Universal IT Support Design for Engineering Education

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***Abstract*—From the point of view of integrating IT into teaching, current technologies do not provide a universal solution for teachers' personal support and have a shorter lifespan than required by teachers and educational processes. As a result, technology cannot be adapted to a wide range of teaching activities, and instead, teachers have to adapt to the technology. This paper presents a universal solution for support based on an interdisciplinary approach to the integration of IT into university teaching and learning, self-study, publishing, research, and other personal activities performed by a teacher, including certain activities of students. It is based on the development of our own in-house universal IT system (educational software, communication channels and combined offline/online infrastructure), which can be used for any form of engineering or STEM teaching. The uniqueness of our solution is based on the design of so-called virtual knowledge, which makes it possible to insert concentrated educational content in the form of text, images, audio and other computer files, in a suitable way. From this virtual knowledge, educational knowledge tables are created using WPad educational software. This allows for simultaneous conversion of the tables into HTML format and their placement on the faculty's virtual learning space or the web. In this paper, we describe the use of this system and how it works on an infrastructure developed for the integration of IT into teaching. The automation of the teacher's work (including applications for visually impaired people) through the creation of educational packages is described, and this will also form the subject of further research.**

Keywords—*technology-enhanced learning, educational software, educational content, virtual knowledge*

I. Introduction

At present, teachers are burdened with a huge amount of information in practice, which also applies to the creation of teaching content; this is because they must not only select appropriate knowledge, but also create quality pedagogical content and teach within a limited time, which is dictated by the length of lectures or exercises. Despite the enormous progress that has been made in the field of computer technology, state-of-the-art systems are not suitable IT tools for the personalized mass processing of human information, which logically includes extensive educational content. The underlying reason for this is that existing technology cannot process human knowledge, since a computer lacks an appropriate representation of knowledge that would allow it to understand humans.

We began to address this issue in the 7th Framework Program for technology-enhanced learning. In our empirical research, the primary goal was to develop all-in-one software that would allow individuals with poor IT skills to collectively process educational content that also involved Internet resources. Our educational software was installed on computers in the classroom as part of the undergraduate teaching program. Achieving this goal made it possible to start working on the automation of knowledge-based processes, which also included teaching and learning. Our other goals were to create communication channels so that teachers and students could exchange, inform, instruct, and communicate with each other. All of this could only be managed thanks to our design of virtual knowledge as a specific database structure (this is registered with the Slovak patent office within the utility model [1]). The computer 'understands' the virtual knowledge as an IT structure that functions as a universal representation of knowledge, while from a teacher's point of view, it is an ordinary row table into which the teacher inserts educational knowledge in a particular way. It is very important that the virtual knowledge is represented in the natural language of human beings (teachers, students, researchers), meaning that it is not encoded in any symbolic language and only plain text is used. In computer science, knowledge representation is often defined as a set of rules, or more generally as the technical problem of encoding human knowledge into a symbolic language, as described in [2]. It has also been stated that "epistemology is the area of philosophy that deals with knowledge, but it has yet to yield a definition that all philosophers can agree". Nevertheless, we believe that the concept of virtual knowledge is universal, in the sense that it can be understood by both humans and computers. It can therefore be used to support the processing of human knowledge as it is understood by a lay person, or as defined by various pedagogical models or knowledge management models. In other words, our in-house WPad software that controls the virtual knowledge can be used as TPACK software or applied to other models such as those by Mishra and Koehler [3,4], Bloom's taxonomy [5] the Anderson/Krathwohl taxonomy [6], or the Nonaka-Takeuchi SECI model [7].

The development of WPad educational software has been for many years and still is a key element of our research on technology-enhanced learning. Thanks to the fact that its designer worked as a teacher at undergraduate level, a researcher, and a programmer, it can be used for all of the educational processes in these areas. The core of this research is precisely the fact that various categories of educational content can be inserted into virtual knowledge in the form of knowledge tables, for use within research on technology-enhanced learning. This research forms one of the key points of the European research strategy, and the literature in this field already contains several monographs such as [8-11].

An additional focus of our research is that knowledge tables can be automatically generated by a computer, rather than only by the teacher. From the point of view of IT, these knowledge tables enable the teacher to perform mass processing of files. These activities are performed by file managers, and in the field of knowledge management this is referred to as information management or content management. From the point of view of a personal user, it offers the advantage of being able to carry out tasks such as finding the folders in which the teacher has stored files, or creating a list of all PDF files (or text files) on the computer, in a directory, on a USB key, etc. (Neither the Windows operating system nor any other software such as Google applications can carry out this function, as they do not have access to an individual's computer and do not even know what the user is doing on the computer). In this content, the current and future goal of this research is to use the virtual knowledge as a switch between the teacher and computer, to allow for the creation and transfer of educational content relating to any educational processes, including assessment and various administrative activities.

From this point of view, the development of personalized educational software can also be considered to add value in area of IT since according to [12] this aspect is absent from software engineering. There is also a lack of certain theoretical starting points for solutions based on learning technologies, as highlighted in [13], meaning that the concept of virtual knowledge into which educational content can be inserted is useful. It is important to understand that the issue of integrating IT into teaching is interdisciplinary and requires synchronization between didactics and IT procedures. However, this is difficult to achieve in practice, and has therefore been the subject of critique in the scientific literature (see e.g., [14, 15]). More detailed descriptions have been provided by authors publishing outputs such as [16, 17].

In view of the challenges described above, there is a wide range of problems that would need to be addressed by universal, all-in-one educational software. Due to the variety of the activities performed by teachers and students, and the aforementioned lack of solutions and approaches, teachers and students currently need to use multiple types of general software for IT integration. From this point of view, this article presents a universal design, since in practice, our WPad educational software works as an all-in-one tool for teaching and research. In other words, instead of a dozen types of software, the teacher needs to use only one, due to its high level of compatibility with the Windows operating system and Internet browsers (it does not replace these but uses their functions). This approach ensures the rapid transfer of knowledge to the computer and fast processing into the outputs necessary to support the teacher's activities. Since virtual knowledge, as a representation of knowledge, is an abstract concept (that is, it works as macro-substituted knowledge, which is changing and not constant), we see a certain resemblance to Peirce’s Pragmatism [18]. This theory considers the representation of knowledge to be a constantly changing element.

All of this is supplemented by the fact that WPad also allows the teacher to process "educational big data" in a user-friendly way, i.e., a huge amount of educational content. Due to the speed of insertion of the educational content into knowledge tables, and the ability to work only with reduced content, information overload is radically reduced. This solves the problems mentioned in [19, 20], such as brain overload and multitasking. Thus, WPad also incorporates elements that are characteristic of the field of human-centered computing, which, according to NASA's definition, can be understood as a combination of IT and social processes [21]. A human-centered approach was presented by the authors in [22].

The proposed design for IT support for engineering education covers dozens of interdisciplinary didactic and IT areas. This support is provided in the form of an all-in-one IT aid or tool for teachers, researchers, and students. In the context of this article, it is not possible to cite all of the relevant scientific literature for each area; however, it should be mentioned that WPad has also been used online (under conditions of distance learning during the COVID 19 pandemic), and as an IT tool operating on a cloud virtual machine, it can cover the area of university cloud-based learning, the importance of which is discussed in [23].

The following sections present a conceptual framework for universal IT support for engineering education (based on the use of our personal educational software WPad), an IT infrastructure for teaching and research, actual research outcomes, and examples of creating educational packages and communication channels (PIKS), including some aspects of teaching blind and visually impaired (BVI) students.

II. Conceptual Framework

The integration of IT into teaching and learning is based on the fact it is a set of knowledge-based processes, which from a pedagogical point of view are represented by specific didactic/pedagogical algorithms. In real life, there is a very diverse range of such algorithms, and these are different for engineering teaching, humanities teaching, and in particular, the teaching of visually impaired students. This situation requires tailor-made computer/informatics algorithms to be written for each individual case. In this context, there is no universal computer software on the market that is particularly suitable for supporting teachers or students as individuals; as a result, teachers must use existing software and technologies, test their suitability, and adapt. Although most teachers are not aware of these things, computer experts explain that as a machine, a computer lacks a representation of knowledge. This problem is compounded by the fact that the terms ‘information’ and ‘knowledge’ have different meanings in different scientific disciplines.

A. Principle of development of educational software

We managed to solve these contradictions through the design of virtual knowledge, which takes the form of a common table. An individual can input tacit knowledge into this in the form of natural language, while for a computer this is just a computer object that can be processed extremely quickly. In this case, the cybernetic principle is implemented, i.e., the virtual knowledge functions on the morphological principle as a switch between human mental processes and the physical processes of the machine. Since the machine works extremely fast, it can deliver the necessary output to the person (teacher) almost immediately, and thus automate his activities.

WPad software, which was written by one of the authors of this article (Svetsky), has been evolving over the years on the principle that source code must always simulate some educational activity, i.e., it must not only work on the creation of learning content but also its transmission. We have continuously reported the progress of our software application for the automation of educational processes in recent years, as new functions were added to the user menu. Mastering the creation and use of content for the teaching of undergraduates required us to solve the problem of how to integrate this content into activities connecting teachers with students; that is, how to select content from the knowledge base (for example from the created virtual learning space on the faculty server) and how to use it directly in lectures and exercises. For this purpose, communication channels connecting the classroom with the online environment were programmed in the form of an Internet application (these were used to exchange information and even in final exams). All of this allowed for a progressive approach and an awareness of the fact that IT integration always requires synchronization between pedagogy/didactics and IT algorithms, and that software must be designed to be compatible with Windows, computer networks and clouds (in other words, it must run on a specific IT infrastructure). The creation of a software system and IT infrastructure has taken research to a higher level, and the vision of the functioning of virtual knowledge as an intelligent educational structure is already beginning to be realized. Our approach will be presented in this paper, including the automatic creation of educational packages (as knowledge-packaged categories), with a special emphasis on applications for visually impaired students.

B. Software adaptation for teaching undergraduates

Our educational software WPad has evolved over the years according to the requirements for teaching undergraduates in the classroom, in order to create quality teaching material for exercises, lectures and self-study in the virtual educational space of the faculty. The user menu was gradually extended to include hundreds of items, and it suddenly became clear that there was no similar software on the market, as students and teachers were able to switch between the Internet and the folders and files on their computers using the same WPad - tables environment. This also meant that the number of clicks needed for a task was reduced. The most important advantage for a teacher, graduate or doctoral student designing educational content was that they could use WPad as a tool for creating notes. Moreover, the CTRL-F1 keyboard shortcut could be used to create a mirror HTML page of the WPad table. In this way, e-learning materials for several study subjects could be created from individual tables and placed on the faculty server, meaning that students could access them from home or the classroom. In other words, WPad worked not only as a simple text editor but also as a simple HTML editor, in which a multi-page table was created. This meant that the user did not need to know the HTML codes for creating web pages, as each row represented an autonomous HTML page.

The original development of WPad began as part of industrial R&D, at a time when the Internet was not yet commonplace. In the testing laboratory, the program and tables were also used as an information system for the ISO 9001 quality standard. It is interesting to note that the Opera browser was used in the offline mode, and without internet access; most users do not know that browsers can also be used offline on a personal computer. In this case, it is particularly convenient to use the Internet Explorer or Edge browsers, as these switch to Windows Explorer that users are familiar with after entering the offline path into the browser address bar (other browsers do not allow for switching to Explorer).

In addition to mastering the mass creation of teaching content, it was necessary to create communication channels. These could be described as chat/HTML sites via which students could communicate with each other and with the teacher, who could give them instructions, tasks, and teaching content. However, in the initial stages, the problem was that the students did not know what to communicate or what to write in the communication channels. In this case, the teacher had to give them instructions (such as ‘write the title of your semester work, your name, and identification data’). In practice, this meant that each teacher or student could have their own communication channels. Although communication channels were introduced into teaching about 10 years ago, the modern state of this technology allows them to be used more effectively. The screenshot in Fig. 1 illustrates the current use of the PIKS communication channel (Personal Information and Knowledge System), which functions as an additional Internet application with the same structure as WPad (in this case, only the contents of the tables are on a database server with MariaDB).

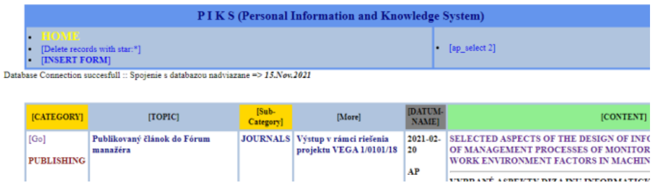

Fig. 1. Screenshot of the PIKS communication channel

C. Comparison of WPad software with other solutions

Although we examined papers from all the well-known scientific publishers (Springer, Wiley, Science Direct, Emerald), we found no software that would allow so many educational activities to be covered simultaneously. WPad also allowed for activities that other software did not provide at the time; for example, an English teacher could enter sentences into a WPad table and generate an HTML page, and when these sentences were clicked, a computer from the American server ImTranslator spoke them aloud (this was around the year 2008, when TTS technology was less common than today - https://text-to-speech.imtranslator.net/).

The result of the back-analysis was that our software could work as an all-in-one system, due to the specific data structure of the table. Based on this, a utility model was submitted and later successfully registered as a technical solution. The utility model uses this specific structure not only for content creation but also for the transfer of tables within an offline context or between the offline and online environments [1]. In the following, we describe research in which this software was installed and tested on a virtual machine in a faculty. This allowed tables to be transferred between a server with a virtual machine and an offline computer that had the same WPad software installed.

It should also be emphasized that if tables contain manually entered notes or selected and copied text, then WPad acts as a tacit knowledge converter (the term ‘tacit knowledge’ is used in the field of knowledge management). From a practical point of view, the main advantage of this is that the students can use the installed WPad, so that the content can be collected and combined from their computers and the teacher can more easily evaluate it and use it for collaborative activities. For example, undergraduates were found to have an insufficient knowledge of chemistry, which was required to take the subject Background in Environmental Protection. Each student was given a task in the WPad table to carry out an Internet search on a topic such as oxidation, reduction, pH, amino acids, etc., and to carry out an internet multi-search using WPad (here, 'multi-search' means that how many words are written to the table as many windows search engine with the search results opens).

The registration of a utility model opened up a new phase of endless possibilities for processing knowledge (didactic content in tables) and information (general content in computer files). The description given above makes clear the difference between the WPad table with the selected, reduced educational content, and computer text files (PDF, DOC, TXT, HTML), which contain general, unreduced content. This difference is more difficult to explain to an educator than to an IT professional, as in the IT field, the function of WPad is understood to relate to knowledge management, whereas working with files relates to information management (the BOX cloud service refers to this as 'content management').

It is important to understand that no other mainstream software allows for the concentration of offline and online content by processing knowledge and files in virtual knowledge tables, or the generation of HTML outputs, in the same way as in WPad. This finding also made it possible to start developing application menus and various sophisticated activities. An application menu means that several simple menu items are combined into a single sequence that can be performed with one click. In other words, from the point of view of the teacher and the user, it works like a black box.

III. IT Infrastructure for Teaching and Research

It follows from the previous explanation of our approach that the integration of IT into education is a very complex matter; this is because it is an interdisciplinary area, and in our case, a completely new technology is being developed for academic engineering education and research. The main output is a universal IT system that can be applied to any activity undertaken by teachers, students or individuals and simulate educational processes as knowledge based. Its theoretical basis is the abovementioned virtual knowledge controlled by the WPad software being developed within a particular IT infrastructure. This functionally enables teachers and students to switch between their local computers and online environments (a university LMS, Internet services, web) within any type of teaching environment (e.g., blended learning, distance learning, assessment, evaluation, exercises, lectures).

Outcomes from many years of research have enabled personal IT support within the teaching of undergraduate courses (Background in Environmental Protection, Chemistry, Occupational Health and Safety, Programming Languages, Simulation Modeling) and research (FP7-technology-enhanced learning, digital libraries, learning analytics, Horizon - Cracking language barriers, V4 project - CSCL). As mentioned above, the portfolio of pedagogical/didactic algorithms is so huge in real life that no artificial intelligence can do it. Our IT support system can now be used to continue the elaborated outputs of the automatic creation of educational packages and provide language support for publishing and a solution for IT support for visually impaired education. In this context, it should be mentioned on the basis of preliminary tests, we find that our educational software can to some extent also be used for BVI students, which will be addressed in the following sections.

Our IT support system, developed within the context of engineering education, consists of:

- SOFTWARE: (i) WPad (educational software); (ii) PIKS (communication channels); (iii) A set of exe-tutorials or HTML tests.
- HARDWARE: (i) Client computers with Windows; (ii) notebooks with Windows; (iii) mobile phones (for browsing the virtual learning space) (iv) e-sources (USBs, CDs, DVDs).
- EXTERNAL INFRASTRUCTURE (personal or faculty IT equipment or cloud services).
- VIRTUAL MACHINES with Windows (for WPad); a LEARNING WEB SPACE (for FTP transmission and PIKS).

Fig. 2 illustrates how the teacher's IT personal infrastructure works.

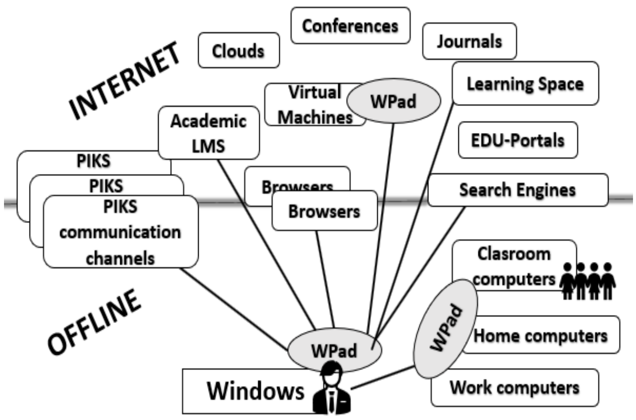

Fig. 2. A teacher's personal IT infrastructure

The basis of working on a personal computer is the use of folders and computer files in offline mode. Windows Explorer is used to access these files, and browsers such as IE, Edge, Chrome, Firefox, Opera, Safari and others are used to work on the Internet. In this case, each browser is a complex piece of software that has myriad features built into it. In practice, this means that it can be used for internet searches, entering paths in the address bar, creating a system of favorite links to sites that are visited regularly, and the like. The left-hand side of Fig. 3 shows this standard way of working with the Windows operating system, while on the right is a demonstration of the use of WPad software.

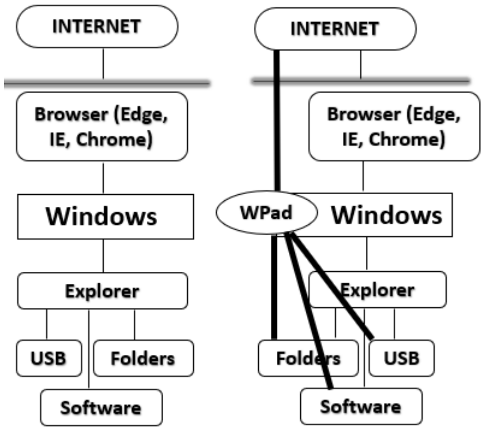

Fig. 3. Direct connections between WPad tables with online bypassing browsers

As you can see, a user can bypass Windows Explorer and the default browser (IE, Edge, Opera), and open computer files and folders or websites directly from the WPad table. This saves time and reduces the large number of clicks needed to switch between the offline and online environments. In practice, an individual can save thousands or tens of thousands of the mouse clicks yearly by using WPad. Teachers can create their own systems and automate their activities, for example by creating a set of Favorites in the tables.

IV. Some Aspects of Actual Outcomes

A. Teachers

It should be emphasized here that WPad has been developed over many years primarily to automate all of the activities of a teacher; these can be divided into content creation, lecture and exercise support, publishing, research, and also self-study and other work-related activities such as administration. The creation of a Favorites set mentioned above is only one of the possibilities for the use of the research outputs of IT integration into teaching. It also covers the teacher’s adaptation to the Windows operating system and built combined offline/online IT infrastructure (software; virtual machine; a web space with virtual learning space/environment; communication channels). The principle of automation is very simple: if the teacher does something regularly on the computer, it can be carried out by writing new source code, which is embedded into the user menu of the WPad. However, it also is important for teachers to adapt to this technology by creating their own didactic-informatics algorithms in order to facilitate their work on the computer. This involves not only organizing folders, but also creating a way of working when using WPad software and virtual knowledge tables.

An example of the use of the schemes in Figs. 2 and 3 can be given in relation to the teaching of undergraduates. In this case, the teacher taught several study courses, and all the necessary data were available from the Academic Information System (AIS), which is like a university LMS (a learning management system such as Moodle or Blackbox). There were already hundreds of links of various categories at the head of the entrance to the AIS. In addition to the internal university e-mail, the teacher most often used the space for the relevant study course where are available student names dividing in groups or assessment data. WPad made it possible to open links to AIS paths or to copy data to the knowledge tables in one row of the WPad table (simply by using combinations of keys, for example CTRL-A +/ CTRL-C + CTRL-V). When the teacher copied a list of students, a table could be created in which each student was listed in one row.

In this case, the teacher usually taught between five and 100 students. In the latter case, each student was listed in one row of the WPad table. During the semester, the necessary records were kept for each student in knowledge tables, which proved very useful during the final examination at the end of the semester. The teacher was able to simply copy the data from the AIS on which of the students had signed up for the exam and to compare this with how the students had worked during the semester (from the table, he directly clicked on their semester work, tests, and emails). In other words, the teacher used the WPad as a personal information system.

When this teacher used the WPad, he created a main table with plain text. This usually had 20–30 rows and was used to store information and knowledge in the given table regions. This “educational” knowledge table should be seen as an educational package in which the teacher can store everything. The table can be transferred from work to a home computer or laptop using a USB key or uploaded to the virtual learning space. Although a resemblance to an LMS such as AIS or Blackboard may be noted, and it is true that this is a teacher’s personal IT tool that performs this function, the dozens of other types of systems do not allow the user to search a personal computer, run software, carry out Internet searches, etc.

The development of WPad to support the teacher focused on the creation of so-called educational packages from a set of computer files (see the next section), whereas the WPad table functions as a container of educational knowledge. This difference is often difficult to explain to colleagues or even IT professionals who have never encountered this personalized IT paradigm, as they simply cannot understand that the relational database paradigm is not used. They therefore do not understand that this is a new way of transferring human knowledge into knowledge tables, involving an interaction between humans and machines. Since the teacher can insert tacit knowledge into the tables (as well as explicit knowledge, by copying texts from documents), the tables contain a selection of educational/didactic content. This understanding is also hindered by the fact that people often exchange and send information to each other using computer files such as TXT, HTML, PDF, DOC, JPG, MP3, which contain unreduced content without added didactic value. For example, the non-reduced content may in the form of a PDF file of conference proceedings, whereas in a WPad knowledge table, the teacher can choose from the proceedings only what is needed.

B. Students

As part of technology-enhanced learning research, WPad was also used in undergraduate teaching. Each pair of students was assigned to one computer in the classroom on which WPad was installed. The teacher gave them instructions, such as "Open WPad and enter in the table your names and the title of your semester work, and write a short abstract. Finally, use CTRL-F1 to make the browser open the converted table in HTML format". Another example can be drawn from the study program Basics of Environmental Protection, in which each student had to perform a multi-search for certain keywords (e.g., oxidation, reduction, amino acids, photosynthesis). A multi-search means that students wrote the keywords in the text field of the table, and after using the appropriate menu option the browser has opened so many search-result windows how many keywords were written (Opera version 9.27 was used in this case). The teacher then merged the content of the students' tables and placed the teaching content into the faculty's learning space (the teacher had designed an e-learning space for this content on the faculty server). In this way, tutoring material for the Chemistry course was created collaboratively, which was then used in subsequent years by other students for self-study (Note: The knowledge of chemistry students was very weak, and without this they would not have been able to master the subject matter).

Due to the need to connect the classroom with the online learning space, communication channels were created for each study program (in the form of an internet PHP/MySQL application). These were mainly used for instruction and information exchange. It is important to add that over several years, even students with poor IT skills had no problem using WPad. Unlike the students, however, some teachers had no incentive to test WPad and claimed to use Google and Microsoft Office instead.

C. *Black Box Principle*

As part of the V4+ACARD project, WPad was tested by around 10 teachers and researchers using a shared computer designed at the faculty virtual machine. They modeled the pilot creation of educational packages, including multilingual support. However, in this case, the use of WPad was rather problematic. The only exception was a Polish researcher, who even started testing WPad beyond the project for the visually impaired. The designer of WPad could not understand this paradox: colleagues with much better IT skills than most students were unable to use WPad, while students with poor IT skills did not have problems. The explanation for this is in fact simple and has to do with the human-computer relationship. The point is that students do not decide whether the program is complex or simple, but instead simply follow the instructions exactly as the teacher gives them. In contrast, since no one gives teachers instructions, they do not understand why they should use WPad (one should also take into account the fact that training on new software takes a certain amount of time, which teachers usually do not have).

This paradox radically influenced the programming style in a such way that further software development focused on the creation of application menus that could function as a black box. In an application menu, a sequence of simple items is concentrated into a single menu item, and all necessary activities are performed with one click. In this case, teachers and researchers had no problem with the application menu, as they knew exactly what the program would do (in this case, they did not have to create content). From the point of view of integrating IT into teaching, it is important to create application menus based on didactic activities or the needs of the teacher (this is in a compliance with the basic requirement that the technology should adapt to the teacher).

The principle of the application menu was used in a project for the pilot creation of educational packages, as explained in the next section. To illustrate this, we give several examples of application menus and what they allow the user to achieve in one click:

- The entire IEEE Computing Edge magazine can be displayed, or the monthly issue can be downloaded.
- After entering the teacher's name, an overview of his or her publications will be displayed from the university database (optional for teachers in any faculty).
- After entering an English keyword, all sentences from a conference proceeding or another text source that contain the keyword will be displayed.
- After entering the path to a folder or disk, a file name or format type (PDF, DOC, PNG), a table is created with as many rows as the number of existing files.
- When PHP source code is entered into the text field of the table, the result of the code is automatically displayed in the browser.
- When a keyword is entered, the browser automatically opens the search engine results, meaning that the teacher can copy educational text and write notes on it in the rows of the table, and can use the table as a search repository.
- Other options, such as direct opening of the communication channels with the possibility of uploading files from a computer; synchronization with cloud services (e.g., BOX, OneDrive).

Even a disinterested person can understand that each of these applications is normally covered by a separate software; however, they can all be covered only by WPad, which is therefore an all-in-one system. Moreover, if standard software development had been applied, then WPad could not have been all-in-one software, or it would have taken several years to achieve the required level. In this context, it is therefore challenging to identify the most common educational situations in the classroom and to create additional application menu items based on them. It is important that the teacher should also adapt to the technology by structuring the content and needs to choose the names and organization of the files appropriately and to apply his or her own navigation marks in the tables in a similar way to HTML tags.

V. Examples from Teaching and Research

Research into the integration of IT into teaching has been ongoing for more than 10 years and has focused mainly on undergraduates. Its basic motive is computer support for all the activities of the teacher, as a key person in the teaching process. In this context, research is based on the automation of teaching processes as knowledge-based processes (starting under the umbrella of technology-enhanced learning). In the initial phase, the problem of automating the creation of educational content was solved, for which the outputs were e-learning materials and an educational repository. After mastering the creation of content, our research focused on IT support for the teacher's activities; in other words, what to do with the content of lectures, exercises, and self-study. A key finding was that it was also necessary to deal with software and adaptation to the Window operating system, the web, virtual machines, and clouds, to create an IT infrastructure.

As part of a continuous publication strategy, we emphasized that the level of computer support for teachers and students was insufficient due to the short life of hardware and software. The average university teacher needs solutions that work for 10 to 15 years, and current technology does not meet this requirement.

Compared to the state of the art, the solution described here focuses on the fast insertion of educational content into WPad tables, fast accessibility, and fast processing thanks to the method used to concentrate content into application time outputs for all types of activities performed by the teacher. The teacher therefore needs a universal, all-in-one software package that can do all this, as the alternative would be to use a dozen different software applications. From this point of view, the basic use of WPad software for universal content creation is probably the cheapest and most effective existing solution since the teacher or user only needs to have a computer with Windows and WPad installed.

In addition, recent research has shown that the basis of adapting technology to the teacher's activities is the parallel and synchronous creation of didactic and computer algorithms. This fact is not mentioned (or at least, not emphasized) in the scientific literature. In this context, we began to address the issue of the creation of educational packages. In contrast to the more common use of WPad to create mass educational content and information in knowledge tables, it was necessary in this case to start by focusing on the mass processing of computer files. Each teacher creates sets of files on a computer, which are contained in different folders on the computer, and which often consist of hundreds of files in dozens of formats (text, images, audio files). Very few people realize that a regular teacher has a small internet on their computer. For example, when the designer of WPad used the program to list all the files on the computer, a table was created that had 600,000 rows (where one row represented one file name). Of course, this also included all of the Windows and software files, but the number of files in the most common formats (such as TXT, PDF, DOC) was between 10,000 and 30,000.

In parallel, it was important to start using virtual machines in the cloud (on which the WPad is installed) and to test a cloud content management service (the BOX cloud was used as a web space for document sharing). It needs to be explained to the average teacher that a virtual machine is a virtual space where a shared computer can be installed. In our case, the IT department provided us with remote access to a Windows 10 computer that was shared by about 10 teachers from five countries. This also solved the problem in which it was difficult to motivate colleagues to install WPad on their computers. In this case, everyone used a remote computer on which WPad was installed, meaning that they could jointly model the educational packages and multilingual support.

Fig. 4 illustrates the principle used to create the educational packages. It is based on the fact that teachers store educational content in different folders and computer files in different formats. The teacher first copies the files manually to the default folder (in the picture, this is labeled 'MIX folder') using File Manager. Then, from the WPad menu, the application menu item is selected to create the educational packages.

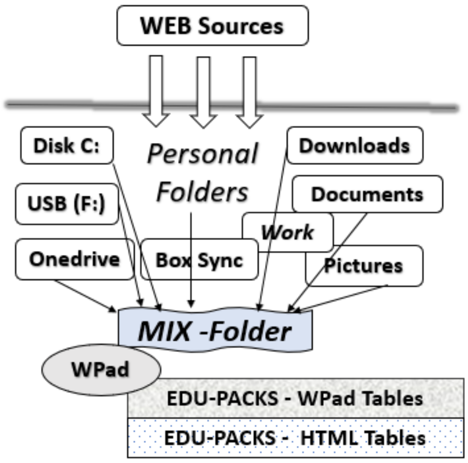

Fig. 4. Principle used to create educational packages

The basic option is to create a WPad table that has as many rows as there are files in the MIX folder. The program lists the file names in the individual rows of the table. The key combination CTRL-F1 causes the default browser to automatically open the HTML table, which is a converted WPad table. The result is that the teacher has concentrated the paths or the content of all of these files into one "navigation" package (WPad table). The educational packages can then be used as needed or uploaded to the virtual educational space of the faculty or to a publicly accessible web space. These educational packages can be used in teaching as they are available online to students.

In real life, the teacher performs several didactic algorithms, each of which requires a different modification to the educational package. In practice, the basic educational table typically still needs to be adjusted according to the immediate teaching needs (i.e., according to the output needed). In terms of programming, this represents a wide range of potential situations that need to be accounted for, including:

- The teacher has ready-made educational content in files whose names are not understandable, e.g., the names are numeric.
- The teacher does not have complete educational material in the files.
- The teacher wants to insert content consisting of unformatted text files (plain text, HTML) into the educational table.
- The teacher wants to insert the content of formatted files (text, images, audio) into the navigation table (this then depends on the number of files, as if there are too many files, the computer memory will not be sufficient).
- The teacher wants to create educational material with high didactic quality, which will involve adding text or HTML text to the tables manually (it should be noted that each line is converted to a separate HTML page, and all pages are combined into one html package (i.e., into a mirrored HTML table).
- The teacher wants to create educational material of high IT quality; in practice, this means that the content is concentrated on one computer screen that

allows for quick navigation up and down and contains links that directly open educational files from the web (normally, one must click to dozens of links, because the content is divided into several sub-pages).

It is important to note that the number of computer algorithms can be radically reduced, and adaptation is easier if the user 'helps' the computer by using appropriate file names and suitable organization of both the knowledge tables and computer files (in particular, automatic numbering of files should be avoided).

One example is the educational package created by a Polish researcher within the V4+ACARDC project. This author also wrote the following section on visually impaired applications. In his case, he had ready-made educational material in the form of PDF files. The paths to these PDF files were first automatically inserted into the table and following the didactic (description) text was manually added to the text field. Fig. 5 shows an example of the output for an educational package on the web. For example, clicking on a record number or on wyk4.pdf will open part of the educational text when teaching AJAX language.

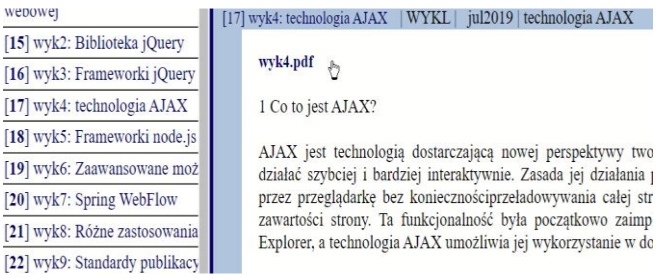

Fig. 5. Example of the creation of an educational package

The previous description illustrates the wide range of possibilities in terms of the creation of educational tables and setting up specific learning portals for this purpose. In this vein, further interdisciplinary research can be carried out. The description given above is supplemented by an example of one way to use the WPad table called Educon, which was used when writing this paper, as illustrated in Fig. 6 (in comparison with tables created half-automatically as educational packages, this Educon table was created manually based on the teacher's mental processes).

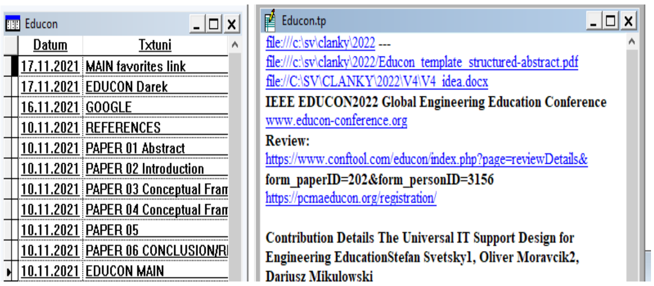

Fig. 6. A WPad table used to write this paper

VI. Research Approach for Teaching Blind and Visually Impaired Students

As is well-known, there are currently many solutions to support collaborative work, remote learning, and entertainment. During the pandemic, these turned out to be very important for multiple user groups and were therefore strongly developed. This was the case for all users, but it was of particular importance to BVI students.

We should note here that BVI students use a computer with specialized software that runs permanently in the background while they are working, called a screen reader or screen magnifier. This enables BVI students to use any software installed on the machines. Screen readers and magnifiers are available for all operating systems and devices: for Windows, we have a program called NVDA [24] Jaws [25], whereas for MacOS there is VoiceOver [26]. There are also native features built into each operating system, such as a magnifier or Narrator for Windows, or Talkback for Android. All of these programs work in the same way: a BVI user operates a keyboard without using a mouse, and while performing different operations, can constantly listen to voice messages from a screen reader. The software reads out the keys that the user is pressing and the object of focus on the screen. If a braille display is also connected to the computer, messages are also sent to this display to allow the user to read them by touch. In the case of a partially sighted user, the fragment of the screen that is currently explored with the mouse or keyboard is automatically enlarged and is sometimes presented in a different color or with higher contrast, depending on the user's pre-set preferences.

Using these basic solutions, BVI students can use standard office programs, browse the web, communicate, use listening and even edit software, etc. However, for this to be possible, these programs must be designed and implemented in accordance with certain accessibility guidelines. For web solutions, the applicable guidelines are the W3C WCAG2.1 [27] standard and the Accessible Reach Internet Application (ARIA) [28]. The rules contained in WCAG should also be applied to desktop and mobile applications. Hence, when programming such applications, the developer should remember to use standard controls and menus instead of toolbars, and to add keyboard shortcuts to each option that will allow the user to activate them.

Large companies such as Google and Microsoft have developed their own platforms for hosting online meetings, exchanging information, or working together on documents or spreadsheets. Google provides applications such as a calendar, meeting application, classroom, online drive for documents, etc. Unfortunately, these are only partially available for BVI students; for example, a blind person cannot perform certain operations in the Google classroom or read the content of the tasks if they are published in the form of graphics. The situation is slightly worse in the case of the solutions provided by Microsoft (i.e., Microsoft Teams and Office 360). BVI students may have difficulty creating a meeting in Microsoft Teams or running a split-screen feature. An example of an online meeting solution that is more accessible for BVI users is the Zoom platform, although it requires installation of the software on the user's computer. Unfortunately, other less well-known platforms, such as clickMeeting [29], Hubilo [30], and Glisser [31], are even less accessible to a blind user.

The situation is similar when we consider educational platforms, and particularly solutions related to teaching mathematics or foreign languages. For example, one of the most popular math teaching platforms, GeoGebra [32], is poorly accessible to BVI students. An example of a solution that is more accessible in this domain is Desmos [33], which offers special functions for blind users such as the ability to write an equation for a function and then draw and play a graph using sound. However, this seems to be the only positive exception.

After analyzing this situation, we come to the conclusion that there is no one solution that would be suitable for mutual communication, knowledge exchange, joint learning and entertainment. Moreover, there is no universal solution that would provide additional facilities for blind and visually impaired people. Taking this into account, in the V4+ACARD Consortium, we undertook work to adapt our existing WPad knowledge exchange software for the needs of blind users. We first analyzed the accessibility of WPad using the version installed on the local computer and on the virtual machine for the project. In this experiment, we used the WPad software with a screen reader in which data from various domains and topics were added to the tables. These data included information on publications and magazines, information on organizations supporting BVI users, as well as educational materials on programming languages and web technologies intended for students. This work allowed us to gain experience and determine the actual level of accessibility of our WPad software for BVI users. It turned out to be almost completely accessible to all screen readers, except in a few of the following use cases.

The WPad user interface is based on the logic of a database table, in which information is collected in the form of columns and records. These can be used to store human-readable information, such as entry dates, subjects, categories, sub-categories, content, links to other entries, etc. A blind individual can navigate through these columns and records using standard keyboard shortcuts. During this operation, the screen reader reads out the contents of the appropriate cells. The use of this logic for information storage allows for the accumulation and structuring of knowledge, meaning that it is a kind of knowledge base, similar to a simplified ontology. In addition, the program has a very extensive menu in which the user can find options in the database for finding necessary information, filtering, searching the resources of the local computer and even searching the Internet. Another useful feature is the ability to automatically generate web pages in static HTML, directly from the data table in the WPad program. In this way, a blind or visually impaired teacher can easily generate educational packages for students. During our experiments, such packages were also created with the support of a NVDA screen reader. These educational packages, which were generated in the form of HTML pages, were then made available for use by students.

However, there were a few problems with the accessibility of the WPad software. The most significant was that the screen reader did not read the content of the text field intended for inserting large amounts of data, which became obvious while navigating through it. Moreover, while working with the program, error messages often appeared; in the case of a blind user who is not very familiar with computer technologies, these may be irritating. The accessibility status of our WPad software is described in more detail in [22]. In the next stage of this work, we made efforts to eliminate these problems and to make the knowledge exchange system fully available to blind users. Work on this issue is currently continuing.

In addition to correcting the problems mentioned above, the idea arose to implement the entire system in the form of a web application, and PIKS was created based on this concept. An important advantage of this idea is that it uses the same table structure as WPad but is accessible via a web browser. This eliminates the most significant problem of the inaccessibility of a large text field, since in PIKS, this is read correctly in the web browser by the screen reader. It can therefore be freely edited by a blind user.

However, as HTML tables are fairly tedious to view using a screen reader, the idea was born to build into PIKS a mechanism of various filters for the displayed data. Using this approach, it became possible to display only data from a given category or subcategory.

By continuing and extending our work, the PIKS system will become a portal through which a visually impaired user can carry out many activities in a single place. For example, one table can be used for work, another for learning and sharing knowledge with others, and another for entertainment. In the next stages of this research, we intend to develop a category system for the user that will divide activities into areas such as work, science, entertainment, music, and communication via social networks.

VII. Conclusion/Recommendations/Summary

The paper has presented a design for interdisciplinary IT support for engineering education, which has been implemented in the context of engineering education and is especially suitable for STEM teaching. In this approach, virtual knowledge enables the user to work with text, images, and computer files, and thus also to visualize educational content and activities. This is primarily useful in STEM, in contrast to managerial and humanities subjects, where text is used more often. We have shown that its universality arises from the concept of virtual knowledge, which the computer understands as a representation of knowledge (as a kind of information, since the computer does not work with knowledge but with information in the form of bytes). As part of a long-term solution for the integration of IT into teaching, a personal IT support system has been developed that can be used primarily by the teacher as an educational IT tool for any activity (teaching, creating e-learning materials, research, publishing, assessment) and which can also serve as an educational tool for the students. This paper has presented examples of the creation of educational packages, communication channels and support for visually impaired students. In this context, the presented universal personalized IT support for teachers is based on the design of a personal set of offline (WPad) and online IT tools (PIKS) that are compatible with any other IT category, such as Microsoft Teams, Zoom (however, these, unlike WPad, only work online).

As for the limitations on this work, it should be emphasized that IT integration is interdisciplinary, and does not consist solely of the design of didactic/pedagogical algorithms and parallel informatics (didactic algorithms must be defined, otherwise they cannot be programmed). Namely, the most difficult aspect of the programming was adaptation to Windows, networks, and clouds, which was the most time-consuming. It should be mentioned that this is research on design educational technology that has not existed before, in which the basic aim is to create a prototype through which thousands of educational activities can be simulated. We encounter surprisingly many misunderstandings on the part of teachers, and even reviewers for pedagogical journals, who do not understand this aspect of our research. In other words, they only recognize if some students work without a computer and some with a computer in order to test a particular hypothesis. From this point of view, we have presented a new type of technology in the form of our educational software WPad, which can already be used, for example in humanities PRE/POST academic research.

This is long-term research that has been running since around 2007–2008, when the predecessors of the communication channels and the virtual learning environment were introduced [34, 35]. Our vision was to equip individual knowledge workers with a universal, personalized, all-in-one IT tool for the mass processing of human information and knowledge, enabling multitasking and minimalization of computer interfaces. The user should not perceive whether this work is being carried out offline on the local computer or on the Internet. In future work, we will continue to design our IT tools with a focus on the development of learning packages and communication channels and with the vision of creating an intelligent learning structure based on virtual knowledge.

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References

[1] S. Svetsky and O. Moravcik, "The connection of an unstructured data processing system using a specific data structure," Slovakia Utility model UV 7340, 2016.

[2] M. Swain, "Knowledge," in: W. Dubitzky, O. Wolkenhauer, Cho KH., H. Yokota (eds.), Encyclopedia of Systems Biology. Springer, New York, NY., 2013. Available: https://doi.org/10.1007/978-1-4419-9863-7_1030.

[3] P. Mishra and M.J. Koehler, "Technological pedagogical content knowledge: A framework for integrating technology in teachers' knowledge," Teachers College Record, 108(6), 1017–1054, 2006.

[4] W. Zhang and J. Tang, "Teachers' TPACK development: A review of literature," Open Journal of Social Sciences, 9, 367–380, 2021. doi: 10.4236/jss.2021.97027

[5] P. Armstrong, "Bloom's Taxonomy," Vanderbilt University Center for Teaching, 2010. Available: https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/.

[6] Biology discussion: Anderson and Krathwohl's taxonomy. Biology. Available: https://www.biologydiscussion.com/living-organism/taxonomy-living-organism/anderson-and-krathwohls-taxonomy-with-comprehensive-view-biology/85945.

[7] I. M. L. Farnese, B. Barbieri, A. Chirumbolo and G. Patriotta, "Managing knowledge in organizations: A Nonaka's SECI model operationalization," Frontiers in Psychology, 10, 2019. Available: https://www.frontiersin.org/article/10.3389/fpsyg.2019.02730.

[8] S. P. Goodman et al., Technology-Enhanced Learning: Opportunities for Change. Laurence Erlbaum, Mahwah, NJ, USA, 2002.

[9] M. D. Roblyer and A. H. Doering, Integrating Educational Technology into Teaching, 6th Edition. Pearson, 2013.

[10] M. Bower. Design of Technology-Enhanced Learning: Integrating Research and Practice. Emerald Group Publishing – Education, 2017.

[11] N. Balacheff, S. Ludvigsen, T. Jong, A. Lazonder, and S. Barnes (eds.), Technology-Enhanced Learning. Principles and Products. Springer, XXVI, 326 p., 2009.

[12] A. Martens, "Software engineering and modelling in TEL," In: R. Huang, Kinshuk, and N.-S. Chen (eds.), The New Development of Technology Enhanced Learning. Concept, Research and Best Practices, Springer-Verlag, Berlin, 2014, pp. 27–40.

[13] M. Oliver, "Learning technology: Theorising the tools we study," British Journal of Educational Technology, 44, 31─43, 2013.

[14] I. Kinchin, "Avoiding technology-enhanced non-learning," British Journal of Educational Technology, 43(2), 43–48, 2012.

[15] D. Lundie, "Authority, autonomy and automation: The irreducibility of pedagogy to information transactions," Studies in Philosophy and Education, 35(3), 279–291, 2016.

[16] S. Svetsky and O. Moravcik, "Some aspects of teaching processes computerization," in: Proc. IEEE Future Technologies Conference, 2017, Vancouver, BC, Canada, pp. 1–5.

[17] S. Svetsky, O. Moravcik, M. Shyshkina, Z. Cervenanska, and J. Kotianov, "The knowledge-based design of educational technology," in: K. Arai (ed.), Proceedings of the Future Technologies Conference (FTC) 2021, Volume 3. FTC 2021. Lecture Notes in Networks and Systems, vol 360. Springer, Cham. Available: https://doi.org/10.1007/978-3-030-89912-7_58.

[18] R. Wille, "Conceptual landscapes of knowledge: A pragmatic paradigm for knowledge processing," in: W. Gaul and H. Locarek-Junge (eds.), Classification in the Information Age. Studies in Classification, Data Analysis, and Knowledge Organization. Springer-Verlag, Berlin, 1999.

[19] L. Serfaty, "Hyperconnected: Brain overload (Hyperconnectés: Le cervau en surcharge)," ARTE France, ZED Productions, INSERM, France, Sep. 3, 2016.

[20] G. Mark, "Multitasking in the digital age," Synthesis Lectures on Human-Centered Informatics, 8(3), 1–113., 2015.

[21] NASA, "Human centered computing." Available: https://www.nasa.gov/centers/ames/research/technology-onepagers/hc-computing.html.

[22] S. Svetsky and O. Moravcik, "Human-centered software design for knowledge-based processes," in: Proceedings of the International Conference on Electrical, Computer and Energy Technologies (ICECET), 2021.

[23] V. Bykov and M. Shyshkina, "The conceptual basis of the university cloud-based learning and research environment formation and development in view of the open science priorities," Information Technologies and Learning Tools, 68(6), 2018.

[24] R. Scholar, M. Mundada, and C. Kayte, "Screen readers for Linux and Windows concatenation methods and unit selection based Marathi text to speech system," International Journal of Computer Applications, 130, 975, 2015. doi: 10.5120/ijca2015907192.

[25] F. Scientific, JAWS for Windows, Screen Reading Software, Consultle, vol. 17, 2013.

[26] B. F. Smaradottir, J. Haland, and S. Martinez, "User evaluation of the smartphone screen reader VoiceOver with visually disabled participants," Mobile Information Systems, 2018, 19, Dec. 2018. doi: 10.1155/2018/6941631.

[27] W3C, Web Content Accessibility Guidelines (WCAG) 2.0 2008. Available: https://www.w3.org/TR/WCAG20.

[28] A. Whitbrook, Programming with the ARIA API, 2010. doi: 10.1007/978-1-84882-864-3_2.

[29] Click Meeting homepage. Available: https://clickmeeting.com/pl.

[30] vFairs Virtual Event Platform - 24/7 Global Customer Support. Available: https://www.vfairs.com.

[31] Glisser: Home. Available: https://www.glisser.com.

[32] GeoGebra | Darmowe aplikacje matematyczne - ulywane. Available: https://www.geogebra.org/?lang=pl.

[33] Graphing calculator (Kalkulator graficzny) - Desmos. Available: https://www.desmos.com/calculator?lang=pl.

[34] S. Svetsky, "Modelling of multilingual e-learning and virtual learning space for R&D staff," in: Proceedings of the ICETA 5th International Conference on Emerging e-Learning Technologies and Applications, Stará Lesná, Košice: Elfa, 2007.

[35] S. Svetsky, O. Moravcik. P. Tanuska, A. Rehakova and. D. Ruskova, "The implementation of technology enhanced learning at dislocated university workplace," in: Proceedings of the ICETA 6th International Conference on Emerging e-Learning Technologies and Applications, Stará Lesná. Košice: Elfa, 2008.