual approach when using human language technologies such as text to speech and speech recognition.

In another autonomous work package, the specific focus is on the development of an educational robot and the Personal Memory System: regarding the former, a proposal for the utility model was drawn up at the time of writing of this contribution, and regarding the latter, the focus is on adding file manager functions into the WPadV4 software.

3.1 The Design of the Educational Packages

Modeling of educational packages was proposed as future work in previous ICL 2018 contribution of the authors. In previous empirical research, it was found that all three of the methodological pillars must be accepted and optimally solved in parallel. In view of this, algorithms for teaching, application and adaptation to software/hardware/networks are solved within the current project. Certain educational domains are intended as the focus of the activities of the project, such as language support using text corpuses, especially in English, and finding a general approach for processing heterogeneous educational content. To generalize these procedures, we first need to model several applications. Fig. 2 illustrates the first steps necessary in working out the heterogeneous "smart educational data".

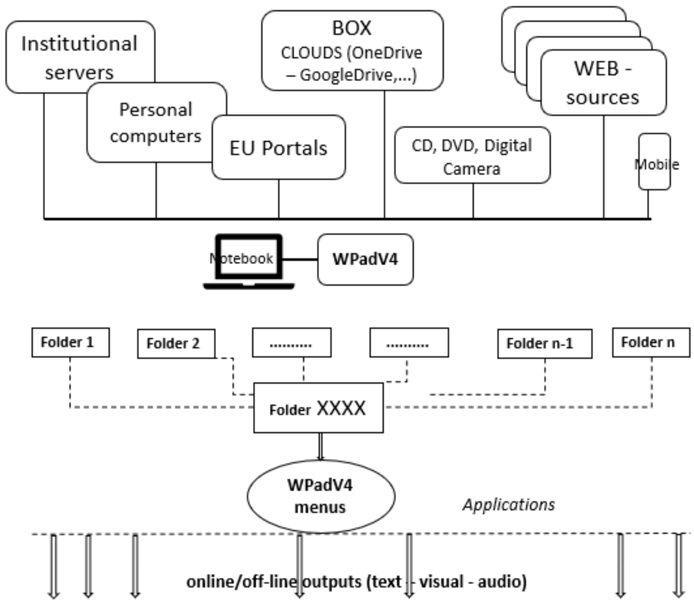


Fig. 2. Scheme of design of the educational outputs

3.2 Cloud Content Management and Virtual Machine Support

One of the outcomes of this project was presented at the ICICKM 2019 conference under the title: “The IT Support of Knowledge Management and Transmission within Community of Researchers”. It was emphasized in this paper that despite the importance of the field of knowledge management in university teaching, the available knowledge management systems only collect structured knowledge content. This does not allow individuals (teachers, researchers, students) to work dynamically in a combined offline/online mode, and to transfer knowledge between the teachers' computers and academic information systems or clouds. Since teaching is a dynamic knowledge process, it was explained at the conference how the knowledge flow (as represented by the various categories of knowledge) is inserted into the virtual knowledge and then processed by the WPadV4 software application; this is then used in the knowledge-based processes that are typical of the university education environment. This is illustrated in Fig. 3.

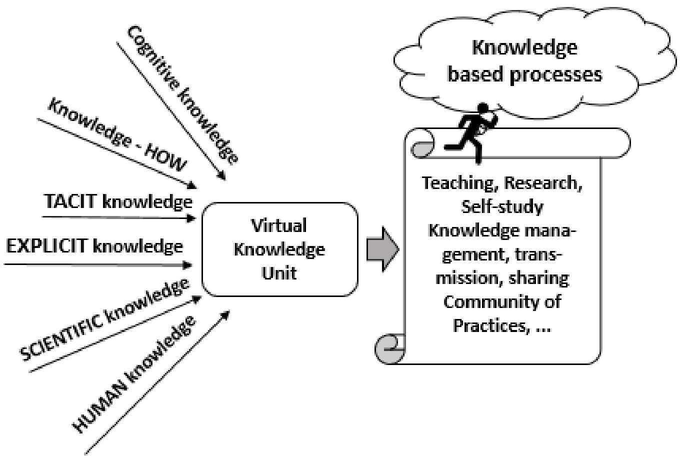


Fig. 3. The flow of various kinds of knowledge into the virtual knowledge unit

The following research shows that we must differentiate between transmission of virtual knowledge (specific/smart content in knowledge cells/tables) and general content (files with heterogeneous formats). Both virtual knowledge tables and common computer files (documents, audio, video, images) must be transmitted within offline/online infrastructures using state-of-art ICT. This does not pose a problem if around ten to a hundred files are used, as was the case when the Consortium launched with the Box cloud; however, there are currently around two thousand files that must be structured into groups, i.e. folders and subfolders within a tree structure. This can be understood in the same way as when using the Explorer folder in Windows, although in the Box cloud this takes place online. Thus, so-called cloud content management one can consider as a type of information management, and an informatic specialist for file management.

In addition to challenges related to Internet safety (which require additional solutions), other challenges have emerged from working with such a large number of online documents and files. Namely, the Box cloud does not have its own operating system, and WPadV4 functions only in a Microsoft Windows environment. It is not possible to solve these problems by writing additional source code. In other words, the researchers have WPadV4 installed on their computers, which are connected to the Box (either directly from WPadV4 or via their browsers). The actual research focus was enlarged to include testing of the faculty's cloud virtual machine, on which the software is installed for the knowledge table exchange. Thus, the partners share knowledge and information via the virtual remote desktop, enabling them to link the offline WPadV4 software with the Box cloud, to start writing source code for the automatic transfer of files, content and virtual knowledge cells and to model the educational packages, as mentioned in the previous section.

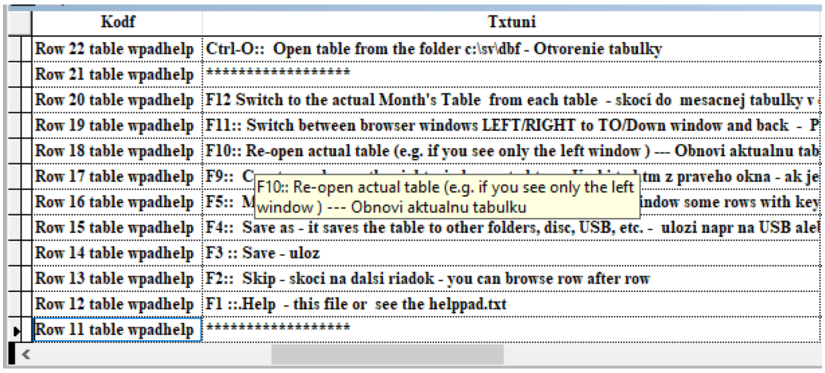
From the point of view of the concept of Industry 4.0, which generally requires not only a simple data transfer (as in the Internet of Things) but also the transfer of information and knowledge (e.g. Logistics 4.0, product design), a research focus on this transfer is needed, as is suitable software [13].

3.3 Specific Challenges of IT Support for Visually Impaired People

Generally, visually impaired people have special needs when using computers and other electronic devices for work and study. When preparing educational electronic materials for visually impaired students, it is important to remember that this population can be divided into two groups, totally blind and partially sighted. The needs of each are often different; Although they sometimes coincide, in some situations they may be mutually exclusive. The first skill that is usually learned by visually impaired beginners is to use the standard QWERTY computer keyboard. Thus, before they start working on the computer, they need to memorize all the memory keys, and additionally, they need to learn the other keyboard shortcuts.

Another important point is that visually impaired people struggle to visualize what is presented on the screen. For blind people, this problem can be solved by using special software called a screen reader, which reads all of the textual information that is available on the screen using automatically generated synthetic speech. Additionally, it is important to note that blind people do not use a mouse, and that all operations on the computer are performed only with the keyboard. They therefore need to learn various shortcuts to replace the operations that a sighted user can carry out with a mouse.

In this context, a modification of the WPadV4 software was tested for IT support for visually impaired people, based on the fact the user menu can be controlled by shortcut keys, meaning that the use of a mouse is not necessary. Fig. 4 shows one of the first trials of modifying the software for visually impaired people. It can be seen that a screen reader can read the table "wpadhelp", including the number of rows and which actions the shortcuts cover.



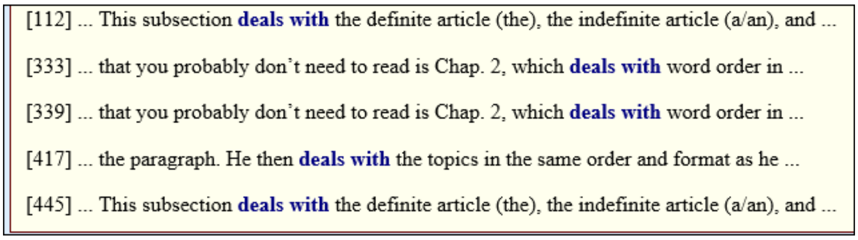
Kodf	Txtuni
Row 22 table wpadhelp	Ctrl-O:: Open table from the folder c:\sv\dbf - Otvorenie tabulky
Row 21 table wpadhelp	*****************
Row 20 table wpadhelp	F12 Switch to the actual Month's Table from each table - skoci do mesacnej tabulky v
Row 19 table wpadhelp	F11:: Switch between browser windows LEFT/RIGHT to TO/Down window and back - P
Row 18 table wpadhelp	F10:: Re-open actual table (e.g. if you see only the left window) --- Obnovi aktualnu tab
Row 17 table wpadhelp	F9:: C… tm z praveho okna - ak je
Row 16 table wpadhelp	F5:: M… indow some rows with key
Row 15 table wpadhelp	F4:: Save as - it saves the table to other folders, disc, USB, etc. - ulozi napr na USB alel
Row 14 table wpadhelp	F3 :: Save - uloz
Row 13 table wpadhelp	F2:: Skip - skoci na dalsi riadok - you can browse row after row
Row 12 table wpadhelp	F1 ::.Help - this file or see the helppad.txt
Row 11 table wpadhelp	*****************

Fig. 4. Example of the WPadV4 help table for visually impaired people (template)

It is crucial to point out that various eye diseases require different methods of support, for instance different views of the screen and different colors or levels of magnification. In practice, this means that each partially sighted person needs to configure these features according to his individual needs. The screen magnifier software is also equipped with functions that allow the user to read certain information from the screen via an automatically generated voice. This is mainly used when the user wants to read a larger piece of text, which may become difficult. In this situation, speech synthesis can be used. Partially sighted pupils can use a mouse and a touchscreen, although sometimes working with a mouse may sometimes be difficult for them. In this situation, they can also learn shortcut keys and use the keyboard to perform operations.

As mentioned above, visually impaired people use special software to access a computer and other mobile devices. Totally blind people can use screen reader software, while partially sighted people can use a screen magnifier. It is essential to point out the difference between screen reader software and a speech synthesizer, in that the speech synthesizer allows text information to be converted to audio speech using a single generated voice. Currently, the Microsoft Edge browser in Windows 10 enables text to be read automatically in pdf or HTML formats in several languages (the required language must be set as the default language).

Fig. 5 illustrates how to select specific word phrases from a textual corpus consisting of English sentences for support in writing papers. The keyword used here was “deals with”, and the output consists of sentences in HTML format that can be read by the Microsoft Edge browser.



[112] ... This subsection **deals with** the definite article (the), the indefinite article (a/an), and ...

[333] ... that you probably don’t need to read is Chap. 2, which **deals with** word order in ...

[339] ... that you probably don’t need to read is Chap. 2, which **deals with** word order in ...

[417] ... the paragraph. He then **deals with** the topics in the same order and format as he ...

[445] ... This subsection **deals with** the definite article (the), the indefinite article (a/an), and ...

Fig. 5. Example of using the textual corpus for support in writing papers

Fig. 6 illustrates the conversion of collected personal data from Excel format to the knowledge table DM_XLS (The content of the XLS-file was simply copied to the table: CTRL-A, CTRL-C, CTRL-V). The data in the table represent useful information for the visually impaired community. The Web pages from the list can be directly opened either using the ALT-F9 shortcut or after converting to HTML format by the browser.

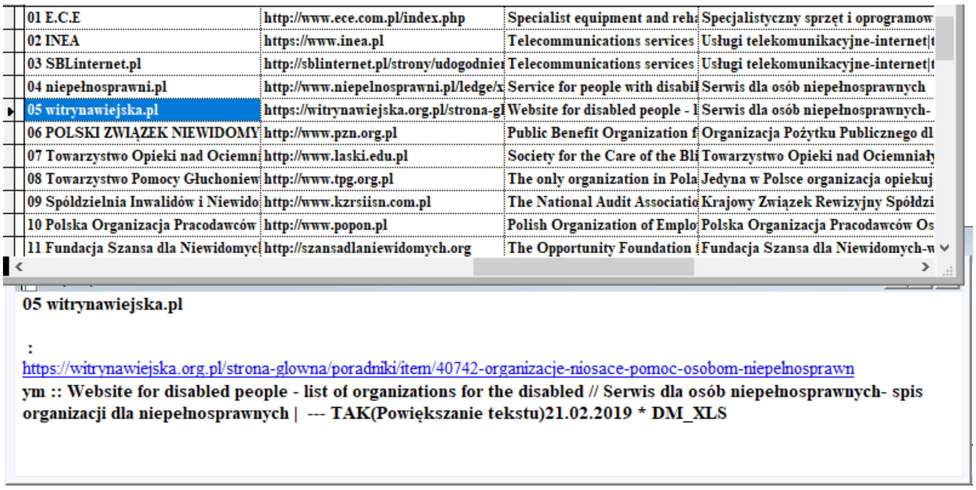


Fig. 6. Screenshot of the converted XLS format with a personal list of useful links

3.4 Some Aspects of Cloud-Based Learning

According to recent research trends, the problems of environment formation and design for cloud-based learning are recognized as a priority by the international educational community (see for example [14-18]) and are now being intensively researched in various areas of education. In this context, cloud computing is now among the leading innovative learning concepts, and its implementation significantly affects the content and forms of the different types of activities in the sphere of education. The general model of the university cloud-based learning and research environment design has proved to be a reasonable framework for delivery and research of cloud-based learning resources and components. For example, to deploy the relevant environment components, a special methodical system was designed based on open education principles that were specific to a cloud-based learning environment [14, 18, 19]. This methodical system includes a number of special developed methods that can be performed at the basic levels of cloud computing, i.e. SaaS (software-as-a-service), PaaS (platform-as-a-service), IaaS (infrastructure-as-a-service). In this view, the system uses the Microsoft Office 365 learning and research cloud, Amazon Web Services, CoCalc mathematical software, and a learning component based on the Maxima system. In comparison with these global services and software systems, which are not knowledge-based, this contribution offers a more suitable research approach and methodology, with a focus on individuals (teachers, researchers, students) and a marginalized group of users (the visually impaired community). While using a global service forces and requires these individuals to adapt to existing technology, the cloud-based IT infrastructure and the WPadV4 software developed within the V4+ACARDC project enables them to process information, human knowledge and content that is tailor-made to their needs. This personalized approach gives added value to cloud-based learning.

4 Conclusions

The trend towards digitalization within Industry 4.0, which is referred to as the fourth industrial revolution, requires researchers and teachers within a university to adopt a new paradigm for IT support for engineering education. Namely, the state of the art in ICT is not yet suitable for these teaching processes, since machines are only able to process simple data (numbers, text strings, data types and structures) rather than human knowledge. However, real teaching processes are knowledge-based, and thus their automation requires to process just educational knowledge; moreover, this is flowing educational content that is time-controlled. In other words, as Industry 4.0 includes cyber-physical systems, the Internet of Things, cloud computing and cognitive computing, (educational) knowledge processing relates particularly to the field of cognitive computing, since the other fields involve only relatively simple data processing. The ICT approach to education that is presented in this contribution can be associated with cognitive computing. It must be emphasized that the paradigm presented here represents a real model for the abstraction of teaching processes as knowledge-based processes, using a virtual knowledge model that is both human- and machine-readable. In essence, our in-house software enables individuals to process their human/educational knowledge in the same way as a calculator uses numbers for mathematical calculations. In other words, the approach presented here and addressed within the V4+ACARDC project represents a kind of manual for how to design modern education technology and applications. Based on the cloud/online/offline infrastructure that has been developed, the focus of our future work will be on the design of educational applications using WPadV4 software.

5 Acknowledgements

This research work was supported by financial resources from the International Visegrad Fund under Strategic Grant No. 21810100, “V4+ Academic Research Consortium for the integration of databases, robotics and language technologies”.

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