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Intelligent Interfaces for Technology-Enhanced Learning

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1. Introduction

Current research in the field of Human-Computer Interaction (HCI), through its user-centred, user sensitive and learner-centred design approaches, places the requirements of the individual as the focus of all theoretical and practical advances, stressing the importance to design technologies for human needs. The role of transparent interfaces and adjustable interactions, suited to different particular needs, thus becomes even more important for users' success. Users with a wide variety of background, abilities, motivations and goals are using computers for quite diverse purposes. In such contexts of knowledge society for all, the role of system interfaces that are more closely tailored to the way people naturally work, live and acquire knowledge is unquestionably important. Intelligent User Interfaces (IUIs) have been advocated as means for making systems individualized or personalized, thus enhancing the systems flexibility and attractiveness. The ability to adapt is one frequently cited indication of intelligence. This implies the adaptation of the interface behaviour to user's individual characteristics, therefore generally relying upon the use of user models.

The chapter elaborates on intelligent interfaces for Technology-Enhanced Learning (TEL) systems, stressing the need to move from the traditional one-size-fits-all paradigm to adaptive and personalized one that takes into account various users' personal characteristics. In order to enrich the process of knowledge acquisition and enhance the system ability to improve the learning experience, TEL systems need to adapt continuously to their users. This can be achieved by initiating and updating a relevant user model. Although acknowledging that differences among individuals have an effect on learning, as of now, user modelling has not yet happened as expected in addressing the variety of the learning environment in terms of personalization and individual user profiles.

First, the chapter introduces TEL system with interaction style adaptation developed in order to support intelligent tutoring. The main objective of a research is both, to improve the learning experience and increase the system's intelligent behaviour. The system offers interaction adaptivity through the provision of suitable interaction styles rather then functionality. Different interface types along with adequate interaction styles are automatically switched basing on knowledge about the individual user and her/his interaction session, which is acquired dynamically during run-time. The user model developed to support interface adaptation strongly relies on user individual differences. In order to consider innovations in user sensitive research, the engaged user model should be

enhanced with personal characteristics that affect learning and its outcomes. Second, an experimental study aiming to examine the affect of users' individual differences in technology-enhanced environment specifically of the ones which need to be accommodated through the system's intelligent behaviour is presented and evaluated. Personal user features assumed to affect learning process and learning outcomes are clearly identified and the methods how to measure them are determined. The study indicated that motivation to learn along with to expectations of learning in TEL environment significantly affects on users' learning achievement. Consequently, an appropriate user model should be engaged in order to accommodate users' characteristics which have an impact on learning process, thus ensuring system accurate usage. The chapter presents how an employment of user sensitive research provides strong foundations for designing usable and effective TEL systems within responsive environments that motivate, engage and inspire learners of this emerging knowledge society for all.

2. Background to the Research

HCI research acknowledges that understanding users' needs are at the core of successful designs for information society technology (IST) products and services. In the emerging knowledge society for all, system user interfaces that are more closely tailored to the way people naturally work, live and acquire knowledge are unquestionably important. The role of an intuitive interface and a flexible interaction suited to different needs, preferences and interests becomes even more important for the users' success, as users with a wide variety of background, skills, interests, expertise, goals and learning styles are using computers for quite diverse purposes (Benyon *et al.*, 2001). This leads to *user-centred design approaches*, a philosophy which places the users at the centre of design (Norman & Draper, 1986) and a process that focuses on cognitive factors (such as perception, memory, learning, problem-solving, etc.) as they come into play during users' interactions with applications (Adams, 2007; Zaharias, 2005). *User sensitive design* can be advocated as one of the natural and most appropriate methodologies developed out of user-centred design (Gregor *et al.*, 2002). The central concept of user sensitive design is an equal focus on user requirements and the diversity of such requirements in the population of intended users.

Additionally, in order to take into account the unique needs of users as learners, a shift from user-centred to *learner-sensitive design* is needed (Soloway *et al.*, 1994). This approach entails understanding and considering who is the user, what are her/his needs, what we want her/him to learn, how is (s)he going to learn it and how are we going to support her/him in achieving the learning objectives. As a result, a variety of learners' types must be considered due to characteristics revealing user individual differences like personal learning styles and strategies, diverse experience in the learning domain as well as previously acquired knowledge and abilities.

Intelligent User Interfaces (IUIs) are being suggested as means for making systems individualized or personalized, thus enhancing the systems flexibility and attractiveness (Benyon & Murray, 2000; Hook, 2000). IUIs should facilitate a more natural interaction between users and computers, not attempting to imitate human-human communication, but instead aiding the human-computer interaction process in diverse areas. The intelligence in an interface can for example make the system adapt to the needs of different users, take initiative and make suggestions to the user, learn new concepts and techniques or provide explanation of its actions, *cf.* (Benyon & Murray, 2000a; Lieberman, 1997). A focus on human

interaction and on a measure of adaptivity to differing user requirements and needs is emphasized. "One frequently cited indication of intelligence is the ability to adapt", as highlighted in (McTear, 2000, p. 324), implying the ability to adapt output to the level of understanding and interests of individual users. A suitable framework for taking into account users' heterogeneity has provided (Schneider-Hufschmidt *et al.*, 1993):

- *adaptable systems*, by allowing the user to control the systems' customization and
- *adaptive systems*, by tailoring systems' appearance and behaviour to each user's individual characteristics.

Adaptive interface generally relies upon the use of *user models* (UMs). User modelling has been concerned with developing systems that provide such an adaptivity by collecting information and assumptions about particular users, such as their goals, skills, preferences, and knowledge, and then using this information to control the system's output (Kobsa, 1995; McTear, 2000; Brusilovsky *et al.*, 2007). The information in the user model is "a representation of the knowledge and preferences which the system believes that a user possesses" (Benyon and Murray, 1993, p. 205). Therefore, while some of the information in the user model may be relatively static and long-term, other information may be updated dynamically as the user interacts with the system. This information is used in various ways to provide adaptivity, i.e., to enable the system to adjust its functionality and/or the communication according to the needs of individual users, needs that may also change over time (Dieterich *et al.*, 1993).

System intelligent/adaptive behaviour strongly relies on *user individual differences*, the claim which is already confirmed and empirically proved by HCI research (Egan, 1988; Ford & Chen 2000; Dillon & Watson, 1996; Jennings *et al.*, 1991; Magoulas & Chen, 2004; Brusilovsky *et al.*, 2007). Such assumption is in line with related studies completed by the authors; see for example (Granić *et al.*, 2007). When considering adaptation of systems to individual use, user personality and cognitive factors have to be taken into account because of their higher resistance to change. Moreover, it is useful to exploit a certain amount of "stable" knowledge about the user, conveyed through long-term characteristics, containing information about user's level of expertise with computers in general, her/his expertise with the system in particular, as well as familiarity with the system's underlying task domain. Certain information related to user's preferences or current goals conveyed through short-term user characteristics should also be considered. Table 1 provides taxonomy of key user characteristics for system adjustment presented in (Granić & Nakić, 2007). Those features are generally categorized as:

- personal user characteristics, quite stable over time and independent from the system, where we can differentiate
  - general personal characteristics, including characteristics that reflect internal psychological state and
  - previously acquired knowledge as well as user abilities, along with
- system-dependent user characteristics, the most changeable category of characteristics as related to particular system.

Nevertheless, as range and complexity of interactive system increases, understanding how the system can dynamically capture relevant user needs and features as well as subsequently adapt its interaction, has become vital for designing intuitive and effective interfaces in diverse areas as intelligent hypermedia, recommender systems, intelligent filtering, explanation systems, intelligent help and technology-enhanced learning.

		A	B	C	D	E	F
personal characteristics	Gender	•	•			•	•
	Age		•			•	
	Personality & Emotions	•	•	•		•	•
previously acquired knowledge and abilities	Experience	•	•	•	•	•	•
	Cognitive Abilities	•			•	•	•
	Psycho-motor Skills			•		•	•
	Technical Aptitudes		•		•		
	Domain Knowledge	•	•	•	•	•	•
system dependent characteristics	Goals & Requirements			•		•	•
	Motivation			•		•	•
	Expectations			•			•

Table 1. User characteristics revealing individual differences; A (Benyon & Murray, 1993), B (Egan, 1988), C (Browne *et al.*, 1990), D (Norico & Stanley, 1989), E (Dillon & Watson, 1988), F (Rothrock *et al.*, 2002)

2.1 Technology-Enhanced Learning

Technology-Enhance Learning (TEL) uses Information and Communication Technology (ICT) to secure advancements in learning. By taking advancements as the objective, it goes beyond the attempt to reproduce classical ways of teaching via technologies. TEL combines but places equal emphasis on all three dimensions: technologies, learning and enhancement or improvements in learning (Manson, 2007). Learning should be delivered seamlessly, providing knowledge without interruption to people's normal work, thus implying holistic and systemic views of learners and their environments (Spector & Anderson, 2000). In this context, greater emphasis should be placed on informal and distributed learning. Tools and technologies to support distributed learners are likely to become more sophisticated and more prevalent, further removing the traditional boundaries between learning and working. In such a context the focus on learners appears well established in principle, but the practice of taking learners for what they are and as they are has yet to catch up (Sampson *et al.*, 2004). The second noticeable trend is on the individualization of learning, specifically the tailoring of pedagogy, curriculum and learning support to meet the needs and aspirations of individual learners, irrespective of ability, culture or social status. These is accompanied by the shift to assessing learning outcomes and doing this according to the learner's progress and needs; see for example (ERCIM News, 2007)

Apparently the appropriate use of the technologies should result in improvements in learning – making it more effective and more efficient. It has been claimed that although "technology is often touted as the great salvation of education, an easy way to customize learning to individual needs, it rarely lives up to this broad expectation" (Healey, 1999, p. 398). It seems that too much of this research is being driven by technical possibilities, while paying inadequate attention to the area of application and improvement of the quality of knowledge acquisition. The result was an over-ambitious and pre-mature attempt to eliminate the teacher's role in the educational environment (Kinshuk *et al.*, 2001). Besides, while acknowledging the important relation between individual differences and education

has a long history, *cf.* (Cronbach & Snow, 1977), user modelling has not yet really succeeded in addressing the variety and richness of the educational environment. Namely simply acknowledging against systematically empirically verifying that differences among individuals in the terms of personal user profiles or characteristics have an effect on learning are two diverse things (Shute & Towle, 2003).
Although a lot of work still has to be done, there are attempts in TEL architectures which attribute individualization and end-user acceptability, emphasizing the need to consider diverse users' individual characteristics, e.g. (Ayersman & von Minden, 1995; Shute & Towle, 2003; Ahmad *et al.*, 2004; Brusilovsky & Millan, 2007). The process of knowledge acquisition should be enriched and system ability to improve the learning experience and increase the system intelligent behaviour enhanced. It has been argued that the solution is to be found in TEL systems that are accessible and usable to the intended populations of users, provide a high quality learner and teacher/tutor experience at the same time supporting rather than replacing the teacher, reflect best practice in learning psychology, can adapt to the needs and individual characteristics of diverse users thus employing a valid user (learner) model, *cf.* (Adams, 2007).

2.2 User Modelling for Technology-Enhanced Learning

Currently technology-enhanced learning systems are moving from the traditional one-size-fits-all paradigm to adaptive and personalized systems that take into account various users' individual differences. In order to be effective and usable, at the same time supporting individualization of learning, TEL systems need to adapt continuously to their users as they gain more domain knowledge while learning. However, adaptive TEL systems are still facing difficulties also including the following: (i) insufficiently utilized potential of flexibility and interaction styles in implementing a successful interface, (ii) only a limited number of user (i.e., learner and/or teacher) characteristics for adaptation are tracked, (iv) ineffective integration mechanism of the learner model with the interaction engine, (iii) there exists neither a widely accepted inventory of relevant adaptation types the system should be able to undertake, nor a definite study on the impact of these adaptations on user learning and performance. Additionally, so far user modelling research has not yet succeeded in dealing with the diversity of the learning and teaching settings. Namely, learning takes place in different social contexts involving diverse learners with different personal preferences, prior knowledge, skills and competences as well as learning goals. Moreover, at the onset of the learning process, when a user first accesses TEL system, the initiation of the user model requires explicit user actions that may require time and effort the user is not willing to invest.
Consequently, as the alternative to customary user interfaces, adaptive TEL systems are supposed to build a model of characteristics, preferences and/or goals of each individual user and use it throughout the interaction, in order to personalize it. This can be achieved by initiating and updating a relevant user model (Kobsa, 1995; Rich, 1999). In general, the quality of the personalized service provided by a system to its user depends largely on the characteristics of the UMs, e.g., how accurate it is, what amount of information it stores, and whether this information is up to date. Hence, as a general rule, the more information is stored in the UM, namely the more knowledge the system has obtained about the user, the better the quality of the service will be. In this context, quality refers to the capability of the system to better assess the learner knowledge in the studied domain, as well as his/her

background and capabilities, so to tailor the learning process accordingly. In practice, obtaining sufficient user modelling data is difficult. This is especially important at the initial stages of the interaction with the user, when little information about the user is available. At these stages, all existing user modelling techniques face the bootstrapping problem, although recent research in ubiquitous user modelling suggests the idea of "user models mediation" (Berkovsky *et al.*, 2008).

While acknowledging that differences among individuals have an effect on learning, as of now user modelling in TEL field has not yet happened as expected in addressing the variety of the learning environment in terms of personalization and individual user profiles, especially at the initial stages of TEL system use. Learners are diverse and have different requirements such as their individual learning style, personality and cognitive factors, individual background knowledge and abilities. Many studies have been conducted on this subject; see for example (Egan, 1988; Benyon & Murray, 1993; Browne *et al.*, 1990; Chen *et al.*, 2000; Juvina & van Oostendorp, 2006) for reviews in the HCI field in general, in addition to work of (Ayersman & von Minden, 1995; Ford & Chen, 2000; Liegle & Janicki, 2006) in the TEL area in particular. However, obtained results are not quite consistent since the effect of individual characteristics on user performance with particular system greatly depends on the system alone (Browne *et al.*, 1990). Even though some of user individual differences can be assimilated by users' education or by interface redesign, a number of these differences will certainly need to be accommodated through adaptive interface behaviour what implies engaging a user model into a technology-enhanced learning system.

In the following two approaches to user modelling for TEL systems are presented and evaluated. Both studies are aiming to examine the affect of users' individual differences in technology-enhanced environment specifically of the ones which need to be accommodated through the system's intelligent behaviour.

3. Individual Differences and Interaction Style Adaptation

Following previous discussion, the role of proper interface design turns out to be central in both improving the learning experience and increasing the system's intelligent behaviour. Technology-enhanced learning systems are still inadequate with respect to the interaction mechanisms they provide. The adaptation effect, like in adaptive hypermedia and web systems, is usually limited to adaptive navigation, selection and/or on-screen presentation adaptivity (Brusilovsky & Maybury, 2002; Brusilovsky *et al.*, 2007). This is the motivation that led us to focus our research on intelligent (i.e., adaptive) interaction which would support intelligent tutoring. Our prototype system, developed in order to validate the approach, is an arbitrary domain knowledge generator with adaptive interface denoted Adaptive Knowledge Base Builder (AKBB) (Granić, 2006). It builds on the continuing research in the area of intelligent learning and teaching systems which has been performed in the last time and resulted with a number of operative systems, all based on the TEx-Sys model (Stankov, 2005).

3.1 AKBB, an Adaptive Knowledge Base Builder

AKBB enforces a simple adaptive mechanism, which selects the most appropriate interface out of a number of them according to run-time tracing of user behaviour. Fig. 1 illustrates AKBB's mixed mode interface style. The system offers interaction adaptivity through the

provision of suitable interaction styles rather than functionality, cf. (Dieterich *et al.*, 1993), or the "educational aspects" of the interface. Different interface types along with adequate interaction styles are automatically switched basing on knowledge about the individual user and her/his interaction session, which is acquired dynamically during run-time. In this way it is an example of a self-adaptation (*ibid.*), where the system itself observes the communication, decides whether to adapt or not and generates and executes the adaptation as well. Parameters that control style swapping strongly rely on user individual differences. Specific values for user characteristics may be explicitly specified either by the user, captured directly from user actions or derived by the AKBB inference engine. Conforming to the initial discussion of self-adaptation, it is important to determine those parameters that are inferred and quantified from the interaction. These include the subsequent ones:

- user level of experience in computer usage in general and in usage of the AKBB system itself; these characteristics are taken into account because of their influence on successful task accomplishment, what is based on general results of user analysis and
- cognitive and individual characteristic of the user, i.e., spatial ability, which has relevance to users' use of AKBB different interface styles.

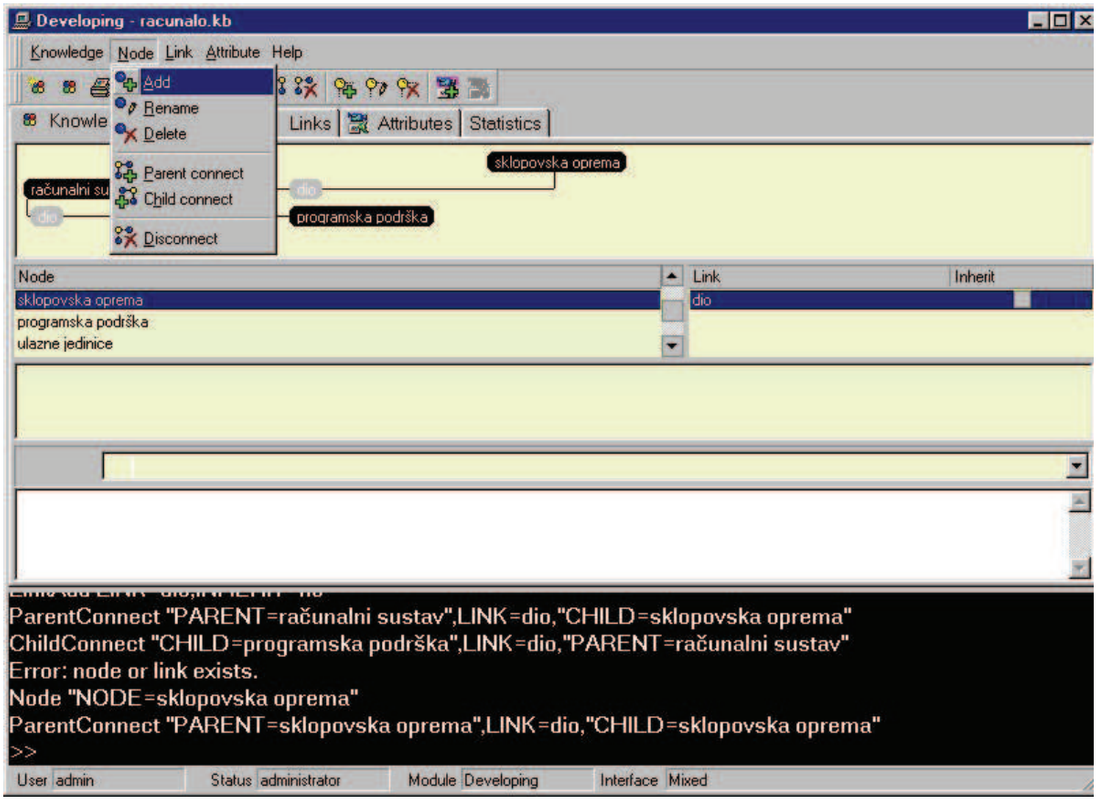


Figure 1. Screenshot of AKBB user interface

As postulated by an "architecture" or reference model for adaptive user interfaces (Benyon, 1993; Benyon & Murray, 2000a), AKBB uses three models for its operation:

- *user model*, based on monitoring the user in run-time,
- *system model*, storing system characteristics that are adaptive and

- *interaction model*, defining the actual interface adaptation through parameter values obtained from the interaction, along with all the relevant inferences and adaptations.

System Model. The system model specifies those AKBB characteristics that illustrate adaptivity. In order to describe system changing characteristics, each one of the levels – task, logical and physical – has to be specified in terms of the respective aspects, as illustrated in Table 2.

Level	**Measuring Concept**	**Parameter Name**	**Value**
Task Level	generation of arbitrary domain knowledge base	task	{1..N}
Logical Level	execution of a logical function	subtask	{1..N}
	wrong syntax; wrong semantics	error	{1..N}
Physical Level	adequate interaction style	interface	{command, mixed, graphical}

Table 2. AKBB System Model

	Parameter Name	**Measuring Concept**	**Value**	**Initial Value**
Cognitive Level	spatial ability	inferred from interaction	{high, low}	high
Experience Profile	experience in command languages	inferred from interaction	{high, low}	inferred at the beginning of interaction
	incidence of system usage	inferred from interaction	{high, low, none}	inferred at the beginning of interaction
Personal Profile	task	from interaction dialog	{1..N}	null
	subtask	from interaction dialog	{1..N}	null
	total subtasks	from interaction dialog	{1..N}	inferred at the beginning of interaction
	error	from interaction dialog	{1..N}	null
	total errors	from interaction dialog	{1..N}	inferred at the beginning of interaction
	interface	from interaction dialog	{command, mixed, graphical}	command

Table 3. AKBB User Model

User Model. The construction of a user model usually requires stating many assumptions about users' skills, knowledge, needs and preferences, as well as about their behaviour and interaction with the system. The user model developed to support AKBB interface adaptation is based on knowledge about the individual user and her/his interaction session that is dynamically acquired during run-time. It allows the current knowledge of the user to be combined with two additional models – the system model and the interaction one. Among the variety of user individual characteristics (cf. for example Table 1), we have considered the following:

- spatial ability, user cognitive characteristic offering a measure of her/his ability to conceptualize the spatial relationships between desktop objects,
- experience in command languages, characteristic concerning user experience in computer system usage in general and
- incidence of system usage, characteristic which regards user familiarity with the system itself.

Note that not all individual differences introduced in Table 1 have been considered in this research. The characteristics which were taken into account in the the offered classification are denoted as previously acquired knowledge and abilities.

Consequently, parameters from both cognitive and experience profile levels as well as parameters from the personal profile are continuously updated on-the-fly in order to record all the relevant aspects of the interaction (see Table 3).

Interaction Model. The interaction model describes the actual AKBB interface adaptation, by including user interaction history along with a set of inference and adaptivity rules. The dialog record logs all the necessary data related to the interaction. This encompasses user model updating, data on successfully completed subtasks and errors committed thereupon as well. In order to accomplish concrete adaptations, a set of inference and adaptivity rules is employed as follows:

1. values of the parameters maintained in the user model (spatial ability, experience in command language, incidence of system usage) are constantly updated as the result of an employment of *a set of five inference rules*, corresponding to user's individuality and her/his changing knowledge and behaviour during the interaction;
2. *a set of twelve adaptivity rules* provides actualization of interface adaptation in accordance to the updated parameter values in the user model.

As an illustration, one AKBB inference rule and three adaptivity rules are offered below.

```
{Inference rule no. 2}
if total subtasks = 0
  then incidence = none
  else
    if interface = command
      then incidence = high
    if interface = mixed
      then incidence = low
    if interface = graphical
      then incidence = low
```

{Adaptivity rule no. 1}

if spatial ability = high
AND experience = high
AND incidence = high
then interface = successor(interface)

{Adaptivity rule no. 5}

if spatial ability = high
AND experience = low
AND incidence = low
then interface = interface

{Adaptivity rule no. 9}

if spatial ability = low
AND experience = high
AND incidence = no
then interface = predecessor(interface)

Three different interface types with suitable interaction styles implemented are: (i) a command interface, enabling interaction through a command line only, (ii) a graphical interface and (iii) a mixed interface, combining the former two.

3.2 Discussion

One of the key problems in the development of adaptive systems is the inadequacy of available evaluation methods and techniques. There is still a lack of evaluation studies (Weibelzahl, 2005) capable of distinguishing the adaptive features of the system from general usability. Furthermore, it has long been acknowledged that systems based on user modelling and adaptivity are associated with a number of usability problems, which sometimes out-weight the benefits of adaptation (Jameson, 2005). Although AKBB evaluation is outside the scope of this chapter, obtained results and conclusions are in line with the above mentioned claims. The applied scenario-based usability evaluation, as a combination of behaviour and opinion based measurements, enabled us to quantify usability in terms of users' performance and satisfaction, see for example (Granić, 2008). According to the achieved results, the main directions for AKBB interface redesign are offered and directions of future work identified:

- the information needed for AKBB user model is collected indirectly by inferring users' proficiencies and attitudes through their interaction with the interface; such approach to user information gathering can be augmented by explicitly asking the users about their preferences or acquiring their goals from questionnaires;
- the presentation of domain knowledge failed to convey in a transparent way the semantics of the linked domain knowledge objects, thus impeding users in obtaining a clear and unambiguous view of a particular subject matter; in order to hide as much as possible the internal structure of the domain knowledge base, the knowledge presentation should be redesigned;
- some work should be conducted in order to provide the users more control both by disabling automatic adaptation and by incorporating manual selection for swapping the operation mode;

- adaptation of communication enables AKBB users to perform the same tasks whether adaptation takes place or not, while conversely potential adaptation of functionality will provide users with the opportunity to employ new or more complex system function;
- further research will be needed to determine whether an AKBB adaptive interface is measurably better than a non-adaptive one and under what circumstances the benefit is more valuable than the apparent loss of control due to unexpected adaptations of the interface.

Nevertheless, the acquired experience indicates that useful evaluation with a significant identification of interface limitations can be performed quite easily and quickly. Conversely, it raised a series of questions which, in order to be clarified, require further comprehensive research, the more so if the employment of universal design within TEL context is considered (Granić & Ćukušić, 2007).

4. Individual Differences and Learning Outcomes

The experimental study (Granić & Nakić, 2007; Granić & Adams, 2008) aimed to question existence and level of interaction among users' individual differences and learning outcomes accomplished while using a TEL system. Personal user features assumed to affect learning process were clearly identified and the methods how to measure them were determined. We have classified characteristics to be measured according to the categorization presented in Table 1 – user personal characteristics, previously acquired knowledge and abilities along with system dependent characteristics. Note that not all individual differences from the presented classification have been examined in this study.

4.1 Research Methodology

Subjects and Research Instruments. Twenty-four undergraduate students (6 males and 18 females) of the second year of a university program were recruited. Since we intended to use an application related to the domain of programming, we have randomly selected students among volunteers who yet did not take an Introduction to Programming course. The participants of the study have been told that their achievement in the exam would have only experimental use and would not affect their future exam grades.

Assessed users' characteristics, which might have the impact on learning process and consequently learning outcomes, were grouped as following:

- intelligence and personality characteristics, including emotional stability, extraversion, mental stability and honesty level,
- previously acquired knowledge and abilities, comprising experience in using computers and Internet as well as background knowledge to material supposed to be learned during the experimental session and
- system dependent characteristics, including motivation to learn programming and expectations from learning in TEL environment.

Intelligence and personality factors were measured by *standard psychological tests*, D-48 and EPQ (Petz *et al*., 2005). Intelligence test (D-48) measured general mental abilities, while personality test (EPQ) measured dimension of emotional stability/instability, extraversion/introversion, mental stability/psychoticism and honesty/dissimulation level.

A questionnaire was designed in order to obtain data about students' gender, prior experience in using computer and Internet, motivation to learn, expectations from TEL systems in general and also expectations and satisfaction with used e-learning application in particular. Students' grades from previously passed exam on Introduction to Computer Science course were regarded as indicators of their background knowledge required to learn programming.

Interaction with a TEL system comprised learning programming basics as well as testing acquired knowledge with quiz embedded in the learning module of the application. System used to test students' knowledge is an intelligent learning and teaching system based on the TEx-Sys model (Stankov, 2005). We consider it as well-accepted instrument for this research since its effectiveness has been evaluated in several case studies and it has been shown that system can support at least 20 users at a time. Participants of the experiment were already familiar with the system functionality since they have already used it for other university courses. However, the students never accessed learning modules or quiz related to a course Programming I, the one selected to facilitate in this study.

Procedure and Results. Experiment was conducted through few steps illustrated in Fig. 2. Firstly, a psychologist and a HCI expert interviewed the experimental group of students to get an insight into some general characteristics of the group in order to design a questionnaire. The students have been introduced with nature and purpose of the experiment as well. Few days after the introductory interview the participants were invited to take intelligence test and personality test.

EXPERIMENTAL PROCEDURE

Step 1: Introductory Interview

Step 2: Intelligence and Personality Test

Step 3: e-Learning Session on Particular Domain Knowledge

Step 4: e-Testing of Domain Knowledge

Step 5: Multiple Choice Questionnaire

Figure 2. Five-step experimental procedure

Two experimental sessions in an on-line classroom were conducted for groups of twelve students at a time. Students were not allowed to take notes or use any external learning material, paper or on-line, besides the lessons related to the selected subject matter. They were free to learn for 30 minutes, and then began to test acquired knowledge on a quiz belonging to the TEL system. Time for testing was limited to 15 minutes and all participants completed the quiz at given time. After the quiz, students were asked to fill in the multiple choice questionnaire.

Although the main objective of the research was to investigate the influence of user individual differences on their learning outcomes, it was interesting to see if there were any connections among individual differences of the users themselves. Some interesting correlations were found between intelligence and personality factors obtained by tests with other user characteristics gained by questionnaire. Those results are given in Table 4. Significant correlations were found between mental stability and motivation ($r = -0.50$, $p <$

0.05) and also between emotional stability and expectations from using the system ($r = -0.45$, $p < 0.05$). This means that mentally stable students are more motivated to learn programming then mentally unstable or "more neurotic" students. Analogous, emotionally stable students have greater expectations from learning than emotionally unstable or "more psychotic" students.

Highly significant correlation was found between students' prior experience in using computers and Internet and their background knowledge required to learn programming ($r = 0.62$, $p < 0.01$) as expected. It seems that students' intelligence and dimension of extraversion/introversion are not associated with any other individual characteristics.

	Intelligence	**Emotional Stability**	**Extraversion**	**Mental Stability**	**Experience**
Experience	0.22	-0.28	0.19	-0.18	
Motivation	-0.17	-0.08	0.07	-0.50*	0.16
Expectations	-0.11	-0.45*	0.36	-0.26	0.01
Background Knowledge	0.39	-0.28	0.06	-0.11	0.62**

Table 4. Pearson correlations between user individual characteristics
* Significant correlations at level of $p < 0.05$
** Significant correlations at level of $p < 0.01$

Correlations between students' individual differences and their learning outcomes accomplished with a system are shown in Table 5. Apparently there are no associations between intelligence and personality factors with learning outcomes. Considering other user characteristics, it seems that only motivation to learn programming in addition to expectations of learning has statistically significant impact on knowledge acquired through interaction with the system ($p < 0.05$).

Analysis by age and by prior experience in using concrete system was not conducted because individual differences among participants were minor in those variables. Moreover analysis by gender would be inadequate as well because of the small samples.

	Intelligence	**Emotional Stability**	**Extraversion**	**Mental Stability**	**Experience**	**Motivation and Expectation**	**Background Knowledge**
Acquired Knowledge	0.05	-0.29	-0.00	-0.15	0.29	0.42*	0.26

Table 5. Pearson correlations between user individual characteristics and knowledge acquired on TEL system
* Significant correlations at level of $p < 0.05$

Additionally, subject group was split by the mean of their scores on the intelligence test. Correlation coefficients with learning outcomes were calculated for both high ($N = 14$) and low ($N = 10$) intelligence group separately. Apparently, students from low intelligence group made much more effort in knowledge acquisition with the system and achieved

better results in quiz assessment then expected ($r = 0.74^*$, $p < 0.05$) comparing to the ones from high intelligence group ($r = -0.41$, $p < 0.05$). Because of very small sample, this result should not be used for generalization purpose, but for further research in order to clarify this and as similar issues. It seems that some of these results could have great internal validity if they confirm themselves on a larger sample.

4.2 Discussion

There are numerous studies reporting minor influences of personality factors on predictions of user performance (reviewed in (Dillon & Watson, 1996)) or no influence at all (Egan, 1988), so the perceived lack of associations between intelligence and personality with learning outcomes in our analysis was not quite unexpected.

Nevertheless, thorough interpretation and observation of the obtained results revealed some shortcomings of applied methodology. First of all, the sample we analyzed was too small and too homogenous to give us strong grounds for generalization of the results. All participants of the experiment were students of the same age, with comparable background knowledge and experiences, intellectual capabilities and motivation for graduating. Similar experiment with larger sample of more diverse users would certainly provide more reliable results.

Besides the necessity to enlarge number and diversity of participants, we have found certain procedural issues in need of refinement in the further research as well:

- instead of intelligence and personality testing, a cognitive test should be completed with the aim to identify some important components of human cognition,
- knowledge acquired in the TEL environment should be measured more accurately, the best as a gain between pre-test and post-test scores,
- pre-test score could be exploited as a measure of background knowledge,
- time required to complete the post-test could be used as an additional measure of learning outcome for each participant,
- questionnaires for measuring independent variables (age, gender, experience, motivation and expectations) for more perceptively measurement should be designed more thoroughly, implying amplification of the quantity of questions regarding particular issue as well as giving special attention to the sequencing of questions and
- reliability analysis of prepared questionnaire should be conducted prior to its involvement into the study.

Accordingly, we consider this study as an experiment that gave us important directions to establish an enhanced user sensitive methodology in our future research.

5. Conclusion

Within emerging knowledge society for all, intelligent user interfaces should aid the human-computer interaction process in diverse areas. Namely, users with a variety of characteristics are using computers for quite diverse purposes. In such context the role of intuitive and transparent interaction tailored to unique personal requirements is crucial and the role of intelligent (i.e. adaptive) interfaces becomes unquestionable. Our research has been focused on the employment of intelligence in interfaces for technology-enhanced learning (TEL) systems in order to personalize them for individual use. Such an interface adjusted to

individual differences of each particular user should provide her/him more pleasant learning experience, resulting in higher knowledge achievement.

The chapter initially elaborates on the intelligent interface of Adaptive Knowledge Base Builder (AKBB), a type of TEL system. AKBB is an arbitrary domain knowledge generator which provides intelligent interaction in the sense of adaptation to user personal differences and behaviour. It offers the users three different interface types (command, mixed and graphical) with suitable interaction styles. The user model developed to support AKBB interface adaptation is based on knowledge about the individual user and her/his interaction session that is dynamically acquired during run-time. The AKBB system design is briefly presented and evaluation results summarized. Although related experience and achieved results were encouraging, the "sophistication" of the adaptation mechanism is required. The user model should be redesigned, further acknowledging and considering user personal differences that have an effect on learning and which certainly need to be accommodated through an adaptive interface.

Consequently, the empirical study aiming to examine the affect of users' individual differences on their learning outcomes achieved within TEL environment is conducted. Personal user features assumed to affect learning process were identified and the methods how to measure them determined. We have analyzed interrelations among quantified personal characteristics and found highly significant correlation between students' prior experience in using computers and internet with their background knowledge, but similar connection of experience and learning outcomes was not found. This experiment indicated that motivation to learn in addition to expectations of learning in TEL environment significantly affects on users' learning achievement. Aware of the great sensitivity of results to the sample (which had certain limitations), instead of generalization of presented results we have used them to determine the guidelines for developing further research design.

Considering similar studies and our own experience, it can be concluded that most of users' characteristics which have an impact on learning process and learning outcomes should be accommodated through an adaptive interface, with an employment of satisfactory user model. Additional research is clearly needed to be conducted in order to provide stronger foundations for a redesign and improvement of an adaptation mechanism for TEL systems.

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