# The Empirical Research on Human Knowledge Processing in Natural Language within Engineering Education

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**Abstract** The state-of-the art of the computer supported or enhanced teaching and learning processes is mostly focused on content acquisition, processing, and management; virtual learning environments; learning analytics; educational data mining. There is an absence of approaches based on knowledge exchange between machines and humans in knowledge based processes. This paper describes such an approach. Within an empirical participatory action research on technology enhanced learning the issue of knowledge is understood as a key element of any automation of human knowledge processing. Teaching is thus considered as a typical knowledge based process. In this context, the utility model is also used, which implemented "virtual knowledge" as a universal construct, which “interdisciplinarilly” bridges the mental processes of humans and the physical processes performed by computers. Examples of such solutions are briefly mentioned. It is also emphasized that a complex computer supported collaborative learning requires, in the real practice, to execute a combined pedagogic (didactic) and informatics research.

**Keywords:** Human knowledge processing, technology enhanced learning, computer supported collaborative learning, human computer interactions, engineering education.

# 1 Introduction

Despite the huge progress in ICT there is still the absence of the computer support of teaching and learning. This absence notably affects the personal level of teachers or students as regards the way how to exchange the flow of human knowledge between humans and machine (computer). This is due to the fact that these processes operate with knowledge and from the informatics point of view they are considered as uncertain processes working with unstructured heterogeneous data. To write computer programs as an abstractions of the real world represents therefore a very challenging problem. In the context of the teaching process there is a need to share such data (human knowledge) between the teacher and many students. In addition, the flow of knowledge must be provided in an appropriate pedagogical (didactic) quality, in real or synchronized time (classroom, at home, online) and within the limited time of the teaching lesson. So logically, these processes should be automated. However, in comparison with automation of a technical system, which produces a product with required technical parameters, the teaching is a process within a living system and nobody can guarantee that students are optimally educated, or even that they will understand the pedagogical/content knowledge or be able to use the learnt knowledge in real practice.

In this context, the Cybernetics (within which computers were invented) represents the basic theoretic discipline focused on the automation (regulation, control) of such complex systems, i.e. on the information, information transfer and processing [1]. However, one should always be aware that any computer (machine) can perform physical processes that only support our mental processes, thus, the computer does not perform the mental work instead of us.

On the other hand, we are able to isomorphically assign the results of these physical processes to our intellectual processes [2]. It is also emphasized in [2], that a large part of cybernetics terms is created by the formal and schematic transfer from neurophysiology and social sciences to physical processes. As a result, the concept of analogy is often misused and the terms like information, knowledge, thinking, intelligence have different meanings in Cybernetics, Computer Science, Information and Communication Technology than in Knowledge Management, Education, Educational Psychology, Philosophy, or social sciences respectively.

In general, teaching and learning processes are cognitive processes, i.e. they are human knowledge based, thus logically connected with thinking and intelligence. Within psychology, according to [3], behaviorists understand thinking as a process of solving problems, while in cybernetics it is a process of processing and using information. Similarly, the problem of definition of intelligence is a very complex issue. For instance, in [4], tens of definitions of intelligence are divided into "collective definitions, psychological definitions, and AI research definitions" (AI means Artificial Intelligence). It can be also emphasized that humans acquire human knowledge or information (this is a lower hierarchical level than

knowledge) through experience or education, while computers as machines by processing gigantic amount of sequences of bits (as units of information). Therefore, definitions of information or intelligence in various disciplines cannot be the same.

The above mentioned problems also resulted in a relatively large terminological chaos in all interdisciplinary scientific papers focusing on the integration computers into teaching and learning, e.g. concerning Technology-enhanced Learning, Educational Technology, e-Learning, Collaborative Learning, Web-based Learning, including Learning Analytics and Educational Data Mining. These problems were published in many scientific papers, e.g. in [5-11], including authors of this paper during their long-term research on Technology-enhanced learning (see e.g. [12-17]). According to their opinion, the above mentioned terminological issues or the general dissatisfaction with integration of ICT in teaching and learning are related to the absence of scientific approaches concerning the role of knowledge, or definition of knowledge, despite the fact that the human knowledge, including educational knowledge, represents the key element of any automation of teaching processes.

To be terminologically clear, in the title of this paper the term ”human knowledge processing” is used in order to differentiate the content of this paper from the concept of information and knowledge commonly used in Computer Science, Artificial Intelligence, Knowledge Based Systems, or in Educational Data Mining, Learning Analytics, where the meaning of information and knowledge is different.

## 2 Objectives, methods and results

### 2.1 Objectives

Our research is aimed at the complex all-in-one solution of the automation of teaching and learning with focus on all kinds of processes performed by the teacher as the key player in order to assure his/her sustainability as a knowledge worker who manages the human knowledge based processes. Fig. 1. illustrates the basic idea of the teacher’s personalized computer support.

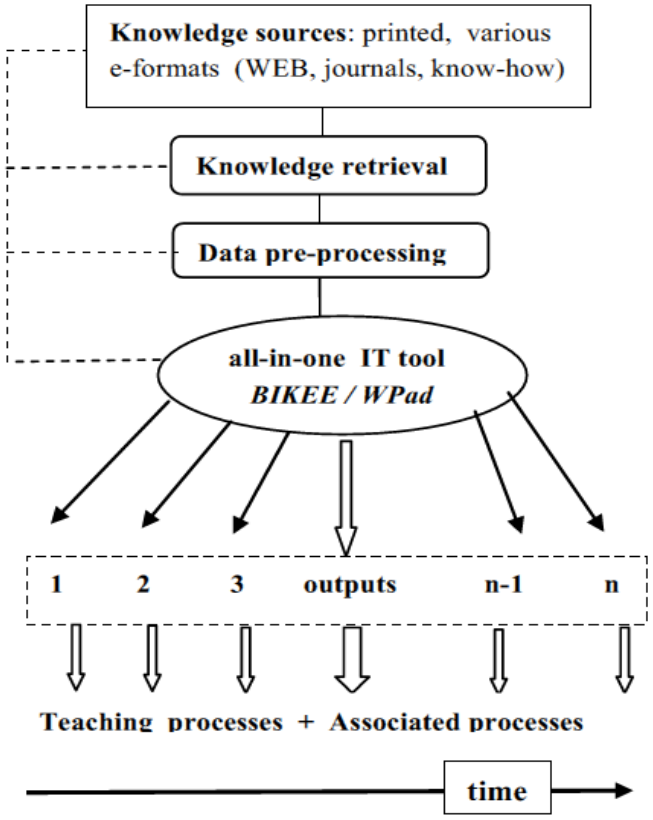


**Fig. 1. Schema of the teacher's personalized computer support**

This schema illustrates how the knowledge from global or external sources (that is suitable for teaching and learning) is retrieved and processed up to the teacher's needs. By using our own educational "all-in-one" software BIKEE (Batch Information Knowledge Editor and Environment, written by Svetsky) the teacher generates time outputs for his daily teaching and associated activities (in classroom, online, during his self-study or production of study materials). One specific part of this in-house software, named WPad, which is installed on the classroom's computers, is used by students for personal or collaborative learning tasks (e.g. they create shared study materials). The empirical research is aimed at automation of all types of activities by integrating computers into teaching and looking for innovative approaches.

Such automation should also extend the teacher's cognitive skills and mental activities in order to work as a "mental prosthesis". This covers all categories of teaching. Actually, the focus is on the computer supported collaborative learning that requires pedagogical and informatics research in parallel, including develop-

ment or innovation of informatics tools and specific software (the all-in-one application using a natural language which is machine readable as well). A specific goal is programming the communication, feedback and mass knowledge production, processing, transfer and utilization within the teacher's daily teaching. Fig. 2 illustrates an example from the research activities of the teacher.

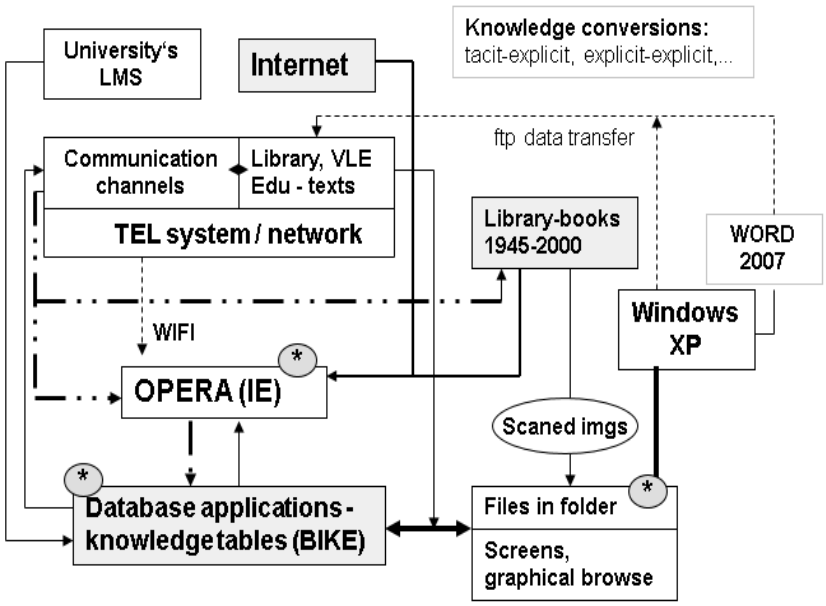


**Fig. 2 Schema of modelling Learning Analytics (Source: FP7 Proposal KEPLER)**

This schema is from the FP7 ICT project proposal KEPLER (2007). In this case, the objective intended to be attained is the modelling of Learning Analytics in the classroom conditions. However, in comparison with the state-of-the-art in the field of Learning Analytics this approach is focused directly on "human knowledge", i.e. educational knowledge flow during real teaching, not only on monitoring of activities of students in online learning environments.

Namely, most of the scientific papers describing research on learning analytics are focused on the monitoring and sampling of simple online data during online teaching, e.g. how many logs (visits) the students have performed on the WEB-pages in the learning environment. However, this data is not associated with human knowledge which is essential for any teaching. In principle, the data only represents the result of the associated informatics activity.

This is illustrated by Fig. 2-1 showing the output of online monitoring by an external service. At the bottom of the figure, the teacher can see the number of students which visited his teaching materials, and at the top of the figure, how

many pages were read by them. Thus, he can evaluate students' activities associated with the learning pages. However, one should be aware that it is not associated with their knowledge.

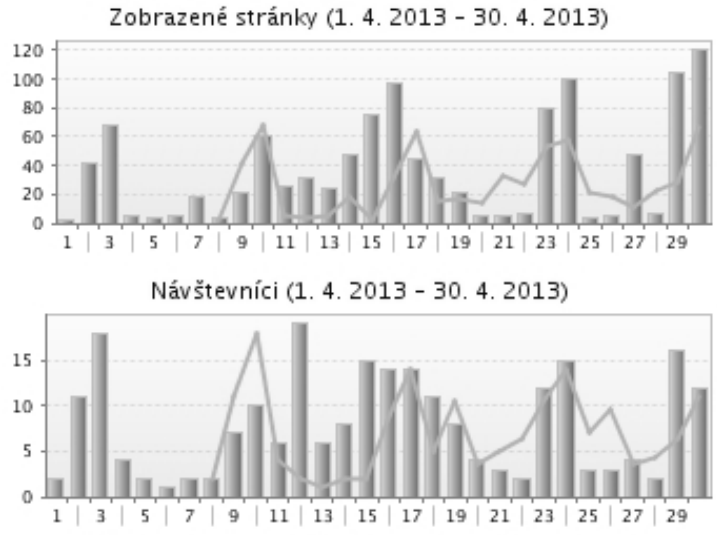


**Fig. 2-1 Example of the monitoring of the visited learning WEB pages by an external service**

Because students also used the WPad software in the classroom with computers, it was possible to monitor how many times they visited the online learning pages during teaching (especially when completing exercises). Thus, this enabled the teacher to evaluate the students' classroom activities. For example, there is a virtual calculation tool, at their disposal, for training chemical calculations. So, when the teacher saw, e.g. that student X visited the virtual calculation area five times and student Y twenty times he can suppose that student Y was more motivated for the learning process. On the contrary, he could also consider the possibility that student X had better calculation skills. But the teacher cannot associate these activities directly with their knowledge.

In our case, the teacher also monitored various WEB pages related to certain courses of study. This is illustrated by Fig. 2-2, which represents a list of WEB pages as they are associated with each of the courses of study.

| | stránka | počet zobraz | % |
|---|---|---|---|
| 1 | Adresa vyžiadanej stránky nebola zistená | 380 | 18,49 |
| 2 | http://www.svti.sk/MTF/DP/SKRIPTA/MTFSKRP.HTM | 266 | 12,94 |
| 3 | http://www.svti.sk/SVTIP.HTM | 251 | 12,21 |
| 4 | http://www.svti.sk/SVTIL.HTM | 228 | 11,09 |
| 5 | http://www.svti.sk/MTF/DP/BOZP/BOZPP.HTM | 222 | 10,80 |
| 6 | http://www.uiam.mtf.stuba.sk/projekt-apw/SV/MI/VCHEMIP.HTM | 153 | 7,45 |
| 7 | http://www.svti.sk/MTF/DP/SKRIPTA/ZE2009P.HTM | 88 | 4,28 |
| 8 | http://www.uiam.mtf.stuba.sk/projekt-apw/UBEI/ZESEMPP.HTM | 72 | 3,50 |
| 9 | http://www.svti.sk/SVTI05P.HTM | 53 | 2,58 |
| 10 | http://www.svti.sk/MTF/DP/SKRIPTA/SEMPPPP.HTM | 45 | 2,19 |
| 11 | http://www.uiam.mtf.stuba.sk/projekt-apw/UBEI/IMGS/SEMPRAC/ | 39 | 1,90 |

**Fig. 2-2 Example from the list of the visited learning WEB pages**

As it was mentioned, the BIKEE or its part, the educational software WPad, works as the all-in-one, i.e. a multipurpose tool, e.g. as well as a convertor of tacit knowledge into explicit knowledge (according to the terminology of the area of knowledge management). In other words, once a student writes his notes (thoughts/tacit knowledge) into the notepad they represent then the so called explicit knowledge. Therefore, by the monitoring how many times he opened the WPad, such data is more closely linked with knowledge. And this is beyond the state-of-the-art in the learning analytics. This can be demonstrated with the case of the teacher - designer of the BIKEE, who monitored his own activities when starting research on learning analytics. He wrote a specific programming code which indicated how many time the so called knowledge table was opened by him. In this case, such monitoring indicates better how the data is assigned to his activities related to processing the teaching content. Fig. 2-3 represents data from his home computer. One can see that the knowledge table was opened by the teacher around five thousand times within ten months.

```
:: 10 :::: 17.12.2015 || 21:09:40 ::
:: 11 :::: 17.12.2015 || 21:09:55 ::
:: 12 :::: 17.12.2015 || 21:11:35 ::
:: 13 :::: 17.12.2015 || 21:11:35 ::
:: 14 :::: 17.12.2015 || 21:22:01 ::
:: 15 :::: 17.12.2015 || 21:22:02 ::
:: 16 :::: 17.12.2015 || 21:24:39 ::
:: 17 :::: 17.12.2015 || 21:24:40 ::
:: 18 :::: 17.12.2015 || 21:25:52 ::
:: 19 :::: 17.12.2015 || 21:25:52 ::
:: 20 :::: 18.12.2015 || 00:12:47 ::
```

```
:: 5250 :::: 03.10.2016 || 20:21:06 ::
:: 5251 :::: 04.10.2016 || 11:39:43 ::
:: 5252 :::: 04.10.2016 || 11:41:40 ::
:: 5253 :::: 04.10.2016 || 12:15:42 ::
:: 5254 :::: 04.10.2016 || 12:15:43 ::
:: 5255 :::: 04.10.2016 || 15:30:20 ::
:: 5256 :::: 04.10.2016 || 15:31:06 ::
:: 5257 :::: 04.10.2016 || 15:31:08 ::
:: 5258 :::: 04.10.2016 || 15:32:18 ::
:: 5259 :::: 04.10.2016 || 15:32:20 ::
:: 5260 :::: 05.10.2016 || 12:29:59 ::
```

**Fig. 2-3 Example from the evidence of opening the personal WPad table by the teacher**

Such monitoring could be modified and more deeply tuned by linking data to the content and appropriated metadata of each record in the knowledge tables. However, the following research on learning analytics associated to human

knowledge was stopped because the project proposal L3Pulse was not accepted within the FP7 ICT call (2013). Despite this fact, some data is monitored (as can be seen in the Fig. 2.3) in order to use it within a starting research on developing an educational robot.

## 2.2 Methods

Our research, which is performed under the umbrella of Technology enhanced learning, represents a typical empiric participatory action research. Within the long-term research a system solution (infrastructure) was built, i.e. personal virtual learning environment, virtual learning space with tutorials, calculation tools, communication channels for each study program (background of environmental protection, chemistry, programming languages, integrated safety), writing of the all-in-one beta software BIKEE and WPad for mass human knowledge processing (the application is installed on each of the classroom's computers or students notebooks). Currently, a teacher's cloud application is being tested, especially the transfer of knowledge between computers, cloud, faculty's server and network. This infrastructure is used for designing innovations and automation of activities in teaching processes. Fig. 3 represents such approach within our research on modelling the multilingual support by designing personal corpuses for processing scientific and technological (human) knowledge.

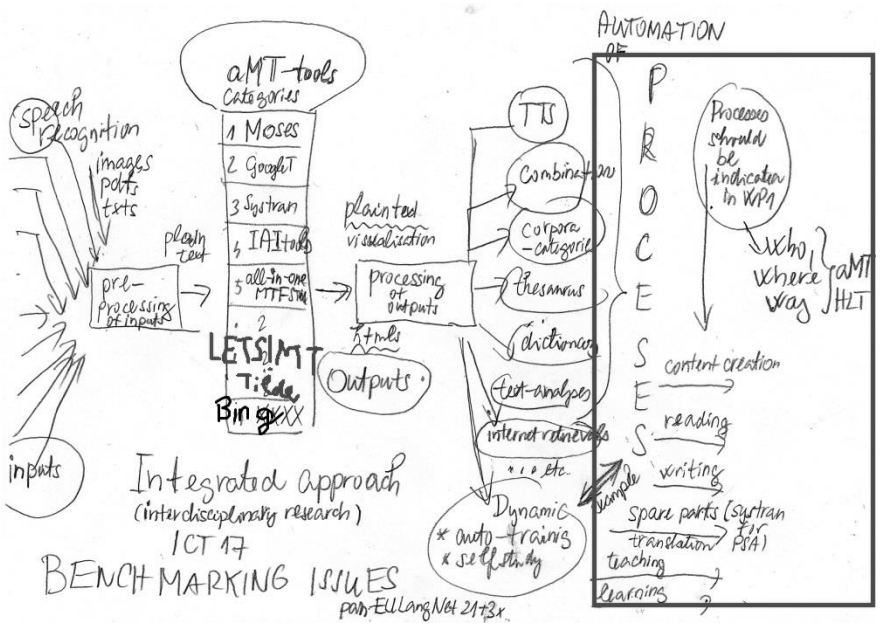


**Fig. 3 Schema of benchmarking issues when designing a personal corpus (Source: Horizon ICT 17 Proposal PanEULangNet, 2014)**

The idea to create personal corpuses which would contain multilingual human expert knowledge from the machinery engineering area was one of the basic objectives of the CSA project proposal PanEULangNet within the H2020-ICT-2014-1 call (topic ICT-17-2014). The Proposal title was: "Pan-European Language Network 21+3 for designing the infrastructure of Human Processes - driven System of Machine Translation for specialised high-quality Translation". The CSA proposal objectives were focused on cooperative benchmarking for the design of the pilot human processes-driven system of automated Machine Translation (aMT) consisting of research infrastructure of recommended multilingual repositories, specialized corpora, ontological batch knowledge sets, aMT software and a federated trans-lingual pan-European portal. The target was to bridge several EU languages together through technical German language. As it is illustrated by the schema, the BIKEE system could have been potentially developed in subsequent research as the aMT - tool (see No. 5 of the aMT tools categories, i.e. the all-in-one MTF STU on the handmade schema). Due to its multipurpose function, it enables one to pre-process inputs in the plain text format and to produce outputs in the form of various applications needed for the automation of the knowledge based processes which are presented on the right side of the schema (content creation, writing, teaching, learning,...).

It must be emphasised that these processes are very important also from the engineering pedagogy and didactics point of view. Moreover, any processing of the expert knowledge by computers requires a very high level of human-computer interaction (HCI) and represents an extremely difficult task. Namely, despite the enormous progress in ICT, the level of human-computer interaction is still not up to the required level from the IT support of mental processes point of view, because these are uncertain processes using unstructured knowledge and unstructured multi-lingual knowledge respectively. This is the basic barrier to computerisation of human processes. Even though the actual level of IT has overtaken human's abilities by many years, the existing solutions for the so called WEB 2.0 technologies, or Big Data are not suitable for processing huge amounts of scientific and technical information and knowledge. The reason is that such technologies are mostly based on internet applications that utilise very well structured and machine readable data. This fact does not enable knowledge workers to process data in natural language. Moreover, computers are able to process unstructured data only in well-organized processes, i.e. when algorithms within the knowledge based processes would be well known and defined. But this is not our case.

In addition, despite the massive advertising of global players or providers of multilingual machine translation and many existing commercial offers and WEB services these are not yet suitable for translation of technical texts. In this connection, a "hypothesis" was presented in the project proposal that no automatic aMT is able to perform high-quality translations without implementing the human factor. In other words, the actual level of statistics based aMT is not suitable for the engineering practice. For example, at the meeting of the Slovak Technical Committee for Corrosion Protection in April 2014, the quality of translations of CEN

and ISO technical standards was evaluated with respect to translations made by translation agencies and aMT. As for the human translators, the problem is the lack of skilled experts, as for the quality of machine translation, this is absolutely unsatisfactory. It has such an impact on the engineering practice that time consuming post-editing is always required. The committee concluded that the key issue is to incorporate terminology and linguistic terminology into Computer Linguistics models and aMT tools.

Similar barriers were indicated by one of the PanEULangNet Consortium's partner from Italy providing translation services. This partner considers the translations of legal texts done by machine translators to be of low quality. The terminology in technical and legal translations is often inaccurate because it does not take into account the specificity of legal systems. Translation errors can be critical as they may have legal repercussions. General translations from and into English are acceptable, while in other languages the quality is low. There are no databases that bring together in one place the legal glossaries that exist in paper form.

According to the partners' experience, the aMT is used in general for the translation of specialized papers, scientific and academic publications, all kind of books, projects and grant proposals, abstracts, newsletters, articles, emails etc. It is used as a starting point in every translation (including agreements, contracts, catalogues, web sites). Very often, field-specific knowledge and expertise is required. It is almost never a "light" superficial editing that is required, very often the machine translated text is unintelligible and the target audience would never be able to understand. Why do people still resort to machine translation if it requires such post-editing process? For two reasons: machine translation provides the first draft with some useful advice on possible translation solutions (it is like a "colleague" of the translator making suggestions you did not think of) and it does speed up the translation process significantly! If you speak a language at intermediate level, aMT is useful when translating into that language. It makes it possible to translate more complex texts than the ones you would be able to do without aMT. But a machine-translated text is far from being directly usable without further interventions as to a great extent it is not even understandable.

When performing a scientific, academic translation, it is necessary to stick to the source text and therefore the translator cannot perform any pre-editing. Moreover, pre-editing takes up too much time to be performed. The main issue however is related to the translation of country-specific concepts: aMT is insensitive to cultural, cross-country differences. In the field of occupational health and safety where regulations vary across countries, as well as the wording used to talk about these issues, aMT makes a mix of legal systems or sticks to US concepts as if they were applicable to every country. It is not culture-sensitive. Also, it is not effective in translating sayings, collocations and field-specific terms, such as: play around: giocato in giro (too literal, meaningless translation in Italian) raise money: alzare, sollevare denaro (translated like "lift money"). With aMT it is almost impossible to vary the register (from formal or informal language) when translating corre-

spondence (email etc.) and also in this case formal language varies from country to country (e.g. British English, US English etc.). These differences are not considered whereas it would be extremely useful. From now on, when doing translations we can collect patterns of aMT mistranslations, if useful.

From the above mentioned one can see that integrating the human factor into aMT systems is very important when solving any automation of processes which uses expert multi-lingual knowledge in general. To be successful in "designing the infrastructure of human processes- driven system of machine translation for specialised high-quality translation" (as it is stated in the title of the project proposal), the researchers need to solve the cooperative benchmarking for the design of the pilot human processes-driven system of automated machine translation. For this purpose, the following five specific workpackages (step by step from WP1 to WP5) were planned as it is illustrated in Fig 5.

WP1 was dedicated to the state-of-the-art, focusing on selected key expert areas: materials, engineering technology, occupational health/safety, environmental protection. The selected issues were to be benchmarked in WP2 (metadata, ontologies, recommended sources). WP3 dealt with specialised corpora, aMT-systems, translation quality, while WP4 represented the synthesis (applications modules, utility model as a tool for collaborative knowledge building). Finally, WP5 was dedicated to the creation of a pan-European portal for networking activities related to aMT.

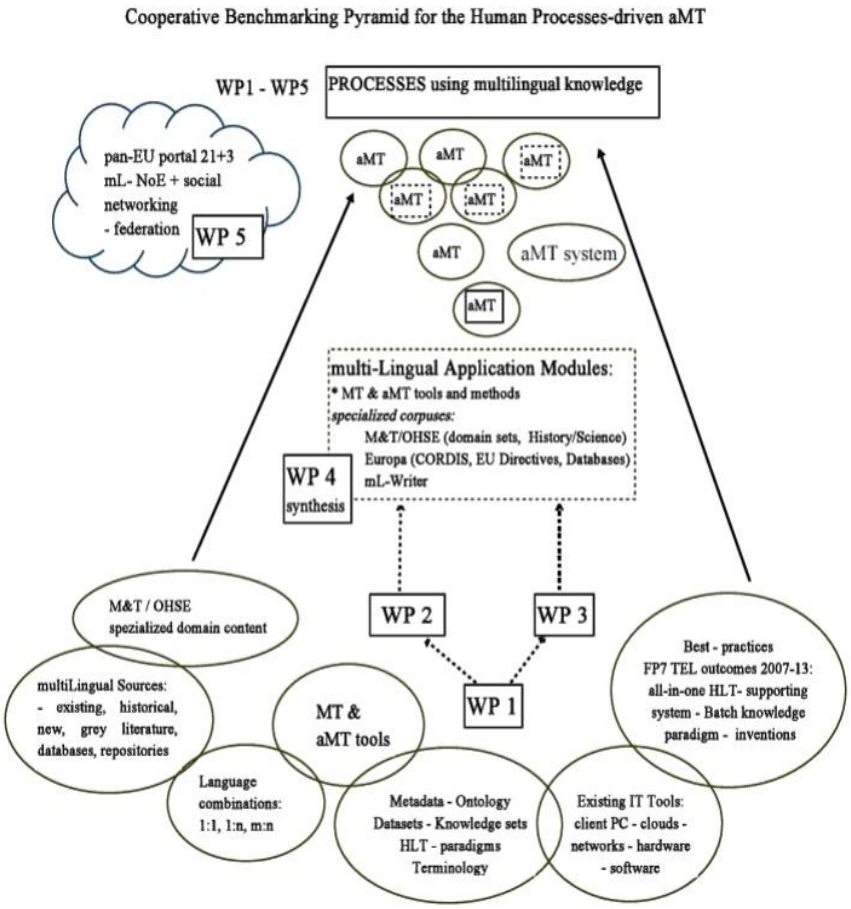


**Fig. 4 The cooperative benchmarking pyramid for the human processes – driven aMT**

In addition, engineering education requires the teacher to solve also many visualizations from the didactics point of view because teaching by using schemas and chemical formulas is needed. However, using the actual global visualization software products for this purpose is often too much time consuming. For example, a more efficient solution than using the common software is to make hand written schemas or formulas on paper or blackboard and using a scanner or digital camera. So we started also with the research on STEM where the visualization is a very important factor [18]. We are actually developing an innovative screenshotting methodology where students' collaboration is used for creating shared educational materials. This represents the case when the pedagogical method, i.e. the creation of the visualized pedagogical content, must be performed primarily. Only after that the integration of IT is possible. In other words, modelling the computer supported collaborative learning requires the combined pedagogic (didactic) and

informatics research (it is not possible to write programing codes if no teaching steps exist).

A specific problem in the empirical research on human knowledge processing, as we found out, is the data transfer within the existing informatics infrastructure (computers, cloud, networks, WI-FI devices etc.). For this purpose, the utility model is used, which is related to a system of processing of unstructured data via using a specific data structure - this is just the "switcher" between humans and computers which enables one to perform the mass knowledge processing (it is a part of the registered utility model UPV 7340 by the national patent office 12/2015). This infrastructure is now used for combined pedagogical and informatics research for computer supported collaborative learning (CSCL) in order to model knowledge exchange and sharing.

As was mentioned in the introduction, the key aspect of our methodology is understanding "human knowledge" as the basic element of automation of teaching processes. The utility model employs a specific data structure which works as a virtual knowledge which can be transmitted between online and offline environment (the virtual learning space and environment, cloud, personalized teacher-students network, notebooks, computers in the classroom). In principle, the teacher or students write or input their human knowledge by using natural language into the virtual knowledge (the specific data structure) that is machine readable. In other words, thanks to such possibility the computer can perform a physical process, so the user instantly obtains the suitable results that support his mental processes within teaching or performing associated activities.

### 2.3 The results

Based on the results of our long-term research we identified the following three categories: (1) pedagogical - unification of content and teaching processes to be computerized, e.g. research on CSCL methods when modelling the writing of the semester work, incl. producing the shared additional teaching materials directly by the students, (2) informatics - adaptation, personalization, development of IT applications, knowledge transfer via network and cloud, synchronization of blended learning, knowledge base building, the utility model, (3) integrated outputs for daily teaching - CSCL cases of study (automating the writing of semester works, model of teaching the programming languages, additional training materials on chemistry created by students for students), diploma works which were tested for production of eLearning materials by pre-service teachers, or small information systems for technological purposes.

From the research point of view, authors of this paper implemented the term of the "virtual knowledge" as a universal construct, which "interdisciplinarilly" bridges the mental processes of humans and the physical processes performed by computers. In the educational practice, it enables teachers, students, or knowledge workers to process human knowledge in their natural language and on the user

friendly basis (the computer makes what they want and need). So, the integration of ICT in teaching and learning can be developed and researched in a natural and effective way.

## 3 Conclusions

The presented empirical research on Technology enhanced learning is based on the collaboration of humans and computers via a specific data structure, which works as the virtual knowledge unit. Teacher and students input their knowledge into this unit which is controlled by an all-in-one software (BIKEE/WPad). The transfer of knowledge between hardware and software systems (cloud, classroom computers, students' notebooks, WI-FI, networks) is performed according to the above mentioned utility model. This is an optimal background for modelling the knowledge exchange and sharing when solving the Computer Supported Collaborative Learning (CSCL).

Thus, the human knowledge processing in natural language within engineering education is based on modelling the automation of teaching and learning processes, in which the human knowledge is the basic parameter, and by using the batch knowledge processing paradigm performed by specific educational software (BIKEE/WPad), and by transferring the educational knowledge between online and offline environment by using the specific utility model. This enables the teacher to perform various teaching activities and solve pedagogical innovation research tasks, including associated processes (writing papers, solving multilanguage support, producing teaching and study materials, advanced searching and retrieving, performing combined online/off-line self-study activities etc.).

According to our latest findings, it seems that the number of actions related to one learning content item requires the researcher to perform a lot of informatics actions related to file management, instructions and cognitive activities (communication, feedback). Therefore, this is a new challenge for designing the educational robot or an educational intelligent system.

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