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Personalised Learning: Educational, Technological and Standardisation Perspective

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Abstract. The e-Learning paradigm shift capitalises on two main aspect: the elimination of the barriers of time and distance, and the personalisation of the learners' experience. The current trend in education and training emphasises on identifying methods and tools for delivering just-in-time, on-demand knowledge experiences tailored individual learners, taking into consideration their differences in skills level, perspectives, culture and other educational contexts. This paper reviews the shift towards personalised learning, from an educational, technological and standardisation perspective.

Keywords: personalised learning, instruction, constructivist learning, intelligent tutoring systems, learning specifications and standards

1 Introduction to Personalised Learning

The emergence of the *Knowledge Society* and the *Knowledge-based Economy* signify a new era for education and training. Within this framework, knowledge and skills of citizens are becoming increasingly important both for the economical strength and social cohesion of the society, and the quality of citizens' life. The structural and functional society transformations raise the demand for major reforms in Education and Training, aiming at reducing the risks for knowledge gaps and social exclusion.

An interesting social and scientific debate is thus continuing, on the paradigm shifts in the way that education and training is planned, organised and delivered, as well as the definition of concrete future objectives of educational systems. Typical demands include [Rosenberg, 2001]:

- ✓ personalised training schemes tailored to the learner's objectives, background, style and needs;
- ✓ flexible access to lifelong learning as a continual process, rather than a distinct event;
- ✓ just-in-time training delivery;
- ✓ new learning models for efficient integration of training on workplaces;
- ✓ cost effective methods for meeting training needs of globally distributed workforce.

On the other hand, the rapid evolution of Information and Communication Technologies (ICT) provides the enabling technological tools for facilitating the implementation of the new paradigm in education and training, referred to as *e-learning*. e-Learning capitalises on advances information processing and internet technologies to provide, among others [Sampson, 2001]:

- ✓ *personalisation*, where training programmes are customised to individual learners, based on an analysis of the learners' objectives, current status of skills/knowledge, learning style preferences, as well as constant monitoring of progress. On-line learning material can be, then, compiled to meet personal needs, capitalising on re-usable learning objects.
- ✓ *interactivity*, where learners can experience active and situated learning through simulations of real-world events and on-line collaboration with other learners and instructors.
- ✓ *media-rich content*, where educational material can presented in different forms and presentation styles, and learning material can indexed and organised in such a way that it can be searched, identified and retrieved remotely from several different learners providing the right material to the right person at the right time.
- ✓ *just-in-time delivery*, where technologies such as electronic performance support systems can facilitate training delivery at the exact time and place that it is needed to complete a certain task, and wearable computers can provide real-time assistance in actual work environments.
- ✓ *user-centric environments*, where the learner takes responsibility for his/her own learning, and the instructor acts as the "guide on the side", rather than a "sage on the stage".

Over the past few years, there is a growing interest in e-learning both in terms of research and scientific developments, as well as, in financial market terms. Significant resources are allocated in collaborative R&D projects in this area, investigating a number of important aspects, both on technological and on pedagogical advances.

With this context, the concept of personalised learning becomes increasingly popular. It advocates that instruction should *not* be restricted by time, place or any other barriers, and should be tailored to the continuously modified individual learner's requirements, abilities, preferences, background knowledge, interests, skills, etc. The personalised learning concept signifies a radical departure in educational theory and technology, from "traditional" interactive learning environments to personalised learning environments. Some of the most prominent characteristics of this shift can be summarised as follows: (i) while "traditional" learning environments adopt the one-to-many learning mode, personalised learning environments are based on the one-to-one or many-to-one learning concept (i.e. one, or many tutors for one learner); (ii) traditional learning environments usually pose a number of constraints in relation to the learning setting; personalised learning environments, on the other hand, facilitate learning independent of time, location, etc; (iii) traditional learning environments are usually being designed for the "average learner"; while, in personalised learning environments, the learning material and sequencing, learning style, learning media, etc, depend on the individual learner's characteristics, i.e. background, interests, skills, preferences, etc; (iv) in traditional learning environments, the curriculum, learning units, etc, are determined by the tutor, while in personalised learning settings, they are based on the learner's requirements (self-directed learning).

This paper reviews the shift towards personalised learning, from an educational, technological and standardisation perspective. Section 2 discusses the educational perspective of personalised learning, whereas section 3 revises the technological perspective, emphasising on intelligent tutoring systems, adaptive educational hypermedia, intelligent pedagogical agents and mobile agent technologies, and section 4 presents relevant international standarisation efforts. Section 5 offers some conclusions and issues for future consideration.

2 The Educational Perspective

> *"Since at least the 4th century BC, adapting has been viewed as a primary factor for the success of instruction"* [Corno and Snow, 1986]; *"Adaptive instruction by tutoring was the common method of education until the mid-1800s"* [Reiser, 1987]

The concept of personalised learning builds mainly on the cognitive and constructivist theories of learning. Instructional principles of cognitive theories argue for active involvement by learners, emphasis on the structure and organisation of knowledge, and linking new knowledge to learner's prior cognitive structures. Constructivist instructional theory, on the other hand, implies that instructional designers determine which instructional methods and strategies will help learners to actively explore topics and advance their thinking. Learners are encouraged to develop their own understanding of knowledge. This does not negate the role of practice and feedback, but rather allows learners more latitude in developing knowledge structures. Both of the above theories share some commonalities, including having learners actively involved in learning and structuring solutions so that learners can extract the maximum amount of data [Schunk, 1996].

Additionally, personalised learning builds on several commonalities in instruction that serve to enhance learning, which are shared between several learning theories. Most theories postulate that learners progress through stages, or phases of learning that can be distinguished in several ways. One scheme, for example, classifies learners in terms of progressive skill levels: novice, advanced beginner, competent, proficient, expert [Schunk, 1996].

The basic idea behind personalised learning can be traced back to the Richard Snow and Lee Cronbach's 1976 research in ***aptitude-treatment interaction (ATI)***, which reflect the notion of tailoring instruction to student characteristics [Cronbach and Snow, 1977]. Aptitudes are student characteristics, such as abilities, attitudes, personality variables, demographic factors, etc. Treatments, on the other hand, are forms of instruction, or sets of conditions, associated with instruction. ATI refers to differences in student outcomes (e.g. achievement, attitudes) as a function of the interaction (combination) of instructional conditions with student characteristics (aptitudes). In this context, ATI research examines how individual learning differences in aptitudes predict student responses to forms of instruction [Schunk, 1996].

In this context, several research efforts have been devoted in the identification of the dimensions of individual differences. One of the most prominent research areas in this context concerns the ***learning styles and learning differences theory***, which implies that how much individuals learn has more to do with whether the educational experience is geared towards their particular style of learning. Learning styles are strategies, or regular mental behaviours, habitually applied by an individual to learning, particularly deliberate educational learning, and built on her/his underlying potentials. Learners are different from each other, and teaching should respond by creating different instruction for different kinds of learning. Learners also differ from each other in more subject-specific aptitudes of learning, e.g. some being better at verbal than numerical things, others vice versa.

Learning styles have been at the centre of controversy for several decades now, and there is still little agreement about what learning styles really are. One of the major distinctions made in learning styles research is the visual/auditory/kinaesthetic distinction. Researchers generally agree that modalities of learning are distinguishable, though whether they represent learning styles or learning differences remains to be seen. Some have included such factors as environmental influences such as intake (i.e. food), light, or heat as components of style.

There are numerous methodologies and tools that attempt to categorise people according to differences in learning and cognitive styles. The most well-known of these efforts include the *Myers-Briggs Type Indicator* [Keirsey, 1998]; *Multiple Intelligences* [Gardner, 1999], [Jasmine, 1997]; *Auditory, Visual, Tactile/Kinaesthetic Learning Styles* [Sarasin, 1998]; *Grasha-Riechmann student Learning Style Scales – GRLSS* [Grasha, 1996]; Kolb Learning Styles Theory [Kolb, 1985]; Felder and Silberman Index of Learning Styles [Felder, 1996]; Honey and Mumford Learning Styles [Honey and Mumford, 1992].

The ATI field, although theoretically elegant, has experienced several criticisms for its practical applicability. The main criticism relates to the fact that, in order for ATI to be effectively applied, we need to be able to (i) accurately classify each learner according to a selected taxonomy of individual differences, and (ii) determine which are the characteristics of the learning environment that are appropriate for this category of learners.

To overcome some of the above practical limitations of ATI, an alternative theory has been proposed, the ***Achievement-Treatment Instruction***. While ATI stresses relatively permanent dispositions for learning as assessed by measures of aptitudes (e.g. intelligence, personality, cognitive styles, etc), achievement-treatment interactions represent a distinctly different orientation, emphasising task-specific variables relating to prior achievement and subject-matter familiarity. This approach stresses the need to consider interactions between prior achievement and performance on the instructional task to be learned. Prior achievement can be practically assessed rather easily and conveniently through administration of pre-tests, or through analysis of student's previous performance on related tasks. This, this approach eliminates many potential sources of measurement errors, which have been a problem in ATI, since the types of abilities to be assessed would be, for the most part, clear and unambiguous [Park, 1996].

A number of practically oriented theories have also been developed. For cognitive skills acquisition, the most important theory, relevant to our discussion, is Cognitive Apprenticeship Framework [Collins et al., 1989]. Cognitive Apprenticeship Framework aims to provide adequate domain competence to the learner while focusing on cognitive skills. According to this framework:

- The learners can study task-solving patterns of experts to develop their own cognitive model of the domain, i.e. about the tasks, tools and solutions (*modelling*).
- The learners can solve tasks on their own by consulting while receiving feedback from the experts (*coaching*).
- The tutoring activity is gradually reduced with the learners' improving performances and problem solving (*fading*).

Typically, a learner starts the learning process by observing a particular task as it would be carried out by the "master" (or subject expert) and then tries to imitate the task. If the results of the trial are not correct, or are sub-optimal, the expert assists the learner in finding the areas of mistakes and sub-optimalities. If necessary, the learner can again observe the master's approach, and, since the re-observation is a result of a query from the learner, the depth of details grasped by the learner from the observation are increased many folds.

Once the learner has successfully imitated the task, the expert provides opportunity to repeat the task in different scenarios so that the learner can get mastery in the task. The repetition process also facilitates the abstraction of the concepts related to the task and helps the learner to apply the abstracted concepts in situated scenarios.

3 The Technological Perspective

This section reviews the technological state of the art with respect to personalised learning. The section covers intelligent learning environments (ILEs), which are capable of automatically adapting to the individual learner, and therefore constitute the most promising technological approach towards the realisation of the personalised learning concept.

Learning environments need to make several communication decisions: what content to communicate, when, how, etc. In the context of this paper, a learning environment is called intelligent in a measure to the extent that these decisions are made dynamically, at run- or use-time, based on an analysis of the learning context, which is defined by the learner characteristics, the type of educational material being exchanged, etc. Therefore, the definition adopted in the context of this report with respect to intelligent learning environments (ILEs) is as follows: *an intelligent learning environment is capable of automatically, dynamically, and continuously adapting to the learning context, which is defined by the learner characteristics, the type of educational material being exchanged, etc.*

ILEs have been shown to be highly effective at increasing students' performance and motivation. For over 26 years, peer-reviewed studies have reported large, consistent gains when quality courseware is used to enhance or replace traditional instruction. In studies where time-to-learn is held constant, we typically observe 15% increases in student outcome performance (*instructional effectiveness*). When student outcome performance requirements are held constant, we typically observe 24% reductions in time-to-learn (*instructional efficiency*). More recently, studies have reported even larger instructional effects - 34% increases in outcome performance - and efficiencies - 55% learning time reduction - for ILE, as compared to traditional instruction. Among effective, proven approaches to raising student achievement, (intelligent) automated instruction is the cheapest and most practical by a wide margin.

3.1 Intelligent Tutoring Systems

In 1982, Sleeman and Brown reviewed the state of the art in computer aided instruction and first coined the term Intelligent Tutoring Systems (ITS) to describe tutoring systems that were "computer-based (i) problem-solving monitors, (ii) coaches, (iii) laboratory instructors, and (iv) consultants" [Shute and Psotka, 1995], [Sleeman and Brown, 1982]. Although R&D efforts in the ITS area are characterised by great diversity, the essential modules that are required for ITS are widely agreed to include mainly the student model, the domain model, the tutoring model and the interaction model, which are briefly described below.

Student Model

Student modelling remains at the core of ITS research. What distinguishes ITS from CAI is, in fact, the goal of being able to respond to the individual student's learning style to deliver customised instruction. The student model stores information that is specific to each individual learner. At a minimum, such a model tracks how well a student is performing on the material being taught. A possible addition to this is to also record misconceptions. Since the purpose of the student model is to provide data for the pedagogical module of the system, all of the information gathered should be able to be used by the tutor.

Domain Model

The key feature that distinguishes a knowledge communication system from standard ITS on the Domain Expertise dimension is that the representation of the subject matter is not merely a set of static frames, but actually is a dynamic model of the domain knowledge and a set of rules by which the system can "reason." These systems have their roots in expert systems research (such as medical diagnostic or electronic troubleshooting systems) and have the ability to generate multiple correct sets of solutions, rather than a single idealised expert solution. This component contains information the tutor is teaching, and is the most important since without it, there would be nothing to teach the student. Generally, it requires significant knowledge engineering to represent a domain so that other parts of the tutor can access it. One related research issue is how to represent knowledge so that it easily scales up to larger domains. Another open question is how to represent domain knowledge other than facts and procedures, such as concepts and mental models.

Tutoring Model

This component provides a model of the teaching process. For example, information about when to review, when to present a new topic, and which topic to present is controlled by the pedagogical module. As mentioned earlier, the student model is used as input to this component, so the pedagogical decisions reflect the differing needs of each student. ITS must model the student's current knowledge and support the transition to a new knowledge state. This requires that ITS alternate between diagnostic and didactic support.

Diagnosis means that an ITS infers information about the learner's state on three levels: At the *behavioural* level, ignoring the learner's knowledge and focusing only on the observable behaviour. At the *epistemic* level, dealing with the learner's knowledge state and attempting to infer that state based on observed behaviour. At the *individual* level, covering such areas as the learner's personality, motivational style, self-concept in relation to the domain in question, and conceptions the learner has of the ITS.

The second facet of pedagogical expertise is didactic support, the "delivery" aspect of teaching. Generally, ITS have concentrated on the modelling and manipulation of the content or domain, with little attention being paid to didactics.

Interface Model

Interactions with the learner, including the dialogue and the screen layouts, are controlled by this component. That is, the interface model is concerned with the presentation of the educational material to the student in the most effective way. Research has been carried out in two dimensions: multimedia content and user exploration.

The use of multimedia objects in ITSs can enhance their efficacy to a great extent. However, just the collection of multimedia objects does not guarantee proper learning [Rogers et al., 1995]. Another important aspect is the proper interaction of the learner with the interface components, specially when learning is recognised as a complex activity (or process) combining various factors such as information retrieval, navigation, and memorisation [Dillon, 1996]. One significant development in this area is the Multiple Representation (MR) approach [Kinshuk et al., 1999] that has been developed to present multimedia objects (such as audio, pictures and animations) into a multimedia interface world where the relationships of the objects to the world are governed by the educational framework. Learners are provided with various forms of interactivity to suit the pedagogical goals of the intelligent educational systems. This approach ensures the suitable domain content presentation by guiding the multimedia objects selection, navigational objects selection, and integration of multimedia objects to suit different learner needs.

Another aspect for interface design is the consideration of user's capability and preferences to explore the learning environment. Exploration of domain concepts/knowledge is treated as an effective technique for constructivist learning. This exploratory learning is often accompanied by cognitive efforts to develop and apply the domain concepts/knowledge, which efforts would enhance learning effects. However, it is not so easy for learners to get good learning results just because they had possibility to explore the domain content. The cognitive efforts may cause cognitive overload. Some intelligent/adaptive support is therefore necessary. Exploration Space Control (ESC) methodology [Kashihara et al., 2000] has been developed for supporting exploratory learning which attempts to limit learning space, called exploration space, to adequately control the cognitive load the learners would face in their exploration process. In ESC, the extent of the exploration space is controlled according not only to the domain complexity, but also to the learners' competence, understanding levels, experiences, characteristics, etc. The control is done by restricting exploration tools provided in user interface, tailoring information to be presented, recommending a few among a number of choices, etc.

The interface allows communication between the student and the other aspects of the ITS. The goal of knowledge communication requires that the interface contain a *discourse model* to resolve ambiguities in the student responses. Since the learner is most likely to provide incomplete or contradictory responses when stymied, providing a properly supportive response that can advance the diagnostic process is important. This helps the ITS avoid redundant presentations and enhances instruction.

3.2 Adaptive Educational Hypermedia

Adaptive Educational Hypermedia (AEH) is a relatively new direction of research within the area of adaptive and user model-based educational applications [Brusilovsky et al, 1998]. AEH systems build a model of the individual user/learner, and apply it for adaptation to that user. In this sense, they can be considered as a sub-domain of ITS. Their distinctive characteristic is that the educational material is represented in a hyperspace form, and adaptation is applied for re-structuring this hyperspace, or for modifying the links between the different nodes of the hyperspace, or for modifying the content of each node in the hyperspace, etc. For example, an AEH system may adapt the content of a hypermedia page to the user's knowledge and goals, or to suggest the most relevant links to follow. AEH systems are commonly used when the hyperspace is reasonably large and where a hypermedia application is expected to be used by individuals with different goals, knowledge and backgrounds [Brusilovsky, 1998].

Existing educational hypermedia systems have relatively small hyperspaces representing a particular course or section of learning material on a particular subject. The goal of the student is usually to learn all this material, or a reasonable part of it. The hypermedia form supports student-driven acquisition of the learning material. The most important feature in educational hypermedia is user knowledge of the subject being taught. Adaptive hypermedia techniques can be useful to solve a number of the problems associated with the use of educational hypermedia. Firstly, the knowledge of different users can vary greatly and the knowledge of a particular user can grow quite fast. The same page can be unclear for a novice and, at the same time, trivial, or boring, for an advanced learner. Second, novices enter the hyperspace of educational material knowing almost nothing about the subject. Most of the offered links from any node lead to material which is completely new for them. They need navigational help to find their way through the hyperspace. Without such help, they can "get lost" even in reasonably small hyperspaces, or use very inefficient browsing strategies.

According to [Brusilovsky, 1998], Adaptive Hypermedia (AH) systems, in general, and AEH, in particular, can be categorised with respect to several dimensions. The first question to pose about a particular AEH system is: *what aspects of the student working with the system can be taken into account when providing adaptation?* To which features - that can be different for different students (and may be different for the same student at a different time) - can the system adapt? Generally, there are many features related to the current context of the student work and to the student as an individual which can be taken into account by an AEH system. The features that are used by existing systems are: student's goals, knowledge, background, hyperspace experience, and preferences. Student's knowledge, which is most commonly used in educational systems, is usually represented by an overlay model based on the structural model of the subject domain, which, in turn, is usually represented as a network of domain concepts. Sometimes, a simpler stereotype student model is used, which distinguishes several typical "stereotype students". The student's current goal is usually modelled in a similar manner. That is, the system supports a set of possible student goals, and an overlay student goal model is used to predict the current goal. Student's background and hyperspace experience is also usually modelled through overlay models, while student's preferences are usually either specified by the student, or are deduced by the accumulation of several student models in a group student model.

Another important question concerning AEH systems is: *what can be adapted by the system?* Which features of the system can differ for different students? What is the space of possible adaptations? The adaptations in AEH systems may include the content of the hypermedia pages (adaptive presentation), as well as the links included in each page (adaptive navigation support). The former case can be further decomposed into adaptive multimedia presentation, and adaptive text presentation, which is most commonly used. The latter case includes direct guidance (providing the "next" node to follow), adaptive sorting of links, adaptive hiding of links, adaptive annotation of links, and/or map adaptation. The latter adaptation techniques can be applied to several types of links, including local non-contextual links, contextual links or "real hypertext" links, links from index and content pages, and links on local maps or global hyperspace maps.

The last broad categorisation of AEH systems concerns how adaptation can help, i.e. the *methods and techniques of adaptation*, for content adaptation and adaptive navigation support. Concerning the methods for content adaptation, the most popular one is to hide from the student some parts of the information about a particular subject which are not relevant to the student's level of knowledge about this concept. Following another approach, which has been termed prerequisite explanation, before presenting an explanation of a concept, the system may insert explanations of all its prerequisite concepts which are not sufficiently known to the student. Alternatively, following the explanation variants method, the system may store several variants for some part of the page content, and the student gets the variant that corresponds to his/her student model; or the system may sort the fragments of information about a concept, and present the information that is most relevant to the student's knowledge. Concerning the techniques for content adaptation, one can distinguish between the conditional text technique, where all possible information about a particular concept is divided into several chunks of text, each one associated with a condition concerning the student's knowledge of the domain, and only the chunks for which the condition is true are presented to the student; or the stretch-text technique, where particular "hot-words" are associated with some text, which is "collapsed", or "un-collapsed" according to the student's knowledge. The most powerful adaptation technique for content adaptation is frame-based adaptation, where all the information about a particular concept is represented in form of a frame, and special presentation rules are used to select which information within a frame will be presented, according to the student's knowledge. Finally, concerning the methods for adaptive navigation support, we can distinguish between global guidance, local guidance, local orientation support, global orientation support and management of personalised views.

3.3 Intelligent Pedagogical Agents

Intelligent agents have been characterised in a large range of definitions. In particular, there is no real agreement on what an agent is. Agents' abilities vary significantly, depending on its roles, capabilities, and environments. In order to describe these abilities, different notions of agents have been introduced. Intelligent agents are introduced by most of the researchers with four major concepts defining their behaviour: (i) autonomy, (ii) responsiveness or reactiveness, (iii) pro-activeness and (iv) social ability. There is also a strong notion on the characteristics of agents, which refer to adaptiveness, pro-activity and intentionality. There are also various taxonomies created for agents, e.g. collaborative, interface, mobile, information, reactive, hybrid, and smart agents. In this context, intelligent agents have been associated with a variety of functions, for example, personal assistants, information managers, information seekers, planning agents, co-ordination agents or collaborative schedules, user representatives, and so forth. Their application in the educational field is mostly as personal assistants, user guides, alternative help systems, dynamic distributed system architectures, human-system mediators, and so forth [Aroyo and Kommers, 1999].

Agent technology appears to be a promising approach to address the challenges of modern day educational environments, influenced enormously by advanced information and Internet technologies. All these changes imply that on the one hand, increasingly complex and dynamic educational infrastructures need to be managed more efficiently and, on the other hand, new types of educational services and mechanisms need to be developed and provided. It is in particular that such services need to satisfy a diverse range of requirements in addition to personalisation, including, for example, support for user mobility, support for users while coping with new types of technologies, effectiveness, information support, and so forth. Agents appear to support in a more efficient way those requirements in comparison to other already existing technologies. Besides the ability to process autonomy and co-operation among themselves, agents possess the capabilities for issues such as security, both online and offline service providing, and so forth [Muller, 1996].

Advances in user interface and autonomous agent technology make it possible to a new type of intelligent computer tutors: animated pedagogical agents that can engage human learners in natural instructional dialogs. These agents have a number of novel and interesting features. They are able to respond and adapt to dynamic environments, allowing them to provide opportunistic instruction in dynamic environments and support learning-while-doing. They have animated personas that permit them to demonstrate how to perform task, and engage in face-to-face dialogs incorporating facial expressions and gestures. They can interact with multiple students and agents at once, in order to facilitate collaborative and team learning. They can learn from human instructors, and then teach what they have learned to human students.

Although pedagogical agents build upon previous research on intelligent learning environments, they bring a fresh perspective to the problem of facilitating on-line learning, and address issues that previous intelligent tutoring work has largely ignored. Because pedagogical agents are autonomous agents, they inherit many of the same concerns that autonomous agents in general must address. It has been argued that practical autonomous agents must in general manage complexity. They must exhibit robust behaviour in rich, unpredictable environments; they must co-ordinate their behaviour with that of other agents, and must manage their own behaviour in a coherent fashion, arbitrating between alternative actions and responding to a multitude of environmental stimuli. In the case of pedagogical agents, their environment includes both the students and the learning context in which the agents are situated. Student behaviour is by nature unpredictable, since students may exhibit a variety of aptitudes, levels of proficiency, and learning styles.

The goal of this line of research is to create agents that have life-like personas that are able to interact with students on an ongoing basis. Animated personas can cause learners to feel that on-line educational material is less difficult. They can increase student motivation and attention. But most fundamentally, animated pedagogical agents make it possible to more accurately model the kinds of dialogs and interactions that occur during apprenticeship learning. Factors such as gaze, eye contact, body language, and emotional expression can be modelled and exploited for instructional purposes [Shaw et al, 1999b].

The advantages of intelligent agents can be summarised as follows [Andre et al., 1997], [Johnson et al, 2000]:

- they can attract the student's focus and attention, and they can guide the user through a presentation; therefore, they increase the computer's capability to engage and motivate learners;

- they can realise new presentation means, such as two-handed pointing; they can convey additional conversational and emotional signals via facial expressions and body movements, i.e. they increase the bandwidth of communication between learners and computers; and
- they can demonstrate physical tasks, such as operation and repair of equipment; demonstrating a task may be far more effective than trying to describe how to perform it, especially when the task involves spatial motor skills.

In this context, animated pedagogical agents can yield important educational benefits. First, animated pedagogical agents can improve students' performance. Second, agents that provide multiple levels of advice and employ multiple modalities produce the best problem-solving performance. The largest formal empirical study of an IPA to date has been conducted with the HERMAN-THE-BUG agent (see below). The study involved one hundred middle school students, each one interacting with one of several versions of the agent, varying along two dimensions. First, different versions employed different modalities: some provided only visual advice, some only verbal advice, and some provided combinations of the two. Second, different versions provided different levels of advice: some agents provided only high-level (principle-based) advice, others provided low-level (task-specific) advice, and some were completely mute. During the interactions, the learning environment logged all problem-solving activities, and the students were given rigorous pre-tests and post-tests. The results of this study were three-fold:

- *baseline result*: students interacting with learning environments with an animated IPA show statistically significant increases from pre-tests to post-tests; some critics have suggested that animated IPA could distract students and hence prevent learning; this finding establishes that a well-designed agent in a well-designed learning environment can create successful learning experiences;
- *multi-level, multi-modality effects*: animated IPA that provide multiple levels of advice combining multiple modalities yield greater improvements in problem-solving than less expressive agents; this finding indicates that there may be important learning benefits from introducing animated IPA that employ both visual and auditory modalities, to give both "practical" and "theoretical" Advice;
- *complexity benefits*: the benefits of IPA increase with problem-solving complexity; as students are faced with more complex problems, the positive effects of IPA on problem solving are more pronounced; this finding suggests that IPA may be particularly effective in helping students solve complex technical problems.
- *persona effect*: the very presence of a lifelike character in an interactive learning environment can have a strong positive effect on learner's perception of their learning experience.

The study also demonstrated an important synergistic effect of multiple types of explanatory behaviours on student's perception of agents: agents that are more expressive (both in modes of communication and in levels of advice) are perceived as having greater utility and communicating with greater clarity.

In short, animated pedagogical agents offer great promise for knowledge-based learning environments. In addition to coupling feedback capabilities with a strong visual presence, these agents play a critical role in motivating students. The extent to which they exhibit life-like behaviours strongly increases their motivational impact.

3.4 Mobile Agents

The benefits of intelligent agents are not limited to only pedagogical aspects. Agent solutions are being also applied to other aspects of learning system to improve personalised learning. The most recent work on agents has brought forward a new “species” of agents: mobile agents.

Mobile agents have the ability to move from one computer to another. Mobile agents technology in recent years has been an area of interest for many big research groups, e.g. Telescript [White, 1996], AgentTCL [Gray, 1997], Aglet system [Chang and Lang, 1996], Bee-gent and Plangent [Bee-gent, 2001], Hive [Minar, 2000]. There are specific benefits that mobile agents provide to learning systems compared to static agents, particularly in the web environment.

- In web-based learning environments, mobile agents can be used to pre-fetch the domain content that the student would most likely request in near future, based on the monitoring of student’s previous interaction. Depending on the state of the network, an immediate request or a reservation can be made with the help of mobile agent. In this way, end-to-end quality of the service can be improved for the delivery of distributed educational content, particularly when large multimedia files are involved. Thus mobile agents technology can avoid unnecessary networking delays, cope the bandwidth limitation and adapt the representations to students.

- With the continuous increase in the number of mobile users, the access to web-based learning environments is increasing from portable-computing devices, such as laptops, palmtops, and electronic books. These devices can have unreliable, low-bandwidth, high-latency telephone or wireless network connections. Mobile agents are an essential tool for increasing efficiency of such access.

- Mobile agents offer learning systems developers a new programming paradigm with higher-level abstraction and unified “process” and “object”. In terms of scalability of system and easy authoring, these features of mobile agents offer a flexible and effective philosophy on learning environment development, design, and scalability.

- Web-based learning environments generally share resources on different systems. Both the computers and networks on which such systems are built tend to be heterogeneous in character. As mobile agent systems are generally computer and network independent, they can provide excellent support for distributed systems and resources sharing.

4 The Standardisation Perspective

During the past few years, a number of international efforts have been initiated for defining specifications and standards which can facilitate re-usability in learning technologies. The main initiatives in the area are the IEEE LTSC (Learning Technologies Standards Committee, http://ltsc.ieee.org), the IMS (Instructional Management Systems) Global Learning Consortium Inc (http://www.imsproject.org), the European CEN/ISSS Learning

Technologies Workshop (http://www.cenorm.be/isss/Workshop/lt), and the US ADLnet (Advanced Distributed Learning Network, http://www.adlnet.org).

These efforts have already resulted in a number of specifications for *e*-Learning applications and services. However, the current versions of these specifications do not support personalised learning.

In particular, today we can describe in a common way learning objects, e.g. through the IEEE Learning Objects Meta-Data (LOM) specification. We can also describe learner characteristics in a common format, e.g. through the IMS Learner Information Profile (LIP) specification. Moreover, we can describe learning packages (i.e. collections of learning objects) in a common format, though the IMS Content Packaging (CP) specification. However, the current version of this specification facilitates only the definition of simple, table of contents-like structures. As a result, an e-learning system importing a content package can only present the same information to all learners, thus personalised, on-demand learning cannot be supported.

In this context, a number of international efforts have been initiated for the extension of the current versions of these specifications, to allow the definition of rules which determine which (different) parts of learning packages should be selected for different learner categories. One such approach is carried out in the context of the European KOD "Knowledge on Demand" project.

The KOD project works on an extension of the CP specification (the ***knowledge packaging format***), so that it can enable the definition of adaptation rules, which specify which parts a learning package should be selected for different learner categories. As a result, the KOD e-learning system (or any e-learning system which is compliant with the KOD knowledge packaging format) can import knowledge packages, disaggregate them, interpret the rules included in them, and present different "knowledge routes" to different learners, according to their individual profiles. Moreover, since the "adaptation logic" (adaptation rules) behind adaptive educational content are represented in a common format, adaptive educational content can be easily interchanged and re-used, thus re-usability for personalised, on-demand access can be supported.

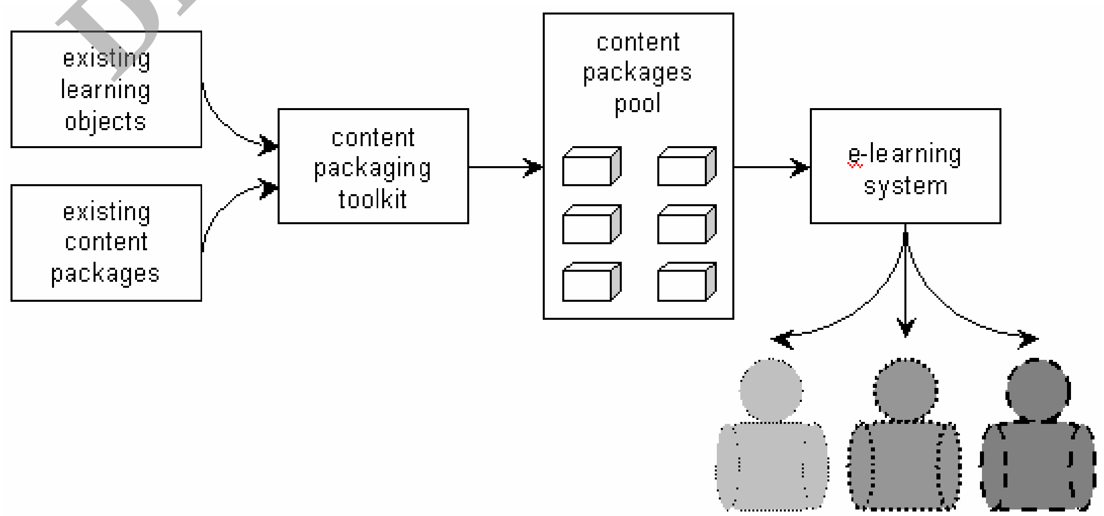

Figure 1 –Through the current version of the CP specification, all learners receive the same learning material

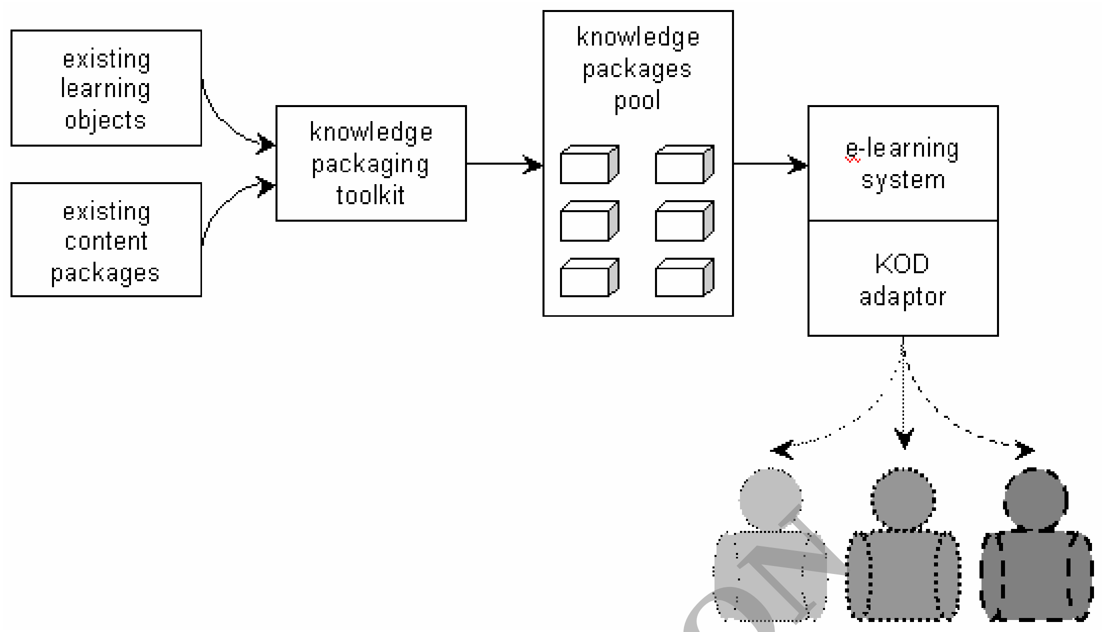

Figure 2 –Through the KOD knowledge packaging format, different learners receive different learning material, adapted to their profile

Another issue in the standardisation of learning material is to provide an efficient way to search and browse various learning objects according to individual requirements. A *web-course search engine* has been developed [Gong and Kinshuk, submitted], which is a user-friendly, efficient and accurate assistant for the learners to get what they want from the vast ocean of learning objects being developed all over the world. The system uses Metadata specifications to record and index various learning objects, and lets the searchers and the resources "communicate" with each other. Following the Metadata specifications, the system collects exact information about educational resources, provides adequate search parameters for search, and returns evaluative results. With intuitive interfaces, the learners can find the appropriate learning objects to suit their needs.

5 Conclusions

This paper reviews the shift towards personalised learning, from an educational, technological and standardisation perspective. Academia has seen a number of changes in the instructional process, including a shift of focus from instruction dominated to constructed dominated learning, system design from Socratic dialogue to student-centred environments, technology advancements from page turners to sophisticated web-based adaptive learning environments. All these changes suggest the increasing support to individual students. The increasing demand for just-in-time learning and learning-on-demand in work environments, and the increasing demand for life-long learning situations, have given rise to those learning environments where traditional human experts are not available on the spot. The need for personalised learning systems to "fill the gap" is therefore to stay and further research in this direction is more than welcomed [Sampson et al., 2002].

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