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Debra K. Tedman (Eds.)

Evolution of Teaching and Learning Paradigms in Intelligent Environment

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With 57 Figures and 24 Tables

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Preface

Teaching and learning paradigms have attracted increased attention in the last few years. Improved access to high speed Internet services and the massive increase in popularity of the Internet have paved the way for alternative but effective approaches in teaching and learning.

This book on the evolution of teaching and learning paradigms in intelligent environment presents the latest ideas pertaining to educational pedagogy. The authors have recognised the role of constructivist thinking in teaching and learning plus the importance of providing a wide range of mental resources to encourage cognitive growth in students.

Electronic learning or e-learning is rapidly transforming the teaching and learning environments of tertiary education facilities, further moulding the educational pedagogy to match the virtual digital modes of communication favoured by teenagers during their secondary education. Teachers need to recognise that while technology should empower the learning process it is important not to neglect educational issues during the systematic analysis and design of the technologies for specific learning purposes. Recent advances in e-learning have emphasised the importance of personalised learning ontology or customising of learning material and activities to provide a personal environment for each learning activity. This means adapting the learning content, its sequencing and maybe some aspects of the learning process so that it can be adapted to different users with different capabilities. This push for personalised learning has also focused upon the need for refining data mining methods to classify e-learning problems e.g. to detect irregular learning behaviours, to study learning system navigation and optimisation, to investigate clustering according to e-learning system usage and to improve systems' adaptability to students' requirements and capacities.

Thus, this book presents an exciting collation of the latest developments in e-learning through case studies, reviews and discussions of soft ware development internationally.

L. C. Jain
R. A. Tedman
D. K. Tedman

Editors

Contents

Introduction to the Evolution of Teaching and Learning Paradigms

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Summary. The increasing popularity of the move to e-learning or web-based education throughout the world has not only accompanied advances in information technology, but has brought about a recognition of the importance of the need for teachers to keep pace with changes in teaching and learning in areas of organisation, curriculum, infrastructure and pedagogy. Constructivism has been an underlying pedagogy that has influenced education since the middle of the twentieth century and continues to form an important foundation for e-learning. It continues to guide the move to help students acquire the higher level cognitive abilities of comprehension, application, analysis, evaluation and hypothesis creation. This chapter provides a brief overview of the changes in teaching and learning including the latest ideas, theories and technologies being applied in web-based education world-wide.

1 Introduction

Evolution and change in information technology and educational technologies are important forces driving developments in education [1]. These changes have significant impacts on educators and developers. Claus Pahl illustrated the impact of change through emphasising the interrelationship of organisation, curriculum, infrastructure and pedagogy in the construction of the teaching and learning environment (TLE). Advances in cognitive sciences and education usually precede the development of the conceptual frameworks for learning support so staff involved in teaching and learning need to keep pace with changes in all four areas of the TLE and be able to adapt to the changes and to manage the changes.

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During the mid to late 1900s, Benjamin Bloom and his colleagues recognised that learning could be divided into three categories or domains (Bloom's taxonomy of learning behaviours); cognitive (knowledge), affective (attitude) and psychomotor (skills) [2–5]. For each of these domains there exists a hierarchy of learning behaviours starting from the ability of the student to acquire knowledge or recall information, ideas and principles, through to abilities to comprehend, apply, analyse, evaluate and finally create new structures, hypotheses, programs etc. Educators in the secondary (high school students) and tertiary (universities, colleges etc) sectors have had varying successes in helping students reach the higher levels of this hierarchy. There are still university courses where teaching and learning are largely teacher centred and reward knowledge acquisition and understanding with little opportunities for application and no opportunities for students to reach the higher levels of the cognitive processes. However, there has been an underlying pedagogy that has influenced education throughout the latter half of the twentieth century and guided the move to help students acquire these higher level cognitive abilities. This is constructivism.

Piaget recognised that education cannot succeed without recognising, using and extending the "authentic activity" with which a child is "endowed" [6]. He further acknowledged that schooling should be adapted to the child and in doing so educators should consider the psychological development of the child in the design of educational activities. Thus, Piaget was an early advocate of the constructivist pedagogy. In the constructivist view of learning, meaning that is constructed by an individual is dependent on the situation itself and the individual's purposes and active construction of meaning [7]. Constructivism recognises that prior experience has an influence on the way phenomena are perceived and interpreted. These authors recognised the importance of active construction of meaning on the part of the learner.

Hendry and King [8] have approached constructivism with a view to understanding the neurological processes that are occurring during learning. They view specific knowledge as specific spatio-temporal patterns of impulses and completion of a pattern of impulses knows, that is perceiving, ideating or reasoning. Along with Iran-Nejad [9] they interpret construction as the integration of patterns in a new form in the same region through synaptic growth. Simultaneous construction in various modality specific sensory areas was considered to be equivalent to Iran-Njad's [9] idea of dynamic self-regulation. Hence, to help young people construct knowledge the teacher must ascertain children's ideas evoked by various contexts [8, 10].

2 Chapters Included in this Book

This book on the evolution of teaching and learning paradigms in intelligent environment presents the latest ideas pertaining to educational pedagogy. The authors have recognised the role of constructivist thinking in teaching and learning plus the importance of providing a wide range of mental resources to encourage cognitive growth in students as recognised by Bereiter [11].

In their chapter on the influence of constructivist thinking in the design of e-learning, Nunes and McPherson emphasise that only with a clear sense of the theoretical foundations that underpin assumptions about learning and cognition, can an efficient online learning environment be appropriately designed. Technology should empower the learning process. It is important not to neglect educational issues during the systematic analysis and design of the technologies for specific learning purposes. Constructivism in online learning is not intuitive to either learners or tutors. Constructivist e-learning requires a set of information, communication and social skills that need to be acquired prior to engaging with online learning activities. Additionally, and during the delivery process, both tutors and learners need the support of adequate learning resources, designed explicitly according to a constructivist approach.

The chapter by Raymond Tedman, Heather Alexander and Robert Loudon illustrates this interaction between pedagogy and technology through a case study into the development of a new medical curriculum using Problem-Based Learning as an underpinning teaching/learning strategy. In this curriculum, the latest developments in constructivist learning guided the design and implementation of an online delivery system that emphasised staff–student interaction in teaching, learning, assessment and evaluation at a new medical school in Griffith University on the Gold Coast, Australia.

Hendry and King [8] believe that we need to modify our commonsense notion of communication as a transmission of knowledge to the relativity of evocation of knowledge. Knowledge is evoked in others through speech and writing and the meaning to words comes from the neural processes. The theory implies that within a classroom, with universal stimulus situations and given that children can have different ideational and logico-mathematical patterns, students might become interested or curious at different times and in various parts of a situation and exhibit different performance outcomes. This reinforces the importance of personalised learning ontology. The chapter on educational ontologies for personalised learning by Fok and IP addresses the issues and methodologies in the design and construction of education ontology and discusses the necessities and issues of an education ontology that can help retrieving, organising and recommending educational resources for personalised learning.

The theme of personalised learning is further investigated in the chapter by Gutierrez and Pardo on sequencing in web-based education. These authors discuss the customising of learning material and activities to provide a personal environment for each learning activity. This means adapting the learning content, its sequencing and maybe some aspects of the learning process. This chapter presents several approaches to the problem of adaptive sequencing – sequencing of learning units so that it can be adapted to different users with different capabilities. The chapter also reviews initiatives in the field of standardisation of sequencing of web-based education. Two important problems are raised: Where to find good learning content and How to sequence to maximise learning?

Iran-Nejad [9] advocated a global restructuring strategy for education in order to prepare a generation of resourceful learners who can take advantage of the many sources that must contribute to learning simultaneously. Increasingly, there is a move towards using the advances in information technology to develop multi-user domains or MUDs to further extend and develop the neural and social aspects of learning that are important in education [12]. Throughout the secondary school years (students in the early to late teens) it is recognised that students process information and construct their understandings by being actively engaged in doing complex tasks. Today's "digital kids" are equally as comfortable with virtual, screen-to-screen relationships as they are with face-to-face relationships [13]. Electronic learning or e-learning is rapidly transforming the TLEs of tertiary education facilities, further moulding the educational pedagogy to match the virtual digital modes of communication favoured by teenagers during their secondary education. The chapter by Slator et al. traces the evolution of MUDs from simple meeting and discussion places to immersive virtual environments, further extending the view of Piaget that "schooling should be adapted to the child".

Debra Tedman has shown in her chapter, *The Development of an Approach to Learning within the Middle Schooling Paradigm*, how constructivist theories can be incorporated into middle schooling to emphasise the importance of affective domain as well as cognitive domain learning outcomes in young teenagers. She reinforces the need to develop teaching/learning strategies that take into consideration the abilities and learning styles of students and provides a case study demonstrating the use of thematic units whereby students investigate issues related to Science, Technology and Society.

Accompanying the expansion of e-learning in university as well as business environments, there has been a need to develop data mining techniques to extract information regarding student behaviour. The chapters by Castro et al. and Vellido et al. review the current research and applications of data mining methods in e-learning. Castro et al. investigated the data mining methods used to classify e-learning problems, e.g. to detect irregular learning behaviours, to study learning system navigation and optimisation, to investigate clustering according to e-learning system usage and to improve systems' adaptability to students' requirements and capacities. Vellido et al. utilise data mining techniques for extracting knowledge from virtual campus data concerning students' system usage behaviour in order to study e-learning problems such as characterisation of atypical students' behaviour and prediction of students' performance. They presented a case study where a partially virtual campus offers postgraduate courses and continuous education to Latin-American students.

Data mining techniques are also being used in a web-based educational delivery system called AHA! (Adaptive Hypermedia Architecture). The chapter by Paul De Bra, Natalia Stash and David Smits, presents a case study of how authoring and management tools have been used to assist teachers and students maximise the benefits of e-learning.

Riitta Penttinen and Sari Minkkinen have reviewed the gap between technology and pedagogy, emphasising the importance of understanding pedagogy in developing processes on how to teach and learn technology. They illustrated the dilemmas faced by staff in attempting to understand the language used in the fields of technology versus educational pedagogy in their attempts to improve the teaching and learning of technology.

3 Conclusion

A good understanding of the theoretical foundations to learning and cognition is vital to the development of an efficient online learning environment. This chapter introduces the concept of change or evolution in teaching and learning, which is explored in this book, by emphasizing that educational issues must underlie the systematic analysis and design of technologies for specific learning purposes. E-learning permits the elaboration of personalised learning to help students develop higher level cognitive abilities. To achieve this, there has been a recognition of the need to accompany the expansion of e-learning with an increasing emphasis on developing data mining techniques to help teachers investigate irregular learning behaviours plus improve the e-learning systems' adaptability to students' requirements and capacities as well as to improve prediction of students' performance. In addition, many writers in this book describe the latest developments and future directions in software for e-learning.

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Why Designers cannot be Agnostic about Pedagogy: The Influence of Constructivist Thinking in Design of e-Learning for HE

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1 Introduction

When instructional designers design online learning environments, they, like all other designers, call on prior knowledge and experience [1]. They call to mind previous solutions and strategies they have used, have experienced, or have seen that fit the particular constraints of the current situation [2]. These previous experiences play a central role in specifying the structure, contents and delivery strategies. Consequently, if the pedagogical component of the design is not consciously considered and planned, the instructional designer tends to incorporate his/her own model of learning into the environment. This may be inappropriate and even conflict with the learning processes which are intended to be supported by Information and Communication Technologies (ICT). Furthermore, the lack of an overall pedagogical strategy implies an absence of a consistent and adequate educational approach throughout the whole online learning environment [3].

As a result, when producing learning materials, assumptions are made about the type of learning and the process of learning that it is hoped will take place [4]. For this reason, online learning environments will always incorporate some form of learning model, which may or may not have been intentionally considered. So, one of the crucial factors to the success of an educational environment is that any assumptions that are made about the

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learner and the learning process, are incorporated into the design process in an explicit and consistent manner. In fact, unless carefully planned from a pedagogical point of view, learning environments could result in a mix of eventually conflicting techniques from different theoretical perspectives [5].

Only with a clear sense of the theoretical foundations that underpin assumptions about learning and cognition, can an efficient online learning environment be appropriately designed. These theoretical foundations provide the means to choose an appropriate educational approach. The selection of an approach can be seen as a *pre-design concern* and is the result of answering basic questions such as: *why* is the environment being developed; *what* is the focus of the environment; and *who* the learners are [3].

Failure to address questions regarding learning theories, pedagogical approaches and explicit learning outcomes, results in the *Everest Syndrome* – using technology just because it is there. This attitude among educationalists is potentially responsible for the apparent failure to establish e-Learning as a creditable educational technology [6]. In fact, this approach to the technology focuses undue attention on questions about what educational technology can be made to do, thus distracting researchers, instructional designers and educationalists from asking the more crucial questions about what this technology should accomplish and what its role should be in the teaching and learning process [7].

The consequences of an inappropriate emphasis on what technology can be made to do, rather than on how this technology can empower the learning process, results in neglecting educational and pedagogical issues, and the systematic analysis and design of the technologies for specific learning purposes [7]. Consequently, ICT-based learning environments often consist of poor and ineffective applications. McKendree uses an analogy with the camcorder to characterise the resulting situation:

> It lets amateurs make movies about themselves which they and their immediate family and friends can enjoy. However, it is unlikely that you or I will want to rent it from the video-store and watch it. The professionals are much better able to design and make something, for a wider audience. [...] It is fine if some lecturers want to take time to hack together some online material for themselves and their students. They will probably have the pride and commitment to get them to use it. However, the material they produce will possibly not be as flexible or as widely applicable as something crafted professionally. [8]

2 Historical Notes

Education has always been central to the survival and success of human societies throughout the centuries. It is neither possible, nor appropriate to review this vast field in this chapter. However, some questions about how we perceive learning and acquisition of knowledge, and how these perceptions influenced our educational systems, are crucial to understand the role of pedagogical thinking in instructional design.

The oldest and most natural form of learning is simply living with other humans and doing what they do [9]. The corresponding earliest form of education based on this *learning by doing* is *apprenticeship* [10]. Apprentices learn a task, such as weaving, masonry or even thinking, under the tutelage of an *expert* [11]. Traditional apprenticeship learning could be characterised by the following [12]:

- Work is the driving force. The progressive mastering of tasks by apprentices is appreciated not as a step towards a distant, symbolic goal (such as a certificate), but for its immediate value in getting the work done
- Apprentices start with skills that are relatively easy and where mistakes are least costly
- Learning is focused on performance. It involves the ability to do, rather than the ability to discourse about a subject
- Standards of performance are embedded in the work environment. What constitutes expert execution of a task is obvious, and judgements about the learner's competence emerge naturally and continuously in the context of the work. The apprentice owns the problem of moving on to the acquisition of the next skill
- Teachers and teaching are largely invisible. In apprenticeship, learning and informal job training in workplaces looks as though little teaching is going on. Whatever instruction the apprentice receives, originates not from a teacher teaching, but from a worker doing his or her work that the apprentice observes.

In short, learning is active, hands-on and based on physical experiences [9]. Apprentices are inducted into a community of expert practice in which the *teacher* continuously engages in, and is a master at the practice being learned. His or her performance constitutes the standard for the apprentice [13].

The invention of writing brought new concepts and definitions into education [9]. The learner now acquires knowledge about the real world from an intellectual distance, by reading about it. This new learner has now available a reservoir of information, organised and stored in books, and education consists of acquiring information through reading. Hands-on interaction with the real world continued to be the education of the working classes, but the intelligentsia were not expected to learn practical skills [9]. This type of approach to learning has recently been criticised by educationalists and educational philosophers, many of whom feel that it promotes shallow learning, mindless memorizing and regurgitating, and the decontextualised acquisition of definitions and facts [14]. In short, they are dismissed as being a tool for

> jogging the memory, not for remembering… [providing students] with the appearance of intelligence, not real intelligence… they will seem to [have] wide knowledge, when they will usually be ignorant.

The quotation above, however, is not from a modern educationalist, mistrustful of new technology, but is adapted from Plato's 'Phaedrus' (p. 69), in which the author recalls Socrates' criticisms of the impact of reading and writing in educational systems.

The introduction of mass schooling at the end of nineteenth century marked the final demise of the apprenticeship model in schooling [11]. Discrete subject areas appeared, social and professional knowledge was divided into independent subjects that we now recognise as mathematics, social studies, reading, language, science and art [11]. Knowledge is contained in the teacher's lessons or in the textbooks. Instruction is seen as essentially a process of engineering learning environments so that transmission of this knowledge from these sources to the student is efficient and effective [15]. This denotes the notorious 'sage on the stage' approach as criticised by [16]. This criticism is shared by many in education [17], who note that this idea that knowledge is something that can be objectively validated and prioritised, transmitted and acquired is the folk metaphor of the industrial and post-industrial age. Knowledge cannot be seen as a commodity apart from individual understanding, experience and needs. The view of knowledge as something tangible and transmissible reflects the epistemological assumptions of the *objectivist* philosophy that still prevails in our educational systems today. Objectivists believe in the existence of reliable knowledge about the world that is received by learners passively from authoritative sources [18]. The philosophic, rather than the scientific, method is the main mode of representing the process of learning and the mind.

At the turn of twentieth century, experimental psychology emerges and develops techniques for the experimental study of memory and the higher mental processes such as learning. The importance of this work for the practical world of education was immediately recognised. A new field in psychology had emerged and an American, Edward Lee Thorndike, is usually considered the first educational psychologist. Thorndike developed an important theory of learning that describes how stimuli and responses are connected.

This new field of educational psychology flourished within the progressive movement in education that had begun in the early twentieth century. Educational psychologists became increasingly interested in how people receive, interpret, encode, store and retrieve information. Attempts to understand the cognitive process tried to interpret human problem solving, memory and creativity. Because of the wide diversity in human nature, instructional settings, and fields of study, no general theory has been formulated that is applicable to all educational psychology. Instead, psychologists work on developing theories about particular phenomena in learning, motivation, development, teaching and instruction. These different theories of learning help educators to understand, predict, and control human learning and behaviour, and therefore shape the way instruction is designed and facilitated. Consequently the adoption of a particular theory of learning also influences the way educators design, develop and use learning technologies and more specifically online learning environments.

Following the functional approach proposed by Thorndike and his so-called law of effect – the more satisfying the result of a particular action, the better that action is learned – the American psychologist B. F. Skinner became the foremost exponent of the *behaviourist* school of psychology. This school of thought believes that human behaviour is explained in terms of physiological responses to external stimuli. This originated programmed instruction, a teaching technique in which the student is presented with a series of ordered discrete bits of information, each of which he or she must understand before proceeding to the next stage in the series.

This approach to teaching has been systematically criticised by the educational community. Myers [19] attacks behaviourism because it emanates from pure positivist reductionism. Therefore, and since behaviourism reduces all behaviour to the level of a correlation between an external stimulus and an internal response, critics of this approach argue that it ignores the importance of higher cognitive processes, which focuses on internal process such as perception and learning from reflection, which have a major part to play in facilitating an understanding learning [20]. However, this focus on reductionism also enabled behaviourism to be easily understood and made it compatible with the dominant Tayloristic and functional views of the world in the early 1900s. Thus behaviourism became a hegemonic pedagogy in educational systems [21] and in combination with functional and *objectivist* philosophies has governed educational practices for most of the twentieth century [22].

Objectivism maintains that the world is completely and correctly structured in terms of entities, properties and relations [23]. Reality is objective and external to the individual and consequently learning is dominated by the *communication metaphor* [24]. Knowledge is external to the learner and contained in an authoritarian source, such as a textbook, a teacher's lecture or even a computer-assisted learning (CAL) lesson. Learning occurs when this knowledge is transmitted to and received by the student. As Kay [25] puts it, students are seen as *empty vessels* that must be given knowledge, drop by drop, from the *full teacher-vessel*.

> Thus hegemonic pedagogy draws on model of learning that largely operates from the transmission end of the learning continua, where students are perceived as acquiring or collecting knowledge and skills and are passive recipients of frequently didactic teaching. [21]

Therefore, according to an objectivist view, learning takes place in classrooms, not elsewhere [24], and the primary concern of educational institutions consists in transferring knowledge as an integral, self-sufficient substance, which comprises abstract decontextualised formal concepts [26]. The activity and context in which learning takes place are thus regarded as merely ancillary to learning, pedagogically useful of course, but fundamentally distinct and even neutral with respect to what is learned [26].

This situation has been heavily criticised by educationalists arguing that the combination of objectivism and behaviourism emphasises observable external behaviour and avoids reference to meaning, representation and thought [20]. Further supporting this critique of behaviourism, Fosnot [27] suggests that the focus of learning should be on concept development and developing deep understandings, rather than simple behavioural changes or skills acquisition. Nevertheless, and despite all criticisms and the proposal of alternative learning philosophies and approaches, learning practices, until the late 1990s, were still grounded in the traditional normative, campus-based, linear teaching experiences, which are dominated by lectures occasionally followed by smaller group seminars [28].

During the last quarter of the twentieth century, the convergence of IT and telecommunications has transformed society phenomenally. A new Information Society emerged, which is characterised by an unprecedented information explosion. As Petruk [30] comments, 'frequent colourful quotes dramatise the exponential growth of new information that our society is generating each year'. The Information Society has resulted in rapidly increasing and changing information and a proliferation of different media for its communication. The impact on educational institutions has been slow, but is starting to build up momentum. In fact, until very recently 'what was learned in school was that all the students really needed to learn' [29]. The graduate after leaving the educational system could rely upon that knowledge for the rest of her or his life. Storing information and being able to recall it was central to the mission of formal education. Technological evolution and change occurred at a relatively slow rate and direct access to information, primarily books, was relatively scarce [30].

Conversely, learning how to think critically and to analyse and synthesise information to solve technical, social, economic, political and scientific problems are crucial for successful and fulfilling participation in a modern competitive society [31]. Today, knowledge expands exponentially and is no longer static in nature [29]. Information is no longer simply organised, stored and made available by transference as proposed by the behaviourists. In fact, successful individuals in this continuously and fast changing society must be creative and flexible problem solvers [32]. These are characteristics based on knowledge construction skills and not simply gathering and memorising skills [31].

Consequently, as the flood of information continues to inundate modern society, educational objectives, approaches and technologies are changing. Since information has become a dynamically changing, random access flood, it does not help to try simply to learn about it, today's students must learn how to *shape* it [9]. That is, students need to be able to select and shape information as our forebears shaped and selected wood and clay. These emergent learning needs point out to a return to the apprenticeship model, where students learn how to learn, how to think and how to solve problems embedded in a larger functional context, that is learning by doing. This *cognitive apprenticeship* approach [10, 26, 33, 34] proposes a paradigm shift in education and instruction and remarkably a return to basics in educational terms. Rather than promote the mere acquisition and memorisation of facts and abstract concepts and theories, instruction now means to improve the abilities of self-regulation of learning, thinking, intelligence and problem solving [34]. Education assumes its modern meaning, as defined by Banathy [35]: 'a human activity system that provides arrangements, opportunities and resources for learning and human development'.

The cognitive apprenticeship model follows the emergent epistemology of learning and understanding known as constructivism [11]. Surprisingly, this emergent and broader theory of learning is not a new perspective.

In fact, at the same time Skinner was proposing and demonstrating his ideas, another American philosopher and educational psychologist John Dewey was developing a very different philosophy of education that is now known as the constructivist approach.

Dewey described learning as an active individual process, not something done to someone, but rather something that a person does [36]. He coined the concept of 'learning by doing' where learning takes place within the context of a whole experience in which the learner is completely engaged, and results from the combination of acting and reflecting on the consequences: reflective experience and reflective thinking. Therefore, learning is seen as a continuous process of reflective experience in which a person is actively constructing her/his own view of the world. Consequently, the learning experience and the process of knowledge construction goes far beyond formal learning and the classroom, that is, learning will necessarily also occur during non-class times and outside informal learning activities [37].

Therefore, the design of e-learning spaces requires a change of pedagogical thinking and the adoption of pedagogical models that support active and collaborative learning, based on authentic, project-based activities as well as informal learning in spaces adjacent to the formal ones [38]. However, if as stated above, educational designers call on their prior perceptions of knowledge acquisition as well as their prior educational experiences when developing their applications, then these previous experiences may hinder the understanding required to produce appropriate e-learning environments. In fact, most online learning environments developers reproduce into their applications the traditional classroom approach as they experienced it, deliberately or accidentally [1]. This is often based on the behaviourist paradigm that characterised their own education. In the earliest attempts at computer-based instruction (CBI), designers treated knowledge as a *fluid*, which was poured into the *student-vessels* [25], and thus used a learning theory that does not match modern pedagogical thinking behind current educational settings. In fact recent adjustments in education denote paradigm shifts both in educational psychology and epistemology of learning. Thus, this rigid connotation of knowledge transmission causes a corresponding *rigidness* with regard to the educational uses of these applications [40].

One of the foci of online learning research is to support learning at a HE level while avoiding the rigidness identified by [40]. Therefore, it is important to clearly characterise academic learning before engaging in online learning environment design and development.

2.1 Characterisation of Academic Learning

Defining academic learning is somewhat problematic. In general terms, it can be seen as a series of activities that promote acquisition of high level knowledge [1]. However, both the nature of knowledge and the way this knowledge is to be acquired is changing due to the impacts of the Information Society.

Therefore learning in HE must be assumed to be much more than a passive process of acquiring inert and abstract facts and concepts (e.g. decontextualised definitions, algorithms and routines) which are of no use if the learner does not have the understanding to apply them in appropriate settings [41]. The aim in HE must be to develop the learner's critical faculties, understanding and independence of thought in addition to the gathering of concepts [42].

This view of academic learning implies the rejection of the classical tradition of transferring some body of knowledge in the form of unchangeable and authoritarian ideas, concepts or definitions to the learner, as defended by the objectivist school of thought [1]. According to the objecttivist view, concepts are considered external to the learner and received through a process of communication. This process focuses on behaviour and its modifications, rather than on cognitive or mental processes that facilitate learning (e.g. constructing, reflecting or planning).

This objectivist view of learning prevails even today in many universities and was developed and defended by the behaviourist school of thought. As discussed above, behaviourist theories of learning do not attempt to account for any mental processes that occur in learning, the emphasis being on what the learner does in response to the knowledge transferred into her/him and passively accepted. That is, learning as a change of behaviour appears as a function of what followed that behaviour in the past [43]. Consequently, this view of learning embodies a strongly individualistic conception of learning, in the sense that the individual behaviour is modified due to presentation of stimuli from the learning environment [44]. Behaviourism embodies a model of the learner as a solitary striver for understanding [4] and acquisition of knowledge as an abstract Platonic form [46].

Laurillard [46] proposed a different view of academic learning, more compatible with the recommendations of the EC Study Group [47], the UK White Paper [48] and what learners actually experience in university environments nowadays. This definition is rooted on the following two main characteristics for academic learning:

- Academic learning must be *situated* in the domain of the objective, the activities must match the complexity of that domain;

– Academic learning must contain both *direct experience* of the world and the *reflection* on that experience that will produce the intended way of representing it.

Therefore, academic learning is assumed to be much more than a mere process of passive reception and acquisition of knowledge. The way learners handle knowledge is what really concerns academics [46]. Knowledge has a contextualised character, which means that it cannot be separated from the situations in which it is used. That is, learning should revolve around realistic and intrinsically motivating problems that are situated in some meaningful real-world context [49]. When learning occurs in isolation it remains inert, that is, the learner has the information available in memory, but never recognises when it is relevant [50]. Acquisition of concepts is of no use if the learner cannot apply those concepts and transfer knowledge across different settings [3].

In short, academic learning involves the acquisition of high-level skills of critical thinking and problem solving in addition to the gathering of facts and concepts. It consists of a process of construction of knowledge and the development of reflexive awareness, where the individual is an active processor of information. Learning occurs through interaction with rich learning environments, and results from engaging in authentic activities, and social interaction and negotiation. This view of learning reflects the constructivist learning theory.

3 Theory of Constructivism

The constructivism school of thought holds that 'knowledge of the world is not a simple reflection of what there is, but a set of social artefacts; a reflection of what we make of what is there' [51]. In other words, there is a meaning that learners attach to newly acquired knowledge in association with experiences of the environment in which the learner is a part [52].

The theory of constructivism stems from the field of cognitive science, particularly from the works of Jean Piaget, Lev Vygotsky, Jerome Bruner, Howard Gardner and Nelson Goodman. It describes the development of knowledge through learning as a process of active construction of meanings in relation to the context and environment in which the learning takes place. A learner's understanding of a subject is embedded in the experience of that individual [26].

> Constructivism proposes that knowledge or meaning is not fixed for an object, but rather is constructed by individuals through their experience of that object in a particular context. [53]

Basic constructivism relies on the use of prior knowledge in the construction of new meanings. Previously constructed structures of knowledge are retrieved and utilised as discrete packets for the development of new knowledge structures. Spiro et al. [54] took this basic theory of constructivism a step further. They argue that a new element of the constructive process must be added to those that are already recognised. That new element is the use of pre-existing knowledge in the active construction of new knowledge. The pre-existing knowledge is brought together from diverse areas of understanding and reassembled into knowledge structures that can be used to interpret and construct new meanings from the new situation presented. This process of knowledge construction by imposing meaning to learning experiences develops metacognitive skills, higher order thinking, deeper understandings and a greater motivation to learn [55]. This then reflects the basis of the constructivist epistemology.

In the literature, constructivism is almost always discussed in opposition to the well-established behaviourist philosophy. The behaviourist approach advocates changes in behaviour and development of skills, derived from drill and practice, as the goals of instruction. Constructivism defends internal knowledge construction and deep understanding of concepts, theories and artefacts as the objectives. Thus, these are understood as constructions of active learner reorganisation [27].

In fact, to discuss and characterise either behaviourism or constructivism nowadays is not an easy task. This is mainly because of the excessive *ideological fervour* that borders on *evangelism* that characterises some of the authors who advocate constructivism [56]. All other perspectives are rejected as ‘heresy’ [56] and behaviourism in particular has become a pejorative label given by constructivists to the offending *others* [57]. Consequently, very few in the educational technology field would admit to being either behaviourist or objectivist anymore [58]. However, the old concepts, methods and attitudes still prevail and many so-called constructivist environments revert to objectivism [17]. This creates additional difficulties when trying to understand and characterise the different uses of these opposite approaches [7].

Nevertheless, the behaviourist/constructivist debate cannot be reduced to a simple dichotomy. In reality, behaviourism and constructivism should be seen as polar extremes of a continuum in order to contrast their assumptions, as opposite underlying philosophies or ways of seeing the world

[45]. Hence, very few people hold radical positions of either persuasion, and probably neither side is absolutely right [59].

Moreover, both perspectives share a vision of education where the role of 'teaching' is to help students to learn about the world they live in [17]. However, objectivism and constructivism differ in a basic set of notions as to how the learners perceive the world: the nature of reality, the nature of knowledge, the nature of human interaction and the nature of science [59]. These are the set of principles that form the epistemological basis of these opposite theories. Designers need to be aware of the differences and implications of these basic notions in order to avoid implicitly incorporating inappropriate models in their learning artefacts.

3.1 The Nature of Knowledge and Reality

Modern constructivists believe that knowledge is personally constructed from internal representations, which are in turn developed by using prior knowledge as a foundation. Prior knowledge that is brought to bear is itself constructed, rather than retrieved intact from memory, on a case-by-case basis [54]. Moreover, it is thought that individual learning is linked with internalisation of knowledge that was negotiated inter-personally, that is, individual thought is internalised from communicative interactions with others in a particular social context [60].

Hence, knowledge is based upon individual constructions that are not tied to any external reality, but rather to the *knower's* interactions with the external world [52]. Therefore, meaning is imposed on the world by the individual. There are many ways to structure the world and there are many meanings or perspectives for any event or concept [2]. In other words, reality is to a degree what the individual conceives it to be [52].

Consequently, meaning is seen as rooted in, and indexed by, experience [26]. Experience includes not only the physical context in which the learner acts, but also both the cognitive and physical tasks that the learner engages with while the experience is taking place [11]. However, since knowledge is indexed to the experience from which it was acquired, the context that characterises it is a significant determinant of what is learned and how it is organised in memory. Other authors [31] consider that there are two kinds of link that need to be developed during the learning activity: internal and external associations. Internal associations reflect the learner's understanding of a concept. On the other hand, external associations refer to connections between the concept and social context. The usability of a constructed concept in the future will depend on these external associations.

The fact that learners must acquire knowledge in ways that will help them use it in similar situations in the future has two major consequences:

– Learning activities must be 'authentic activities' which must be embedded in realistic and relevant contexts (*situated learning*)
– Learners must be provided with the opportunity to explore *multiple perspectives* on an issue, that is, one activity is not enough to acquire a comprehensive view of a particular concept

Situated learning raises another important issue in constructivist learning, that is, the way an individual learns, and the cognitive resources which are called upon, depend on the nature of the learning situation and previous learning activities [60]. Furthermore, exploring multiple perspectives may take the form of multiple interpretations of the same concept, event or fact or multiple manifestations of the same interpretation in different contexts [63]. Through this process, learners are expected to gain both cognitive flexibility and transferability of knowledge.

Therefore, any learning activity is framed by the domain specific perspectives, language and culture [26]. Consequently, meaning and purpose must be socially constructed through negotiations among present and past members of the society that surrounds the domain [57]. That is, learning happens in a social context and conceptual growth comes from sharing of perspectives and testing of ideas with others. Learning, in the sense of reaching common understandings and shared meanings, results from social interaction and negotiation with peers and teachers [31].

3.2 The Nature of Human Interaction

The central point of constructivism is that knowledge does not exist independently in the world. Hence, any situation can be understood from many perspectives and there is not a correct meaning to strive for [2]. However, individual experiences, perceptions and constructions do not mean that it is impossible for individuals to construct essentially the same understanding for any object or event in the external world [45].

Therefore, the process of social negotiation becomes of paramount importance. The construction of knowledge by individual learners is based on the processes of interaction with peers, facilitators and experts. Conceptions and ideas are compared, confronted and discussed through this interaction process. In the process all actors modify their views to finally achieve a common understanding. Therefore, dialogue and the negotiation of meaning provide the basis for the individual to develop, test and refine their knowledge [64].

Basically, two very different types of interactivity are proposed [65]. The first is an individual, private activity between the learner and the learning materials, which may range from the traditional textbook to computer-based simulations. The second is a social activity between the learner and the tutor, the facilitator or other learners.

Private interaction with the learning and conceptual materials is expected to promote learning by provoking cognitive restructuring [66]. Cognitive restructuring occurs as learners revise their ways of thinking to provide a better fit to reality when faced with discrepancies between their own ways of viewing the world and new information [67]. Social interaction with tutors and facilitators is expected to promote development through the guidance provided by interaction with people who are skilled in solving the problems emerging from the learning activities [67]. Social interaction with the learner's peers is expected to promote learning by joint problem solving and meaning negotiation between partners working with independence and equality on each other's ideas [67].

Both private and social interactivity are required in the process of social negotiation and have to be supported by the learning environment. Learning is the process of socially constructing a communal understanding, a collective, constructive social process [40].

> All human learning is fundamentally social or collaborative; language is never private; meaning is inter-subjective; knowledge is situated in culture and history. [61]

Therefore, the learner must be surrounded by a learning environment, which supports the communication and negotiation processes between members of a social community inserted in a rich learning environment.

3.3 Rich Environment for Active Learning (REAL)

The need for situated learning, social negotiation and multiple perspectives implies that a number of different learning strategies must be adopted to assist the learner in the construction of knowledge. The adoption of these different strategies creates the need for a different conceptualisation of learning environments. Grabinger and Dunlap [31] devised the term Rich Environments for Active Learning (REALs) to describe environments that promote learning within authentic contexts, and encourage the growth of learner responsibility, initiative, decision-making, intentional learning and ownership over the acquired knowledge. Additionally, REALs should provide an atmosphere that encourages the formation of knowledge-building learning communities. These communities encourage collaborative social negotiation of meanings and understandings among the members of the community (peers, tutors, subject matter experts).

In particular, REALs can be said to comprise five criteria: student responsibility and initiative; generative learning activities; authentic learning contexts; authentic assessment strategies; and co-operative support [31]. Therefore a number of requirements have been proposed for REALs [68]:

- Provide support for active learning – Learners are active because knowledge is permanently being constructed through interaction with the environment
- Provides authentic, real world learning experiences. Knowledge that is taken out of context during instruction is not authentic, so learning must be supported by means of real world activities
- Provide multiple perspectives – although reality is constructed by each individual, the process of learning is the consequence of the interaction with multiple information sources (e.g. experiences, conceptual materials, teachers, peers and authors)
- Provide support for communication and social negotiation
- Provide support for collaboration, not competition
- Focuses control at the learner level. Since learners are expected to be active, learning in context and collaborating with other learners and the instructor, they are more in control of their learning.

As observed by Jonassen [69], most constructivist learning environments, including cognitive flexibility hypertexts [70], anchored instruction [71], goal-based scenarios [72], and causally modelled diagnostic cases [69], share a common goal: the construction of advanced knowledge by learners that will support complex performance, such as problem solving and transfer of learning. These environments stress situated problem-solving skills, because that is the nature of skills that are required and rewarded in the real world. In most professions, people are paid to solve problems, not to memorise information [73].

Having established the nature of academic learning and found a compatible learning theory is not enough to support actual design and development of online learning environments. The design and development of these environments requires explicit and clear pedagogical models that can be translated from theory into practice. In fact, a designer, solely faced with constructivism as a learning theory, would have difficulty in translating this epistemology into an appropriate conceptual model, and ultimately in developing a constructivist online learning environment. REALs provide the translation from general constructivist theory to an understandable design model.

3.4 Constructivism and the Reality of Practice

However, 'constructivism is a philosophy not a strategy' [59]. This opinion is further rationalised by the statement that constructivism is a theory about knowledge and learning (an epistemology) not a theory of teaching [27]:

> Constructivism is a theory about learning, not a description of teaching. No 'cookbook teaching style' or pat set of instructional techniques can be abstracted from the theory and proposed as a constructivist approach to teaching. Some general principles of learning derived from constructivism may be helpful to keep in mind, however, as we rethink and reform our educational practices [27].

Despite the characterisation of academic learning as a constructivist process, higher education (HE) lecturers and academics are constrained by a number of practical limitations intrinsic to the educational system we have inherited. HE institutions were designed according to a decidedly *Tayloristic system* combined with a legacy behaviourist approach. Universities are divided into faculties, faculties are composed by departments, departments offer courses, divided into modules and, in turn, these are divided into units. Academic life is divided into semesters, where the lecturers tell the students what to do, check that they have done it and assess the result according to a measurable quantitative mark. Modern education aims at uniformity of teaching quality standards and curricula. Lecturers have to operate within these parameters, cope with increasing numbers of students in classes, administrative processes of assessment and student progress monitoring and comply with institutional and national policies. Furthermore, academics today have to foster their professional careers in institutions that increasingly devote a disproportionate weight to research and administration in comparison to teaching. Finally, and in great contrast with what happens in secondary education, it is not unusual that lecturers at HE today have little or no formal training in teaching and learning, although this is gradually changing. Therefore, it is not surprising that teaching and learning approaches at Universities are still predominantly based on a lecturing approach. Historically, teaching in HE has always been carried out through what is termed as *traditional* lecture-based education. This method of delivery remains generally unchanged, and is proven, efficient and time efficient.

However, significant change is taking place with the advent of e-learning and the spreading of new pedagogical paradigms, such as constructivism. It is apparent, from the pace of change that has already taken place, that we will be seeing what might be an exponential acceleration of the introduction of constructivist e-learning applications into HE teaching and learning.

This change and introduction of constructivist approaches will be hindered by the Tayloristic nature of the system. The semesterisation of modules implies that learning must happen in blocks and short periods of time. Therefore, the amount of time allowed for personalised knowledge construction and social negotiation is very limited. Teaching strategies cannot be limited to flexible scaffolding, but requires large amounts of objectivist and explicit input by the tutor. For instance, could you expect a second year physics undergraduate student to develop an understanding of the Theory of Relativity in a semester without the support of explicit materials?

Furthermore, the behaviourist nature of the HE is rooted on completing your degree (a set of modules) with a measurable and comparable classification: a grade. Conversely, constructivism advocates the acquisition of a set of knowledge and skills. Students, parents, employers and the society in general expect graduates to emerge from HE with a clear and comparable quantitative mark. Companies may advertise they now want students with a wider set of skills, yet they are still selecting the graduates for interview and testing based on the degree classification. Therefore, constructivist approaches often fall foul of expectations and societal demands. Worse still, constructivist approaches taken during the semester are then often assessed through traditional objectivist examinations, confusing students and failing to reward effort intensive and time consuming processes of skills acquisition and knowledge construction.

Therefore, so-called constructivist e-learning in HE, is often used to complement traditional lecture-based approaches with moderate constructivist learning processes. The design and development of such e-learning environments must, therefore, adopt pedagogical models that are not *fundamentalist* in nature and allow for complementarity with objectivist delivery. These pedagogical models should adopt moderate constructivist approaches, based on active and problem-based learning. These pedagogical models, rooted in actual practice, may be better understood by designers and educationalists and therefore contribute to the design of learning environments that are actually different from the traditional objectivist environments so common in the e-learning universe.

Nevertheless, it must be pointed out that the focus of e-learning is frequently placed on the design and development of ICT based learning environments. Even if designed with an appropriate and explicit pedagogical model in mind, these learning environments may face failure and under-use due to the fact that insufficient attention is given to the delivery process. These efforts have little chance of succeeding without a tutoring team that has appropriate online tutoring skills necessary to explore and maximise the designed environments. Therefore, the tutoring team is at least as important as the design team. Furthermore, both parties need to be aware of appropriate pedagogical approaches in order to maximise the benefits of tutoring and the use of learning environments by students. More importantly, learners are expected to develop high cognitive skills such as negotiation of meaning, life-long learning, reflective analysis and meta-cognition without first acquiring appropriate learning, information and communication skills.

In fact, learning in online REALs has to be supported by appropriate resources and requires a number of specific skills from both tutor and learners. This need for learner support clearly requires a different approach from conventional tutor and learner skills. Online Learning Support (OLS) could be defined as computer-mediated approaches to support and facilitate learning, using a combination of skills that encompass information and IT expertise, as well as expertise in the educational uses of online learning resources, environments and communication technologies [74].

Therefore, delivering e-learning is not simply a matter of designing pedagogically sound learning environments, integrating these in efficient educational settings (that may even be very traditional) and selecting a tutoring team with subject matter expertise and/or technical skills, but it is also about choosing skilled and motivated educationalists with appropriate pedagogical, information and communication skills that are required to manage and facilitate online learning.

4 Conclusions

Academic learning should be seen from a constructivist viewpoint as a process of acting upon what has been learnt, and reflecting upon that learning and doing, inorder to contextualise the knowledge gained. By acting and reflecting upon the knowledge acquired, learners construct their own views of the world in relation to that new knowledge and put it into a useful context. This differentiates them from the passive learner who soaks up information without applying it and then never knows when it is appropriate to use it [75]. Without a context in which to place what has been learnt, newly acquired knowledge becomes meaningless and irrelevant. Constructivist REALs may therefore be crucial to provide students with learning environments in which they may contextualise the information they are taught, be this within lectures, tutorials or even through explicit e-learning materials. This should enable them to develop a deeper and longer retained knowledge of the subjects under study.

Educationalist and designers need pedagogical models in their practice, rather than mere enunciations of learning epistemologies. These models, although reflecting the philosophy of the learning theories they are rooted in, need to address the pragmatic aspects of teaching in HE institutions. Using pedagogical models that do not consider these constraints may be as damaging for the emerging field of e-learning as not using pedagogical models at all. In fact, the fate of e-learning may become as ephemeral as so many other ICT technological applications in education.

However, using constructivism in online learning is not intuitive to either learners or tutors. Both groups were probably educated in highly objectivist educational systems and are often ill-prepared for the independence, action and interaction required by this epistemology. Successful online learning courses require much more than well-designed environments, motivated tutors and interested learners. Constructivist e-learning requires a set of information, communication and social skills that need to be acquired prior to engaging with the online learning activities. Additionally, and during the delivery process, both tutors and learners need the support of adequate learning resources, designed explicitly according to a constructivist approach. Failing to address these issues may compromise the success of any online learning initiative.

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Problem-Based Learning in an e-Learning Environment: A Case Study at Griffith University School of Medicine

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Summary. Increasing numbers of medical schools in Australia and overseas have moved away from didactic teaching methodologies and embraced problem-based learning (PBL) to improve clinical reasoning skills and communication skills as well as to encourage self-directed lifelong learning. In January 2005, the first cohort of students entered the new MBBS program at the Griffith University School of Medicine, Gold Coast, to embark upon an exciting, fully integrated curriculum using PBL, combining electronic delivery, communication and evaluation systems incorporating cognitive principles that underpin the PBL process. This chapter examines the educational philosophies and design of the e-learning environment underpinning the processes developed to deliver, monitor and evaluate the curriculum. Key initiatives taken to promote student engagement and innovative and distinctive approaches to student learning at Griffith promoted within the conceptual model for the curriculum are (a) Student engagement, (b) Pastoral care, (c) Staff engagement, (d) Monitoring and (e) Curriculum/ Program Review.

1 Introduction

For over 100 years most medical curricula have relied on didactic teaching in disparate subjects such as physiology, microbiology, biochemistry, anatomy, pharmacology, etc. throughout the first half of the training period often referred to as the preclinical years. These subjects were taught and assessed as independent entities with few clinical applications and no exposure to patients. During the last 30 years there has been an increasing

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recognition of the need to improve the clinical reasoning skills, and communication skills as well as to encourage self-directed lifelong learning of medical graduates [1–3]. Consequently, increasing numbers of medical schools in Australia and overseas have moved away from these didactic teaching methodologies and embraced problem-based learning (PBL) to address these improvements.

In January 2005, the first cohort of students entered the new MBBS program at the Griffith University School of Medicine to embark upon an exciting, fully integrated curriculum using PBL. This curriculum combines the latest developments in information technology and state-of-the-art, purpose-built facilities supporting a modern curriculum where students begin their clinical skills activities from the beginning of semester 1 of year 1.

This chapter reviews the theoretical perspectives behind the PBL approach used in this new medical school that is located adjacent to the Gold Coast Hospital at Southport in Queensland, Australia. It will also examine the educational philosophies and design of the e-learning environment underpinning the processes developed to deliver, monitor and evaluate the curriculum.

2 What is PBL?

Problem-based learning (PBL) is a well-described method of interactive learning that has had a marked impact on higher education, especially in medical schools [4–6]. The learning focuses on patient problems as a context for students to acquire problem-solving skills and knowledge about the basic and clinical sciences [7, 8]. Students usually work in small groups, two or three times a week with a tutor who has a role of facilitator rather than a provider of content. The PBL process involves students: discussing possible hypotheses; developing strategies to test the hypotheses; collecting and analysing new information; refining their hypotheses and in doing so determining the gaps in their knowledge and understanding; and developing learning goals to direct their independent learning outside the PBL tutorials [9].

PBL has been used to describe a wide variety of educational methodologies thus compromising attempts to evaluate the evidence base for comparisons of the value of PBL compared with traditional, teacher-centred approaches [4]. PBL has many advocates who emphasise the importance of this teaching/learning method to not only increase the retention of facts and their recall in a clinical situation, but more importantly to develop skills in problem solving and self-directed study skills [7, 10].

However, reviews of the effectiveness of PBL curricula have indicated that PBL does not necessarily make students learn more in the short term, although they may retain more, but PBL has a small but significant effect on clinical reasoning and diagnostic abilities, plus consistent gains in satisfaction [11–13]. In a study of the impact of PBL on medical students at Harvard medical school, Moore et al. [14] reported that students from a PBL curriculum learned in a more reflective manner, preferred active learning and demonstrated greater psychosocial knowledge and more humanistic attitudes than students from a non PBL-based curriculum cohort. Further, these effects were maintained over a decade later [15]. Recently, Schmidt, Vermeulen and Van der Molen [16] reported higher scores in 14 of 18 self-reported professional competencies in 820 graduates of a problem-based medical school.

3 Theoretical Underpinning of the Griffith Medical Curriculum

The cognitive basis to the rationale for using PBL as a core component of a curriculum incorporates activation of prior knowledge, elaboration of learning, including prior knowledge, restructuring of knowledge, learning in context and the use of relevant problems to increase curiosity. In other words, PBL uses, as its underlying pedagogy, constructivism. In the constructivist view of learning, meaning that is constructed by an individual is dependent on the situation itself and the individual's purposes and active construction of meaning [17]. Constructivism recognises that prior experience has an influence on the way phenomena are perceived and interpreted. These authors recognised the importance of active construction of meaning on the part of the learner. Bereiter [18] also emphasised the importance of providing a wide range of mental resources to encourage cognitive growth in students. Thus the new medical curriculum at Griffith University uses constructivism as the underpinning pedagogy for its development and delivery. In addition, it was recognised that, as stressed in the chapter by Nunes and McPherson, technology should empower the learning process and that it is only with a clear sense of the theoretical foundations that underpin assumptions about learning and cognition, that an efficient online learning environment can be appropriately designed. Additionally, and during the delivery process, both tutors and learners need the support of adequate learning resources, designed explicitly according to a constructivist approach. This approach to teaching and learning determined the choice of curriculum that was to be developed at Griffith University.

When federal funding was announced in 2003 for a new medical school for the South East Queensland region, Griffith University's vision for a medical school for its Gold Coast campus came to fruition. With the first cohort of students due to start in January 2005, a decision was made to license a respected, PBL-based curriculum from Flinders University. The clinical scenarios, curriculum documentation and associated resources were used as the framework for the Griffith curriculum. Over a period of almost three years the Flinders curriculum has been reviewed and updated to reflect the latest ideas in management and treatment as well as being redesigned for online delivery. The medical curriculum at Griffith has been carefully planned to encourage integration of teaching and learning so that the scientific basis of normal as well as diseased processes is integrated with the acquisition of clinical skills and understanding of medical law, ethics, professional practice, epidemiology, population and public health as well as community health. A totally new electronic delivery, communication and evaluation system was designed and built to incorporate the underpinning cognitive principles surrounding the PBL cases.

4 School of Medicine Resources Management System (SOMRMS)

In 1995, Griffith University established the Flexible Learning and Access Services (FLAS) as part of an ongoing investment in networked communication technologies for flexible learning. A university-wide learning management system (Blackboard) was implemented in 2001 to manage the delivery of online resources and activities. Since 2003, Griffith has been combining refinements to online enhancement of flexible learning with appropriate digital infrastructure to implement a university wide e-learning strategy that emphasises human-centred systems. Student engagement has been an important priority during this period and continues to be recognised as a vital part of course management and curriculum design initiatives [19].

From the very beginning of the developmental phase of the Griffith medical program, Griffith University devoted considerable efforts to strengthen its initiatives towards human-centred, e-learning and student engagement in curriculum design and course management. Subsequently, the School of Medicine Resources Management System (SOMRMS) was developed by Robert Loudon and other members of the FLAS team in consultation with the academics responsible for the development and delivery of the program. This system is a customised curriculum integration tool developed to support the medical program, via online delivery of various types of learning resources, particularly sequenced PBL case studies and associated resources. The system is more than just a digital repository, and includes a range of functionalities that enables the School of Medicine to manage, maintain, deliver and evaluate the resources and activities on a cohort basis. Among the features of note are:

- Integration of School learning objectives with online evaluations of PBL cases with immediate feedback to the course convenor. The School learning objectives are not revealed to the students until the end of each PBL case. The evaluations allow the course convenor to pick up on curriculum difficulties and make program adjustments (e.g. in lecture content) during each system block
- Online entry, storage and retrieval of student identified learning issues
- The timed and staged release of PBL cases and resources
- Ease of navigation through the screens
- Ability to deliver student and tutor versions of content, without duplicating items unnecessarily (lower and better maintenance)
- Excellent quality control by ensuring changes to content are conveyed to all users
- Seamless integration with the larger online Griffith learning environment
- Robust and extensible design, allowing for extension of e-learning into the clinical environments in later years of the program

Although PBL, and the online delivery of some of its components, is not new, SOMRMS seeks to support the process with a robust and dependable best practice delivery system, and so make maximum use of the possibilities afforded by an online database driven application. Among these are:

- Automatic scheduled release of content to selected tutorial and year groups of students
- System management of learning resources and associations with PBL cases, lectures and workshops
- Storage of relevant metadata for resources, enabling discovery of resources (student resource search function not yet implemented)
- Online delivery of content enabling instant updating and minimising of print costs
- Quality control by ensuring that changes to content are conveyed to all users
- Storage and retrieval of all versions of PBL cases and other content, so students can always access their version of content

– Ability to deliver student and tutor versions of content, without duplicating items unnecessarily (lower and better maintenance)
– Online entry, storage and review of student identified learning issues
– Online, regular collection of evaluations by tutorial groups of their perceptions of their learning against the stated learning objectives, and the immediate availability of these results for review

We believe that the storage of learning objectives and association with PBL cases, and the subsequent use of these to inform students and to provide the basis for regular case evaluations is innovative if not unique amongst online medical PBL case systems. This feature is one of those most enthusiastically endorsed by academics involved with the program.

Technologically the system has been developed with careful regard to the robustness of coding, ability to extend the system even to functionalities not yet identified, integration with the wider LMS and security issues. An overall goal of SOMRMS has been to support student learning by delivering the curriculum as transparently as possible, that is, a system that is reliable, logical, easy to use and timely.

E-learning has been used as a tool to deliver curriculum elements and monitor the curriculum and student progress. It has not replaced regular contact and interaction with teaching staff. As recognised by Oliver and Omari [20], we place heavy emphasis on staff–student contact in curriculum and pastoral care to improve student learning, motivation and satisfaction. This further supports the importance placed by Griffith University on student engagement and this is reflected in the conceptual model presented below.

5 A Conceptual Model for Student-Centred PBL-Based Curriculum in an e-learning Environment

The literature indicates the importance of the learning environment [21, 22], the ease of access to learning resources [23] and well-prepared teachers [24] in improving student learning and satisfaction, as well as the importance of engaging students in quality improvement initiatives [25]. Griffith medical school staff recognised the importance of creating a teaching and learning environment that combined modern pedagogy with initiatives that promote student and staff satisfaction and engagement. Core staff (the year 1 and 2 co-ordinator with assistance from the Senior Lecturer in Medical Education) oversee and co-ordinate all of the curriculum development, e-learning developments, administrative support, staff training, assessment, evaluation and pastoral care, providing for a consistent approach across all teaching blocks of the first two years of the program. This relationship is shown in Fig. 1.

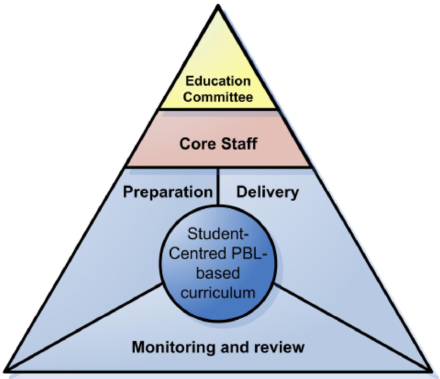

Fig. 1. The relationship of core staff to educational delivery

A conceptual model (Fig. 2) was developed to underpin the student- centred PBL-based curriculum within an e-learning environment.

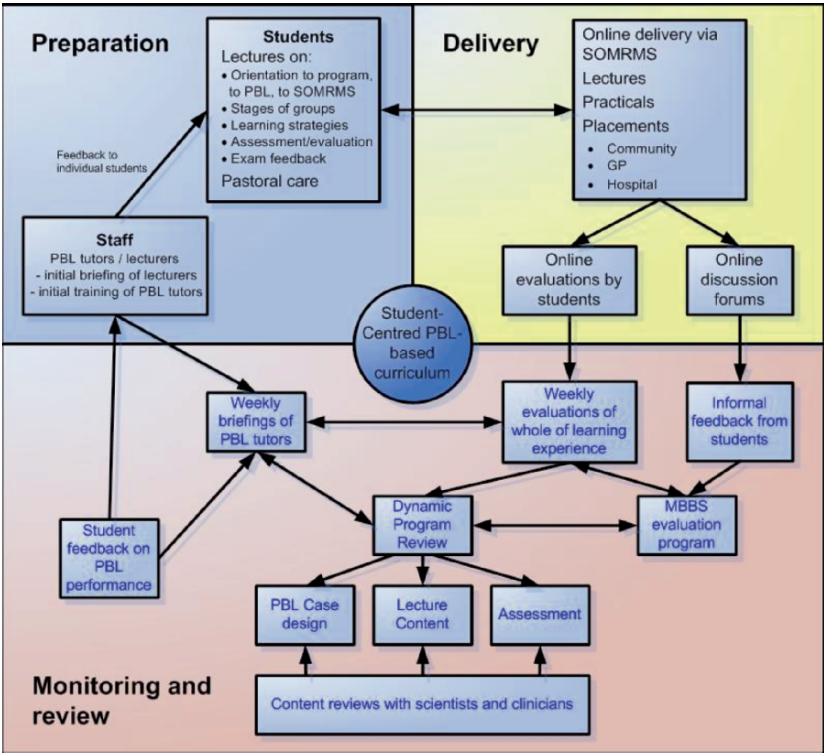

Fig. 2. Conceptual model for student-centred PBL-based curriculum

Key initiatives taken to promote student engagement and innovative and distinctive approaches to student learning at Griffith shown within this model are:

1. Student engagement
2. Pastoral care
3. Staff engagement
4. Monitoring
5. Curriculum/Program Review

5.1 Student Engagement

Students are engaged in the PBL process through (1) good preparation for learning in a new curriculum model, through lectures and interactive workshops (2) feedback through their tutors to weekly case briefings and (3) development of an online system that has been designed so as to emphasise the two important team activities of (a) identifying learning issues and (b) reflecting on the learning process, that is we chose to have them recorded per team not per individual. We recognised the concerns of various researchers regarding the possible equity issues in demanding sophisticated computer skills in using new learning management systems of our first year students [26–28]. Griffith University places heavy emphasis on training of staff and students for e-learning and for providing for equity in access to e-learning. This has been continued in the Griffith medical curriculum where considerable effort has and continues to be expended in preparing first year students in the Griffith medical program for participation in the SOMRMS including surveys of student access to hardware and software requirements plus student representation on various committees within the medical school. We have carried out a questionnaire each year in August, seeking feedback regarding SOMRMS and the Learning@Griffith website and the generally high levels of satisfaction in the surveys indicates that students feel that the online system supports the PBL process well. Computer literacy and attitudes to e-learning continue to be important issues amongst medical students worldwide [28].

5.2 Pastoral Care

One element of the teaching and learning process that receives little recognition in tertiary education, especially in courses utilising e-learning is that of pastoral care. Our approach to student issues has been one largely based on an ‘open door’ policy. This has had several outcomes. Students have had someone to turn to for advice regarding curriculum and personal matters in an atmosphere of confidentiality, trust and understanding. We have offered advice in context and ‘in time’ rather than forcing students to access more generic help from student services which are also available to students if they wish. This has helped to solve many of the issues faced by students in university courses before the issues can develop into irretrievable problems and helped students to focus on their studies. In an environment where students are exposed to multiple academic and clinical staff for short periods of time, the appointment of a year 1 and 2 co-ordinator has provided an element of continuity in not only curriculum matters but also in pastoral care. The emphasis on pastoral care has helped build an atmosphere of team work, confidence and care, respect and understanding within the student community as well as collegiality plus student ownership and satisfaction with the medical course. The success of this approach with the first three cohorts of students at Griffith (80 students in 2005, 125 students in 2006 and 150 students in 2007) has been validated by the course evaluations, informal feedback from staff and students plus positive comments from the recent AMC accreditation report.

5.3 Staff Engagement

Staff are engaged in the PBL process through (1) contextualised training for PBL tutors, (2) student feedback on PBL tutor performance that influences the quality of the tutoring, leading to well facilitated PBL tutorials and improved learning for the students, (3) weekly tutor briefings and (4) online access for the tutors to see what students have recorded as learning issues throughout each week and also what they have recorded in their weekly evaluations. Throughout the first two years of the Griffith medical curriculum, tutors and students are encouraged to use a diagnostic approach to learning. Through this approach, students develop skills in differential diagnosis and clinical reasoning by continually using conceptual frameworks to explain mechanisms responsible for normal and diseased processes. Students are encouraged to use flow diagrams to create concept maps in PBL tutorial discussions and in integrated examinations. This approach, also called ‘reciprocal teaching’ involves the use of cognitive strategies, for example, conceptual frameworks, to facilitate learning and knowledge retention [29, 30]. Novak et al. [30] further suggest that the use of conceptual frameworks to facilitate the development of expert-like knowledge structure may improve the retention of the knowledge structure.

The most frequent issues regarding PBL process that are raised as arguments against PBL are the dominant student, individual quietness and absenteeism or lateness and the greatest hindrance to learning are the dominant student, a disorganised/haphazard tutorial/clinical reasoning process and a superficial study of the problem [31]. An understanding of these issues has guided the development of processes designed to train both students and staff in the medical curriculum at Griffith. We have followed the work of Maudsley [4], Hendry, Ryan and Harris [31] and Trappler [32] in (1) emphasising the role of the tutor as an expert in the process not the content; (2) creating a supportive learning environment; (3) facilitating the group to progress through the problem – questioning, challenging, probing; (4) encouraging all students to be involved; (5) addressing group problems if/when they arise; and (6) giving regular, constructive feedback and thereby providing role models for lifelong learning, team work and development of clinical reasoning skills.

Griffith has developed a staff development program whereby new PBL tutors undergo training in the theory and practice of the PBL process that involves observation of real PBL tutorials (current year 1 and 2 students), hands-on experience in mock and real PBL groups, and careful allocation of student groups so that new tutors are exposed to experienced student groups in order to gain confidence and experience. This is reinforced by weekly debriefing sessions, student evaluation of tutors and tutor evaluation of students. PBL group performances are monitored each week through the weekly debriefing sessions plus the online evaluation system where students complete weekly evaluations of learning objectives, resources, readings, lectures, practicals and clinical skills sessions. This system is accessed by all teaching staff and allows the year 1 and 2 co-ordinator to monitor the progress of the PBL groups and instigate processes to correct any problems that might appear before they develop into more serious issues. These processes usually involve consultation with PBL tutors and discussion at the debriefing sessions about mechanisms to use to deal with the sorts of problems highlighted by Hendry, Ryan and Harris [31] and sometimes might necessitate requests for interviews by the year 1 and 2 co-ordinator with specific students from certain groups. Considerable care is taken in selecting students for their PBL groups each time they are changed (twice per year) in the light of formative feedback from tutors about student performance in the groups and to balance the groups with respect to gender, age, background. Similar care is taken to match the PBL tutor to the student groups.

5.4 Monitoring

5.4.1 Monitoring Student Activities in PBL

Monitoring of student activities in their PBL, individually and as a group, is an important part of the PBL process [6]. As part of the process of implementing PBL as the major instructional method used throughout the first two years of the Griffith medical program, we considered it important to provide formative feedback to students about their performance in their PBL groups as well as to evaluate the performance of the PBL tutors. Students receive detailed feedback from their PBL tutors at the end of each block of teaching (four to 10 weeks). They have a different tutor for each block but remain with the same PBL group for each half year (17 weeks).

Students cannot access the School learning objectives until they have completed the online case evaluation at the end of each week, which includes free-text spaces where issues can be raised and comments made. Much emphasis is placed on the communication back to the students on any issues that are addressed by the School in response to the comments in these evaluations in order to ensure that the students feel that their comments are not a waste of time. Through this process we are quickly able to respond to student and tutor problems.

5.4.2 Monitoring of PBL Tutoring

There are two opportunities each week for informal feedback from students about the PBL tutoring. There are weekly briefing sessions for PBL tutors, during which, time is set aside for discussion of the behaviour of the student groups plus any issues that the tutors raise. In the weekly online evaluations, students are invited to comment on any issues related to their PBL group in addition to other teaching elements in the program.

More formal evaluations of PBL tutor performance are done at the end of each block of teaching. In the absence of an existing suitable instrument for the evaluation of PBL tutoring in the institution, a new questionnaire was designed. This questionnaire is consistent with the university-wide process used for Student Evaluation of Teaching (SET) at Griffith. However, in designing this questionnaire, we had to enunciate a conceptual framework that would support such an evaluation by providing an explicit rationale for all the questions asked [33]. In the process, we developed a framework with three dimensions of PBL tutoring which provides an explicit rationale for our selection of questions. These dimensions are the underpinning cognitive principles of PBL, the roles of the tutor in the PBL process and the stages of the PBL process. Feedback on the range of roles and functions of the tutor is essential for their own professional development and for further development of quality tutorials for the medical program.

5.4.3 Monitoring of Curriculum Elements (Lectures, Practicals, Resources)

The weekly online evaluations include questions asking for specific feedback about lectures, practicals and resources. This feedback is distributed to the relevant teachers to close the feedback loop. A further informal avenue is provided by offering the students an opportunity to provide feedback on any aspect of the course on the discussion board available within the website.

5.5 Curriculum/Program Review

Dynamic program review and development has resulted from being responsive to feedback from staff (at tutor briefings) and students (via weekly PBL evaluations and direct comments to communication boards on SOMRMS). Finally, ongoing review of the content and delivery of the entire medical program for year 1 and year 2 has improved the medical curriculum. In particular, the near-instantaneous feedback gained through the online student evaluations has allowed curriculum changes to be made immediately, ready for implementation for the next cohort of students. This is vastly preferable to postponing such review till a later date when the reasons and circumstances have been forgotten.

This conceptual model for the Griffith medical curriculum addresses the issues that have been identified as underlying the poor implementation of PBL in many educational institutions and have thus compromised its potential [34]. Online evaluation conducted through the SOMRMS as well as formal course evaluation conducted with the Griffith University Institute of Higher Education and a recent accreditation review by the Australian Medical Council have acknowledged the success of the PBL-based curriculum at Griffith. Further, success of the conceptual model for the curriculum and the SOMRMS has been acknowledged by Griffith University through the award of the Griffith University Medal for Excellence in Teaching in Innovation Across the Institution category in 2006.

6 Conclusion

In January 2005, the first cohort of students entered the new MBBS program at the Griffith University School of Medicine, Gold Coast, to embark upon an exciting, fully integrated curriculum using PBL, combining electronic delivery, communication and evaluation systems incorporating the underpinning cognitive principles of the PBL process. The cognitive basis to the rationale for using PBL as a core component of a curriculum incorporates activation of prior knowledge, elaboration of learning, including prior knowledge, restructuring of knowledge, learning in context and the use of relevant problems to increase curiosity. Thus PBL uses, as its underlying pedagogy, constructivism.

E-learning has been used as a tool to deliver curriculum elements and monitor the curriculum and student progress. It has not replaced regular contact and interaction with teaching staff. We place heavy emphasis on staff–student contact in curriculum and pastoral care to improve student learning, motivation and satisfaction. This further supports the importance placed by Griffith University on student engagement. In this Chapter we also present the conceptual model that underpins the PBL-based curriculum in an e-learning environment. In this model, the key initiatives taken to promote student engagement and innovative and distinctive approaches to student learning at Griffith are (a) Student engagement, (b) Pastoral care, (c) Staff engagement, (d) Monitoring and (e) Curriculum/Program Review.

This conceptual model for the Griffith medical curriculum addresses the issues that have been identified as underlying the poor implementation of PBL in many educational institutions and have thus compromised its potential. Online evaluation conducted through the SOMRMS as well as formal course evaluation conducted with the Griffith University Institute of Higher Education and a recent accreditation review by the Australian Medical Council have acknowledged the success of the PBL-based curriculum at Griffith.

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Educational Ontologies Construction for Personalized Learning on the Web

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Summary. Educational resources available on the Web are invaluable learning objects that should not only be accessible, sharable and informative, but also reusable, constructive, and responsive to various pedagogical aspects. Using "Ontology", the knowledge representation core of the Semantic Web, to organize, personalize, and publish learning resources and to discover, generate and compose learning objects has been widely proposed. In response to the diverse education needs, especially learning on the Web, this chapter addresses the issues and methodologies in the design and construction of education ontology and discusses the necessities of such an education ontology that can help retrieving, organizing, and recommending educational resources for personalized learning. Follow a systematic ontology construction approach, the design and implementation of a Personalized Education Ontology (PEOnto) will demonstrate the flexibilities of ontology usages in performing different education tasks as well as enhancing system extensibilities and exchangeabilities.

1 Introduction and Motivation

The Semantic Web "transforms the Web by providing machine-processable and meaningful descriptions of Web resources" [32]. According to the W3C Semantic Web Activity Group statement, the Semantic Web is an extension of the World Wide Web in which information is given well-defined meaning, better enabling computers, and people to work in

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cooperation. Making the Web content machine understandable, allowing agents and applications to access a variety of heterogeneous resources, processing and integrating the content, and producing added value for the user. Data on the Web must be defined and linked in a way that can be used for more effective discovery, automation, integration, and reuse across various applications. To support and reinforce the functionalities that the Semantic Web promises, Semantic Web researchers are working intensively to develop various markup languages to enhance expressivity and retrieval of relevant resources.

Ontologies play a prominent role on the Semantic Web. They make possible the widespread publication of machine understandable data, opening myriad opportunities for automated information processing. Originally, ontology is a systematic account of existence, studies about the nature of existence. For Artificial Intelligent (AI) systems, when the knowledge of a domain is represented in a declarative formalism, the set of objects that can be represented is called the universe of discourse. This set of objects, and the describable relationships among them, are reflected in the representational vocabulary with which a knowledge-based program represents knowledge. Thus, ontology is a "specification of conceptualization" [26]. For Semantic Web services, ontology was designed and built on top of the Semantic Web, which provided a machine-readable semantic framework. However, just a framework is not sufficient to make sharing easier. Data have to be structured and organized in a semantically meaningful way. OWL, a Web Ontology Language, is a means to fulfill this task.

Automatic understanding and processing of resources on the Internet was accomplished through Semantic Web technology [68]. Underlying the promise, it was wrapped up with RDF and XML authored by W3C to represent knowledge to be presented in a universally accessible platform [73]. XML adds "arbitrary structure to documents without saying what these structures mean" while RDF allows "meaning to be specified between objects on the Web and was intentionally designed as a metadata modeling language" [52]. Combining these technologies, it is expected that, in the near future, "discovery, integration, and use/reuse" [32] of Web resources and automation of tasks [36] could be improved. Figure 1 presents the W3C graphical view of the Semantic Web.

Ontology, as a semantic foundation, provides human readable and machine-processable metadata and establishes the technological basis for the semantic processing of Web information and resources. Ontology, as a scheme, is an alternative way to describe the meaning and relationships of terms. This description helps computer systems use terms more easily, and to decide how to convert between terms through a mapping between the ontologies.

Fig. 1. The W3C graphical view of the Semantic Web. www.w3c.rl.ac.uk

1.1 Real World Semantic Web Applications

Ontology describes the concepts and relationships that are important in a particular domain, providing a vocabulary for that domain as well as a computerized specification of the meaning of terms used in the vocabulary. Ontologies range from taxonomies and classifications, database schemas, to fully axiomatized theories. In recent years, ontologies have been adopted in many business and scientific communities as a way to share, reuse, and process domain knowledge, including Knowledge Management, Legal, Heritage Archive, Value Chain Service, Common Sense, and Problem Solving Theory, etc. Ontologies are now central to many applications such as scientific knowledge portals (MeSH, http://www.nlm.nih.gov/mesh; SEE at Elsevier http://wlsevier.com [30]; MBASE http://www.embase.com), information management and integration systems (R-Objects Pepper http://www.r-objects.com/; OntoMat-Annotizer [31]; CARMEN [40], electronic commerce (Amazon http://amazon.com; RosettaNet http://www.rosettanet.org), and semantic Web services (The Web Service Modeling Ontology (WSMO)].

Knowledge Management embedded ontology design into application in digital libraries [1, 65, 67] semantic heterogeneity [14] and multimedia visualization [76]. Heritage Archive did a similar thing to Knowledge Management, the difference was the resources it handled, which was cultural heritage resources [75]. On the other hand, Legal area used ontology to categorize law descriptions and cases [33]. Business field was another area. Value Chain Service used ontology to analyze service bundle, topological connections and business rules [1].

1.2 Semantic Web in the Context of Education

In education, there are two major investments. First, the processes of delivering educational services, e.g., conventional teaching, e-learning, distance learning, Web-based learning etc. Second, the design and development of educational content/resources, e.g., a single content, courses/lessons resources. Given the continuously changing learning environments, the management of different types of learning objects (LOs) from distributed and diverse sources becomes extremely difficult as well as not cost effective. Making the LOs reusable (i.e., obtain high reusability), it is essential that the LO itself must be interoperable, discoverable, and modular. The need to minimize the courseware development cost and to optimize the reusability of available resources leads to the development of learning technologies standardization. Learning technologies standardization helps to increase the integration, usability, and reusability of heterogeneous systems for education. One of the main contributors to this effort is the IEEE Learning Technology Standards Committee (LTSC) (http://ltsc.ieee.org/) Learning Objects Metadata (LOM) working group. The LOM specification (http://ltsc.ieee.org/doc/wg12/LOM_WD4.PDF) describes learning content cataloging information. The European ARIADNE project (http://ariadne.unil.ch) uses LOM for indexing and exploiting its network of interconnected knowledge pools (KPS) and the IMS project (http://www.imsproject.org/metadata) provides the IMS Learning Resources Metadata Specifications which would be incorporated into the IEEE specifications. Apart from the learning metadata definition studies, the description of learner profiles and records (http://edutool.com/papi/), course structure formats, course packaging (http://www.imsproject.org/content), questions and tests interoperability (http://www.imsproject.org/ question), learning architectures and run time environments, have also been investigated with a view to provide recommendations and specifications to enhance interoperability between different educational platforms. Unfortunately, all of the existing educational resources have been developed diversely and independently; they cannot be shared or reused by other systems/users easily. Additionally, for the convenience of independent studies, the definition of LOs takes different forms among these studies that further reduced the interoperability, reusability, extendibility and modulability of the LOs. For definitions and examples of LOs, readers are referred to [6, 47, 55, 64, 66, 72].

Use of LOs will empower online learners in unprecedented ways by enabling them to participate more actively in the contextualization of information [43]. The question here is "How?" In view of this, different types of LOs have emerged. Examples are Atomic LOs, Composite LOs, and Generative LOs. To make these objects usable, models were introduced to encapsulate them. Two examples of these models were SCORM's Content Aggregation Model (ADL 2004b) and Topic Maps [74]. With these standards and types, it became easy to apply LO technology in educational systems. Subsequently, several e-learning systems, such as MERLOT, MIT OpenCourseWare, and WebCT [66], are conformed to these standards and can be made compatible with each other.

Development efforts with LOs lie in metadata design and construction [52]. The lack of instructional design in LOs often resulted in a weak association between LOs and the instructional process. This poor connection would make the LOs difficult to fit in and to be reused. Researchers soon realize the importance of pedagogy issues in LO design [7]. With a common interest to better use, share and process the "meaning" of data to fuse our education growth, a number of "Ontology," the knowledge representation core of the Semantic Web, have been proposed to organize and publish learning resources and to discover, generate, and compose LOs. [29, 34, 80] At the same time, noting the potential dangers of employing technologies in an instructionally unprincipled manner, [62] propose an instructional design theory for LO design and sequencing called Learning Object Design and Sequencing Theory (LODAS) to address the important relations between instructional view and instructional use of LOs regarding a significant amount of reusability across objects.

2 Education Ontology for Semantic Learning Objects

The adoption of Semantic Web Technology into education gave rise to education ontology: ontology that encapsulates the knowledge of an education system and related pedagogical knowledge. A number of ontology names (i.e., types of ontology) can be found in numerous research works and several systems or tools are developed to fulfill particular education purposes. Recent examples of education ontology are: EduOnto – An Ontology for Educational Resources [60]; OntoEdu – Ontology-based Education Grid System for e-Learning [23]; The Gene Ontology (GO); and The OntoGeo (Geography). Educational sites that make use of ontologies include The Gateway to Educational Materials (GEM) and The Open Directory Project (dmoz). OntoWeb (http://www.ontoweb.org/) is an ontology-based portal which serves the academic and industry community about Ontology-based information exchange for knowledge management and electronic commerce. The Open Directory Project (http://dmoz.org/) is a large, comprehensive human-edited directory of the Web that uses Semantic Web technologies and demonstrates the benefits of using an ontology language. It is constructed and maintained by a vast, global community of volunteer editors. This project provides strong foundation as our experimental pool for the ontology construction as well as for validation and evaluation.

Education ontology is yet another step forward beyond LOs. In recent educational technology development, adaptation support to assist in learning is a primary challenge in online educational systems. Education ontology provides a promising solution to this challenge. In an education ontology, educational resources were organized in a "conceptual domain presentation" [3] fashion. Concept-based course sequencing was featured to allow adaptive courseware authoring, concept-based navigation, and searching of courseware [3] and Topic Maps [74], which organized LOs by topics. More importantly, these technologies enable learners to organize the learning materials in their own way. The differences between Topic Maps and Education Ontologies are summarized in Table 1.

Aiming to investigate the current development trend in Education Ontology, especially what approaches are being used to adopt Education Ontology in different education systems, a survey has been conducted that focuses on (1) Discussion on the definition of Education Ontology; (2) The history, current development trend, and problems of education ontology; (3) The strategies/techniques that are being used for the design and development of an education ontology; and (4) Ontology Service Tools that have been developed based on a particular/number of education ontology. Papers for this survey are mainly collected from the ACM Digital Library (http://portal.acm.org) and IEEE Xplore (http://ieeexplore.ieee.org/), while a few are collected on the Web, from the year 2000–2005.

Table 1. Differences between Topic Maps and Ontology

Terminology	
Ontology Terms	Topic Map Terms
Concept of class	Topic class
Instance	Topic
Slot	Association, occurrence
Class hierarchy	Superclass-subclass
Resource	Occurrence, subject identity
Features that only one party has	
Ontology	Topic Map
No link resources, i.e., occurrence, in ontology	No class hierarchies, constraints, inference rules
General classification schema	No provision for checking logical consistency
Provides content for a topic map	Representation of ontologies under specific topics

2.1 Survey Findings

Attracted by the notion of automatic processing by machines and using ontology as a knowledge model to improve the semantic awareness of computers, ontology research within the context of education has become an area of active research in recent years. These researches have mainly addressed the basic principles such as knowledge representation formalisms, techniques and tools of ontology construction and management. The observed survey results and the main research areas in this field are summarized as follows:

2.1.1 Ontology Frameworks

To share the idea of efficient ontology engineering, a number of highly conceptual frameworks have been proposed. To structure and describe the design and functionalities of e-learning systems, Zheng et al. [79] explained the structure and functions of ontologies and proposed THREE ontology frameworks include (1) Shared Domain Ontology, (2) Shared Task Ontology; and (3) Individualized Ontology. On the other hand, an interdisciplinary project framework proposed by the Mediator HAM [42] has been designed around a series of learning activities in controlled settings. Interdisciplinary project ontology is developed to coordinate team work and support standard workflow in a learning context. Kitamura and Mizoguchi [38] proposed an extended device ontology and a conceptual design knowledge framework called Systematization of functional knowledge and its applications to engineering knowledge management through Ontological Engineering. Sekiya et al. [63] presents a knowledge intensive engineering framework (KIEF) with a pluggable metamodel mechanism for integrating design tools using ontologies of modeling elements in conceptual design.

2.1.2 Consensus and Common Interests

Ontology Definitions

Derived from the original definition of ontology in the area of philosophy, the concept of ontology as "A specification of conceptualization" is widely accepted. For more practical or specific, ontology that is regarded as a "logical theory which gave explicit, partial account of a conceptualization" is the most common definition that appeared in a number of studies: [24, 26–29, 36, 41, 52, 56, 58–60, 81, 82].

On the other hand, for the convenience of independent studies, various interpretations of (using) ontology are found such as: ontology is "an axiomatic characterization of the meaning of a logical vocabulary" [8, 82] Ontology is "A huge network of machine-understandable and machine-readable human knowledge." [34]; and ontology is "an agreement about shared conceptualization of a problem domain, entailed by a set of concepts with their definitions and relationships" [42]. Ontology has also been referred to as "a system of fundamental concepts, a system of background knowledge of any knowledge base, explicates the conceptualization of the target world and provides us with a solid foundation on which we can build sharable knowledge bases for wider usability [38]."

Most of the research found in our survey (95%, 131 papers out of total 140 papers) do not explain the details of ontology engineering or implementations. Only the names and simple descriptions about the ontology (i.e., types of ontology) can be found. Those that indeed describe a few details of ontology design and implementation can be found in, for example, Crampes et al. [8] who described a conceptual navigation ontology stored as a resource specified with a DTD written in XML and can be freely downloaded at http://www.site-eerie.ema.fr/~multimedia. Liu and Huang [42] described interdisciplinary project ontology while Williams and Ren [75] described the steps of its agent design and the ways its agents use and learn from ontology, but gave no detailed description about the ontology itself. Gupta et al. [29] developed an ontology service of an educational digital library and provided descriptions on the ontology construction processes with some examples of the ontology service.

Ontology Applications/Types

Researchers commonly agreed/believed that ontology is useful for semantic retrieval, agent communications, and knowledge repository. Ontology that is used to deliver meaningful education services is mainly used for three types of applications (1) searching for the most relevant set of materials which uses ontology for indexing and structuring learning contents [29, 54, 68–70]; (2) knowledge representation and storage (i.e., database schemas) which use ontology for effective and efficient access [9, 13, 15, 35, 42] (3) authoring of learning activities and/or objects [8, 16]. Aroyo and Dicheva [3] used a courseware authoring task ontology to assist the course material authoring process. Other applications include automatic evaluator of students' achievement level [50]; instructional strategies [2]; metadata extraction [37]; system function description [38] for conceptual design and so on.

Concerns regarding the pedagogical, psychological, and cognitive aspects of using e-learning systems are emphasized and widely discussed among these works. While Gruninger and Lee [26] consider that domain knowledge and pedagogical modeling are essential, Liu and Huang [42] consider "An interaction monitoring function and a learning outcomes assessment method" are essential, and are working intensively in the use of ontologies for dynamic Web page authoring [46] and for modeling adaptive instruction [45]. A tutorial agent system (TAS) [44] adopts the ontological representation to design the student model regarding the classification and detection of error types in primary mathematics learning. An instructional ontology that captures the "Instructional semantics" of a virtual or text-book learning resource has also been proposed [71]. StyLe-OLM of OntoAIMS [9] uses a domain ontology to maintain the dialog and to update the user's Short-Term Conceptual State through a dialog agent.

2.2 Problems and Solutions

The survey presented in the last section has shown that ontology is increasingly a topic of active research in education, particularly in handling the diversely distributed LOs. However, there also exist many challenges and obstacles within the ontology construction process. These include the lack of ontology authoring tools and ontology service tools. The following sections highlight several recent techniques and solutions to these problems.

2.2.1 Tools for the Design and Development of Educational Ontologies

Ontology Authoring Tools

In order to speed up the ontology engineering process, ontology authoring tools are designed to create and construct ontologies for educational platforms. KAON is an ontology management framework that includes a comprehensive tool suite allowing easy ontology creation and management and can be freely downloaded from its project Website: http://sourceforge.net/projects/kaon. Another popular ontology framework developed by the Standford Medical Informatics, the Protégé http://protege.stanford.edu/index.html also provides a flexible base for rapid prototyping and application development of ontologies. General ontology for wide applications [4, 21, 22, 46, 77, 78] and specific ontology for targeted areas such as Computer Science [36], Medical and Bioinformatics (http://www.geneontology.org), receive the most attention.

Ontology Service Tools (Mapping, Managing and Visualizing Ontologies)

"Semantic mappings among ontologies" and "semantic correspondences" [11] are two of the prominent issues to be investigated in Semantic Web research. While different terminologies have been used to describe similar or even the same domains, semantic mapping among ontologies was essential to make the ontologies sharable. Mapping of ontologies requires integration according to their "semantic correspondences." Manually specifying the correspondences would be time-consuming and error-prone. Therefore, the development of an ontology mapping tool was critical to realizing the goals of Semantic Web.

The main obstacle of ontological engineering is achieving consensus across a community whose members may have radically different visions of the domain under consideration. Versioning of ontologies is one of the concerns [26]. Multiple versions of ontology make reusability difficult so [57] suggested a detailed management framework to deal with this, from transformation rules to inference support, while proposed to apply "bridge ontology" to relate different ontologies.

With regard to distributed ontologies, GLUE [10, 12] employs machine learning techniques to assist in the ontology mapping process and handle complex mappings between them. To further improve matching accuracy, GLUE incorporates commonsense knowledge and domain constraints into the matching process. Williams & Ren [75] employed DOGGIE agents to address the problem of sharing knowledge with diverse ontologies. These agents rely on using an inference mechanism and machine learning to assist groups of people in locating, translating, and sharing knowledge. However, through mapping of ontologies, networks of ontologies were formed which induced a different type of problem: Ontology sometimes got too big to be extracted. Small and specific sections of ontology may be needed. Bhatt et al. [5] introduced a distributed approach to extract "subontology."

Besides having to deal with the mapping problem, the development of ontology management tools is the next step toward successful functioning of ontology. OntoEditor [4] is one of the kinds which used graph data structure to visualize ontologies. OntoLearn [51] is a software environment which provides tools for ontology learning, ontology validation and ontology management for small- and medium-sized tourism enterprises. Precursors KAON [69] and Protégé (http://protege.stanford.edu/index.html) are relatively popular and being used and discussed in a number of studies including Courseware Watchdog [29], which supports the user in finding and organizing distributed courseware resources.

2.3 Summary

Our survey has shown the growing needs of applying ontologies in education. Researchers find particular interests in the use of ontologies in (1) searching, (2) structuring, and (3) authoring, of educational resources so that more responsive and meaningful education services can be delivered to fulfill dynamically changing and diverse teaching and learning needs/demands. Although numerous works have been done, most of them have not stated or elaborated the details of the required ontology design and/or implementation. Highly conceptual frameworks proposed in previous works have mainly highlighted alternative ways of using as well as interesting applications that use ontology, none of them has shown or evaluated the feasibilities or usefulness, strengths or weaknesses of the required or expected outcomes of the ontologies.

The design and development of ontologies are diversified and take many forms. There is much room for further studies on both ontology service tools and the potential and effective use of ontologies. In the following, we will discuss the process and the construction of an ontology for Personalized Education (PE).

3 Personalized Education and PEOnto

The advent of the Web, Internet computing environment offers great flexibility for supporting various aspects of personal development. From the view point of fostering an information-literate person with the necessary multidisciplinary skills to cater for the anticipated life-long learning, "Personalized Education" (PE) environment offers an ultimate solution for learners to learn in his/her own pace and for his/her specific needs with the consideration of his/her interests and preferences that can potentially strengthen and reinforce learning effectiveness. Education is a highly interactive process that requires active participation of teachers and learners. As teachers are one of the key players in an education environment, the notion of PE emphasizes not only on facilitating learners to learn better via combining different strategies to create a variety of learning experiences, but also considers the teachers' teaching needs in preparing, designing, and managing their instructional packages throughout the instructional design and delivery process. A "Personalized Education" (PE) environment encompasses methods and techniques that can be used to deliver value-added teaching/learning experiences to teachers and learners by exploiting and incorporating Web-based personalization technologies [17, 18]. Viewing personalization in relation to education (teaching and learning) requires an understanding of the challenges in articulating various teaching/education pedagogies and individual learning processes. To conceptualize as well as to realize the notion of PE, we have proposed a PE conceptual framework [17, 18] and the design and implementation of an agent-based architecture of a Personalized Education System (PES) [19, 20] that supports personalized learning activities. Central to the design of PES which serves to support the delivery of a range of personalized educational services is Personalized Education Ontology or PEOnto. This is an ontological representation of a (computerized) Web-based educational environment that takes into account of the stakeholders, the subject domain, the learning content, the curriculum, the pedagogy, and the software agents that execute the system functions, etc. PEOnto consists of *five* interrelated educational ontologies (1) People Ontology which represents the key players with their essential attributes, (2) Subject Domain (Language) Ontology which represents the general knowledge in a particular domain,

(3) Curriculum Ontology which represents the goals stage, the possible learning path and the corresponding objectives/tasks, (4) Pedagogy Ontology which represents the methodologies/strategies of organizing and sequencing education resources and its relations to various learning activities and tasks, and, finally, (5) the PEA Ontology that represents the roles and responsibilities of different learning assistances (software agents) should perform. Figure 2 illustrates the relations of these ontologies within the PEOnto framework.

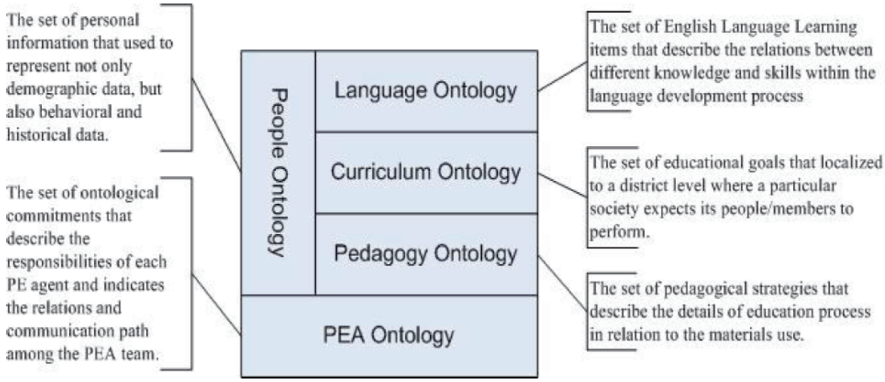

Fig. 2. The PEOnto framework

An ontological representation of an educational environment including people, processes, activities (interactions), and the content (i.e., LOs) is one possible way to deal with the interoperability and reusability of LOs through providing a semantic infrastructure that will explicitly declare the semantics and forms of concepts used in labeling LOs. This section will describe the methodology of developing PEOnto in order to address the psycho-educational aspects and instructional design principles for the use of semantic Web technologies in PE area, PEOnto aims to describe and organize the (hypermedia) educational learning resources in a systematic way that allow teachers and students to search, evaluate, acquire, and use in a more effective and efficient way.

3.1 Construction of PE Ontology: Use of Design Tools and Standards

Since we require high metamodeling facilities of the RDF Schema (e.g., defining classes of classes, or attaching properties to classes), we use OWL

Full to examine the possible representation alternatives. In addition, an ontology editor, Protégé, and an ontology parser, Jena, have been selected as the development tools, respectively, mainly because they are currently the most popular ontology tools and can be shared in the open domain.

Protégé is a free, open source ontology editor and knowledge-base framework, supported by the Stanford Medical Informatics and is used for the design and modeling of the PEOnto. Protégé provides a suite of tools to construct domain models and knowledge-based applications with ontologies. At its core, Protégé implements a rich set of knowledge-modeling structures and actions that support the creation, visualization, and manipulation of ontologies in various representation formats. Protégé can be customized to provide domain-friendly support for creating knowledge models and entering data. Further, Protégé can be extended by way of a plug-in architecture and a Java-based Application Programming Interface (API) for building knowledge-based tools and applications. For more details, please refer to the Protégé Web site (http://protege.stanford.edu/index.html).

Jena, (http://jena.sourceforge.net/), is a Java Toolkit for manipulating RDF models from HP Labs Bristol. It is a powerful, flexible and easy Java based toolkit for developing applications for the Semantic Web. It provides ARP-RDF/XML Parser, Persistence databases checking, Ontology Subsystem that have APIs for managing RDF, RDFs, OWL, Reasoning Subsystem that have inference capabilities for RDFs and OWL.

PEOnto is composed of FIVE core ontologies and each of them represents a specific stage throughout the personalization delivery cycle. In order to make this ontology usable, sharable, and extensible for other interested researchers, all classes and property elements are conformed to the prevailing Standards that include IEEE LOM in Pedagogy Ontology for content descriptions and annotations, IMS LIS in People Ontology for user profiling and profile constructions, and IMS RDCEO in Pedagogy Ontology for competence descriptions and evaluations. Also conforming to the W3C OWL specification, the PEOnto specification will be released with a control document using W3C OWL Schema Language (i.e., an OWL file) and not with a document type description (DTD) due to its greater flexibility and precision. Since the volume of PEOnto specification is quite large, the PEOnto owl files are made available on the Web for download: http://peonto.cityu.edu.hk/index.jsp.

3.2 Construction Methodology

According to [25], ontology is a formal explicit specification of a shared conceptualization that can be communicated between people and application systems. The design goal of PEOnto is to share definition of education entities and their relation in a standardized format. For instance, hypermedia educational learning resources are related to other education entities, such as curriculum, subject, topic, and pedagogy. Since there are many types of learning resources gathered, analyzed, and recommended through machines (i.e., systems or agents), we need a flexible way to represent various types of existing learning resource and to support new types of learning resource. Such knowledge representation can only be achieved by defining metadata for the learning resources. Hence, the linkage between learning resources and PEOnto vocabulary items provides precise and meaningful descriptions of the LO and can potentially benefit future implementation of the LO.

Here, we adopt the paradigm of balanced cooperative modeling [53] for the construction of ontologies for PE. Also, based on the Ontology Learning Framework proposed by Maedche & Staab [49], the construction of PEOnto has gone through the FIVE iterative stages. These include (1) Import and Reuse existing ontologies, (2) extract the major parts of the target ontology, (3) adjust the ontology to its prime purpose, (4) refine the given domain ontology and complete the ontology at a fine granularity, and finally (5) apply the ontology to the target application as a measure for validating the resulting ontology. The purpose of our work is not only to reduce the duplication of effort involved in building an ontology from scratch by using the existing vocabulary, but also to establish a mechanism for allowing differing vocabularies to be mapped onto the ontology in order to enhance the LO metadata descriptions as well as its reusability and extendibility for personalization use in education.

3.2.1 Import and Reuse Existing Ontologies

To make the PEOnto more attractive to other developers, it was important to study the presentation, collection, and extraction from the useful/related work through the ontology repositories such as the Protégé Projects, DAML the DARPA Agent Markup Language Homepage, Open Directory Project and Ontologies for Education. To understand the existing available ontology design, the DAML group Library and Protégé Ontologies Library provide different ontologies contributed from many researchers who are interested in the studies/development of Semantic Web or related applications. The Open Directory Project demonstrates a clear expected result set to understand the real world ontology-driven application. The Ontologies for Education provides a number of related research papers and is categorized by a simple ontology to understand the research interests and trend of the development of education ontology. ELENA project has developed a service-oriented architecture for personalization services on the Education Semantic Web which highlighted three common education features of recommendation, annotation, and searching for education resources. Figure 3 shows the mechanism of integrating two ontologies.

```
<?xml version="1.0"?>
<rdf:RDF
   xmlns="http://peonto.cityu.edu.hk/Curriculum.owl#"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
   xmlns:lang=" http://peonto.cityu.edu.hk/Language.owl#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
   xmlns:owl="http://www.w3.org/2002/07/owl#"
  xml:base=" http://peonto.cityu.edu.hk/Curriculum.owl">
<owl:Ontology rdf:about="">
<owl:imports rdf:resource=" http://peonto.cityu.edu.hk/Language.owl"/>
</owl:Ontology>
<owl:Ontology rdf:about="http://www.w3.org/2002/07/owl"/>
<owl:Class rdf:ID="Curriculum">
   <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
   >The attainment of a set of educational goals. The set of total learning experiences through which students
learn.</rdfs:comment>
   <rdfs:subClassOf>
     <owl:Restriction>
       <owl:allValuesFrom rdf:resource="#Goal"/>
       <owl:onProperty rdf:resource="#hasGoals"/>
     </owl:Restriction>
   </rdfs:subClassOf>
   <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
 </owl:Class>
```

Fig. 3. The Import mechanism for the integration of two ontologies

3.2.2 Extract the Major Parts of the Target Ontology

All ontology has its own prime goals for a particular application that hardly fulfills other applications needs. To enhance the interoperability and reusability of ontologies, we can simply extract the major parts of the selected ontology and extend the required classes and attributes of such classes for the expected implementation. In our case, the PEOnto is expected to provide meaningful language education descriptions for personalized learning.

Similar to EduOnto vocabulary and GEM (Gateway to twenty-first century Skills) controlled vocabularies, we have included in the Curriculum

Ontology (a) A Level Element that is used to designate the intended level of learners or trainees in a formal educational system, (b) A Mediator Element that describes an intermediary which mediates between the ultimate beneficiary of the resource and resource itself, (c) A Subject Element, and (d) A Teaching Methods Element. These elements together incorporate all the essential vocabulary items as attributes for the identification of curriculum related resources. The following illustrates these elements in more detail.

Level Element. Words or phrases used to designate the intended level of learners or trainees in a formal educational system include Grade: 1, 2, 3, 4, 5, 6; Key stage: 1, 2, 3, 4; and Educational Level: Preschool Education, Elementary Education, Secondary Education

Mediator Element. Words or phrases that describe an intermediary that mediates between the ultimate beneficiary of the resource and resource itself. Instance: Administrators, Curriculum Supervisors, Elementary School Teachers, Librarians, Parents, Secondary School Teachers, Students, and Teachers have been used. This set of elements will be used for the system (i.e., PEAs) to identify the user role as well as his/her privileges/access rights.

The *Subject Elements* are incorporated into the Language and Curriculum Ontology that not only represent the structure of a particular subject domain, but more precisely describe the relations between subject domain items and curriculum goals (i.e., domain (knowledge) items that fulfill education goals in a systematic/organized way.

The *Teaching Method Elements* are incorporated into the Pedagogy Ontology that not only view different learning activities as teaching methods, but emphasize the pedagogical approach in relation to the design of the learning activities (i.e., pedagogical/instructional principles) as well as the procedures of conducting such activities.

3.2.3 Adjust the Ontology to its Prime Purpose

Knowing and understanding the user are the key elements in Personalization. Hence, a precise prescription/description/representation of a user must be obtained. While the People Ontology in other application domains mainly shows personal information, the People Ontology (PeOnto) extends the idea of the Project ELENA (http://www.elena-project.org/en/index.asp?p=1-1) in facilitating the construction of segment knowledge from profiles and conforms to the IMS LIP. PeOnto in PE is used for describing the structure of school education, people, schools, and the activities performed between them. More significantly, the People Ontology represents not only individual users' demographic information, but also observed knowledge from users' behaviors to facilitate dynamic construction and monitoring of ontology-based user profiles as well as user models. Such models or profiles can then be used to adapt the instruction strategies (sequence of LOs) with regards to learner characteristics, to track learner's learning activities and interactions with the learning materials, to analyze their performances, to identify needs or interests and to evaluate learner's psychological profile and learning style. According to the ELENA project [39], different aspects of a user can be identified by different user profile fragments. To fully exploit the usage of the profile knowledge, by integrating the multiple ontologies, it enables us to precisely reflect the user status as well as identify the usage patterns (i.e., explain/ understand the meaning behind the usage results).

3.2.4 Refine the Given Domain Ontology and Complete the Ontology at a Fine Granularity

Ontology construction is an iterative process. To refine the given domain ontology and complete the ontology at a fine granularity, this process consists of five major steps (1) Define scope of represented domain; (2) Identify classes/entities in the domain; (3) Define properties of classes; (4) Define restriction on properties of classes; and (5) Create instances of classes. Through these steps, we can annotate each education entity by identifying its attributes and its relation with other entities iteratively.

Define Scope of Represented Domain

The first step of building ontology is to define the scope of the represented domain, so that similar classes can be grouped under the same domain. Classes that are closely related to each other should be grouped in the same domain, so that they can be shared within the same domain. In order to create a personalized experience, a general Personalization System must perform several distinct tasks (1) Identify the user; (2) Store and update user information; (3) Learn and identify the user preferences, needs and interests; and (4) Provide and recommend specific personalized services. In summary, personalization techniques serve to enable the system to identify the user, understand the user, and adjust their personal memory of the user according to the user's changing needs. Thus, the PEOnto is a description of the concepts and relationships in English language teaching and learning and use different knowledge clusters or ontologies to link "People →Subject Domain Knowledge →Pedagogy →Context →Content" together.

Identify Classes/Entities in the Domain

After defining the scope for a domain, classes can be identified by writing down the "noun" object inside a complex concept. Then, classes with common characteristics can be grouped under a parent class. All the common properties can be inherited from the parent class to the subclass. After organizing classes, a class hierarchy can be formed. In Fig. 4, the class hierarchy is visualized in Protégé editor.

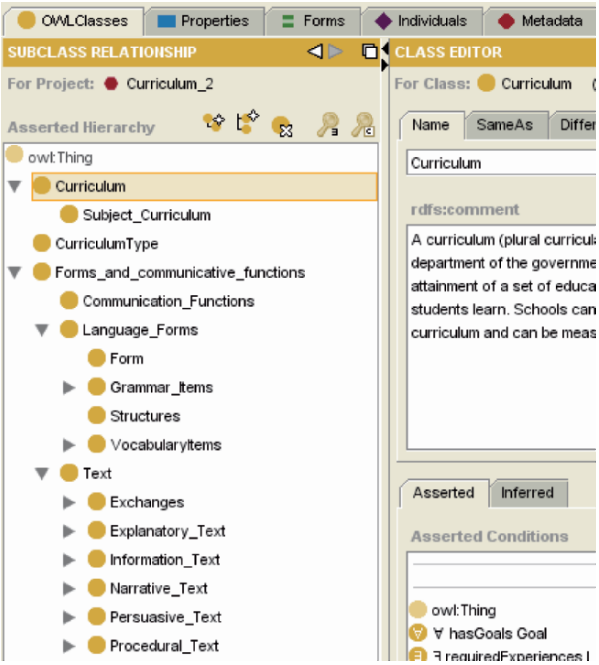

Fig. 4. Classes of a domain

Define Properties of Classes

Inside a class, object properties can be identified by writing down the "verb" describing the relationship between other classes. Data properties can be identified by the classes' attributes, such as class name and description (Fig. 5).

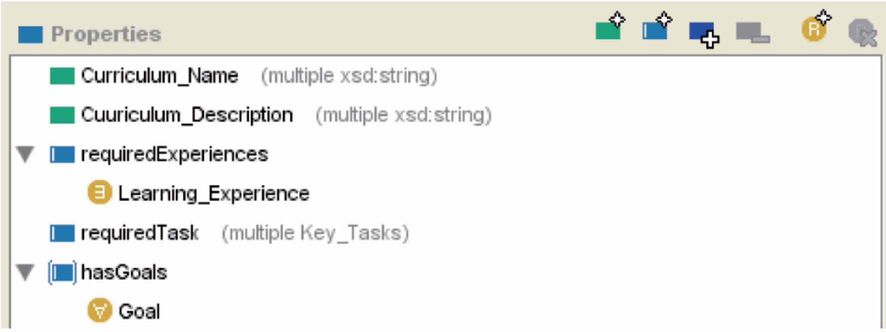

Fig. 5. Data property and object property of a Class

Define Restriction on Properties of Classes

Some properties may have restriction on what kinds of values are required. Restriction can be applied on the properties to further limit the value a class can have (Fig. 6)

Fig. 6. Property restrictions

Create Instances of Class

Classes can only represent the general concept, not the actual metadata itself. Therefore, instances data are used to represent actual data. Figure 7 shows the create instance input form and Fig. 8 shows the generated OWL description of the instance.

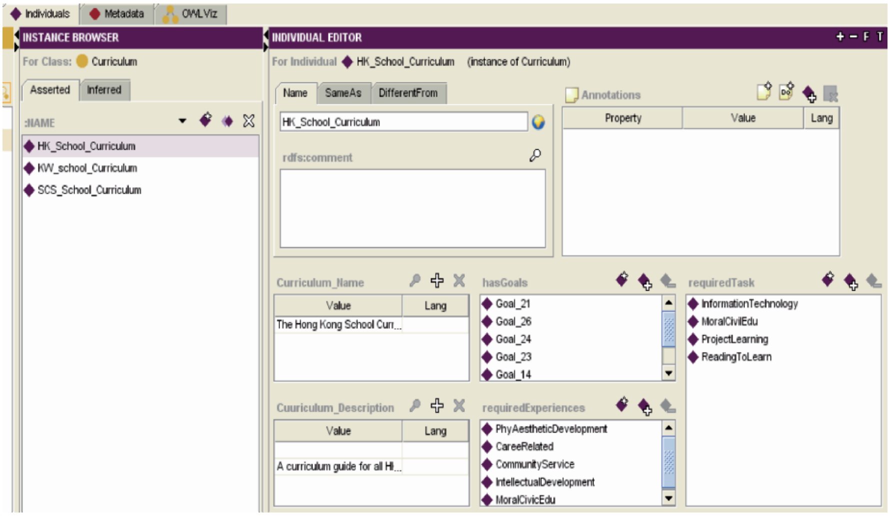

Fig. 7. Create instance input form

```
<Stories rdf:ID="Stories_5">
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >Pirate's Treasure</rdfs:comment>
  <Text_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >A pirate in Jimmy's dream tells him where to find buried treasure.</Text_Description>
  <Text_URL rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >http://www.magickeys.com/books/pirate/index.html</Text_URL>
  <Knowledge_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >Give expression to imaginative ideas</Knowledge_Description>
  <Knowledge_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >treasure, pirate, deeper, higher, deepest, highest</Knowledge_related_term>
 </Stories>
 <Stories rdf:ID="Stories_4">
  <Text_URL rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >http://www.magickeys.com/books/witchstw/index.html</Text_URL>
  <Knowledge_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >Recognize some obvious features of English</Knowledge_Description>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >The Witch's Stew</rdfs:comment>
  <Knowledge_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >witch, mean, magical stew, ingredients</Knowledge_related_term>
  <Text_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >The Witch's Stew: Help the witch choose which ingredients will change her into a friendly
fairy.
  </Text_Description>
 </Stories>
<Songs rdf:ID="Songs_1">
  <Text_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >A song of seasons</Text_Description>
  <Knowledge_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >describe the seasons</Knowledge_Description>
  <Text_URL rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >http://www.songsforteaching.com/sarajordan/differentseasons.htm</Text_URL>
  <Knowledge_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >spring, summer, autumn, winter</Knowledge_related_term>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >Blowing in the wind</rdfs:comment>
  <Knowledge_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >concepts</Knowledge_Description>
 </Songs>
 <Rules rdf:ID="Rules_2">
  <Text_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >library rules</Text_Description>
  <Knowledge_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >knowing the rules of a library</Knowledge_Description>
  <Text_URL rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >http://www.ift.edu.mo/ift_library/lib_rules.htm</Text_URL>
  <Knowledge_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >admittance, library loans, book drops, conduct</Knowledge_related_term>
 </Rules>
<Rules rdf:ID="Rules_3">
  <Knowledge_related_term rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >permitted, discouraged, allowed, not allowed</Knowledge_related_term>
  <Text_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >Conduct rules for library use</Text_Description>
  <Text_URL rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >http://www.ulib.csuohio.edu/policies/conduct.shtml</Text_URL>
  <Knowledge_Description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
  >follow the regulations</Knowledge_Description>
 </Rules>
```

Fig. 8. The OWL instance description of PEOnto

4 PEOnto Applications

Ontology learning should be embedded in a process-oriented view [48]. And the vocabulary needs to be tested with LO designers, educators, and learners [61]. The goal of fully automatic ontology construction and LO annotation remains to be a long-term goal. In order to validate and refine PEOnto and the vocabulary needed for PE, an ontology-driven Personalized Instruction Planner (PIP) has been designed and implemented to facilitate teachers during the instructional design process. Ontology can be used to provide machine processable and meaningful descriptions of educational resources as LOs for better automation information retrieval.

While the teacher is preparing teaching/instructional materials, he/she has in mind specific ways of how a student would make use of the material in learning. Hence, materials embedded in the instruction plan constitute an explicit or implicit pedagogical model. Therefore, it is very difficult to identify and reuse single-type LOs between different approaches as if they are relevant or with the same objectives. For examples, given a JPEG image of different kinds of animals in a forest, such an image can be used for a task-based approach of teaching vocabulary items, a communicative/theme-based approach of using the vocabulary items, and/or a project-based approach of showing relevant collected data. The PE environment (i.e., PES) introduces exciting potential for education, including new approaches to knowledge creation and new ways of learning [17–20]. PIP offers personalized teaching tools to accomplish various teaching tasks (e.g., authoring teaching materials, instruction planning, and teaching schedules etc).Through PIP, a new innovative E-pedagogy can be highlighted (e.g., multiple and dynamic instructions that synchronize various learning approaches). Three particular tasks will be accomplished in PIP. Task 1: Personalization Search – Retrieve personalized search results in respect to the user's profile. Task 2: Personalized Instruction Design – Organize and structure instruction plan according to school-based curriculum or teaching preferences. Task 3: Generating PE LOM resources – Incorporate educational vocabulary items (i.e., PEOnto) to label and annotate PE resources as LOM for improved interoperability and reusability. PE agents in PIP are ontology-driven agents that offer personalized educational services such as (1) identify and extract educational resources from the Web; (2) classify and organize retrieved resources for personalized planner; and (3) annotate and generate descriptive LOs for the development of PE as well as other applications. Figure 9 illustrated the workflow and the duties of the PEAs.

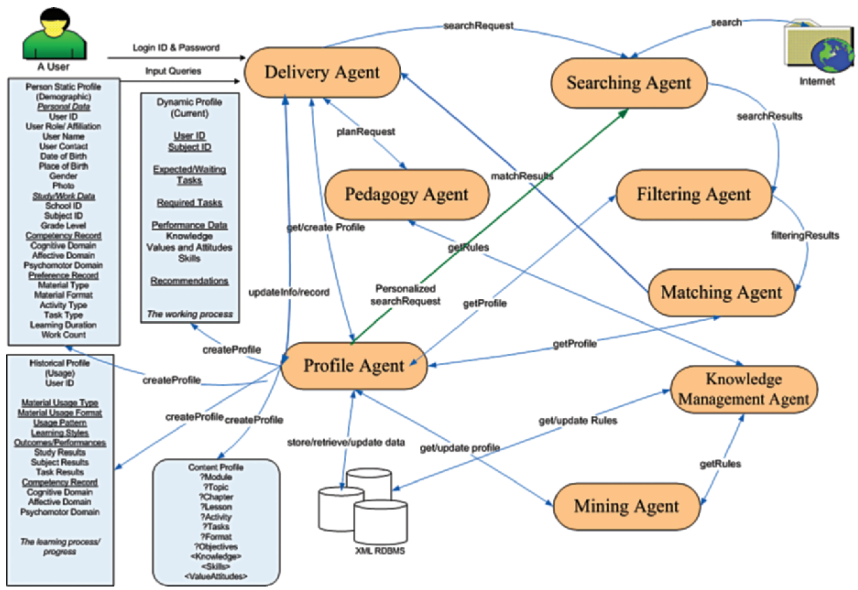

Fig. 9. The workflow and duties of the PEAs

As the ontology schema has been designed through Protégé, the educational information, such as subject, key task, learning experience, module and topic, can be annotated according to ontology schema. As teachers do not have knowledge on ontology language such as RDF or OWL, it is not possible for teachers to annotate their educational materials manually (i.e., provide metadata description). PIP can be viewed as an annotation tool as well as a Web-based ontology editor (there is not any Web-based ontology editor) for teachers to strengthen/enhance their teaching effectiveness through a common, sharable infrastructure. To exploit and demonstrate the integration of the PEOnto and the PIP, in the following, we will explain the PIP features and the use PIP in several PE tasks. Figure 10 shows the interface of the PIP and its key features.

To support and provide personalized instruction planning, five main features have been incorporated in the PIP:

(1) *Administrative functions*. Administrative functions are restricted to PIP administrator, since these functions can change the ontology schema, and hence affect all ontology data stored in PIP.

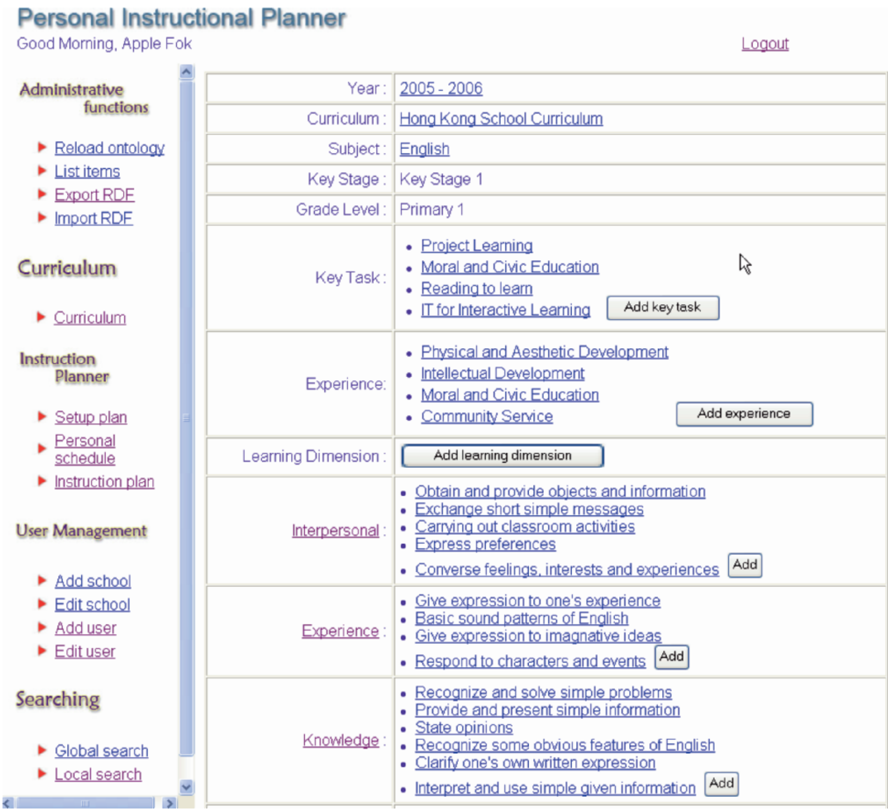

Fig. 10. The interface of PIP key features

(2) *Design or create a curriculum based on the PEOnto*. Our current implementation of PIP is focused on English language learning in Primary school education. Loading ontology schema into PIP implies that the Hong Kong (English) School Curriculum has been inputted by PIP administrator because the Curriculum Ontology of PEOnto has been constructed based on the Hong Kong English Education School Curriculum in the previous stages. This not only helps saving school administration efforts in design or reuse of a school-based curriculum, but also helps create new cases or instances more easily. Schools can simply copy the Hong Kong School Curriculum for modification and does not need to input all items from scratch. Figure 11 shows the basic elements of a general curriculum design.

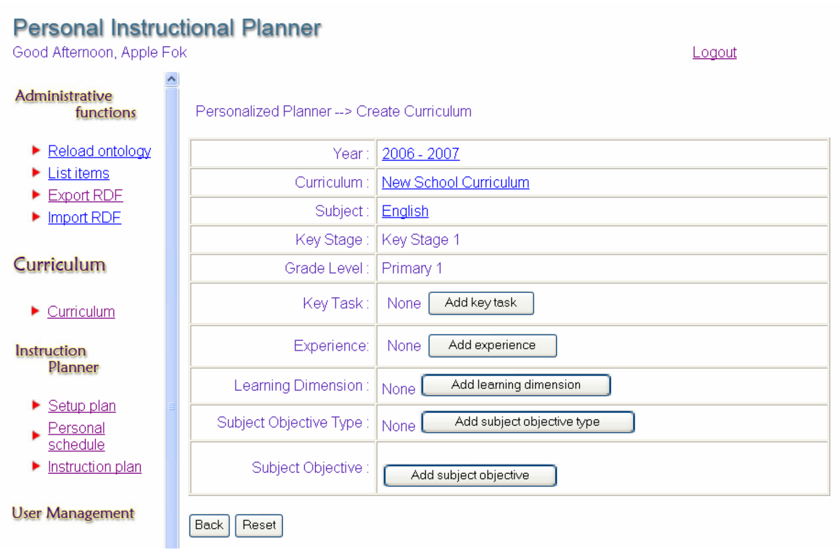

Fig. 11. The basic elements of a general curriculum design

(3) *Design or create instruction plans based on the PEOnto*. To facilitate teachers in the instruction design process which can be guided by different instruction principles, based on the PedaOnto, a form like instruction plan template has been designed. While teachers are designing his/her instruction plan, s/he only needs to fill in the template and the data would be stored and annotated for further manipulations. Figure 12 shows two different instruction plan styles in PIP.

(4) *Maintain user profile* (*Demographic Information*). Based on the People Ontology, the “User Management” is not only used to update and maintain the user profiles, but more importantly, it enables the relations between school–teachers-curriculum. Based on the relations between school and teachers, the system can automatically generate the corresponding curriculum and instruction design plan to the teachers. And different access rights will also be granted.

(5) Search LOs from the Internet (Global Search) or the PIP (Local Search): The Global Search function allows teachers to search for educational materials on the Web. Teachers can input search keywords through the global search user interface (Fig. 13).

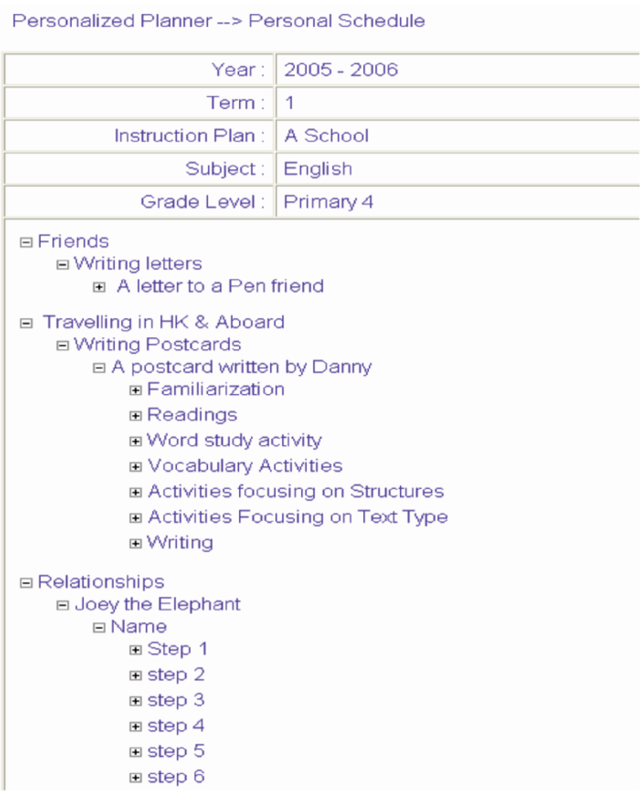

Fig. 12. Two different instruction plan styles

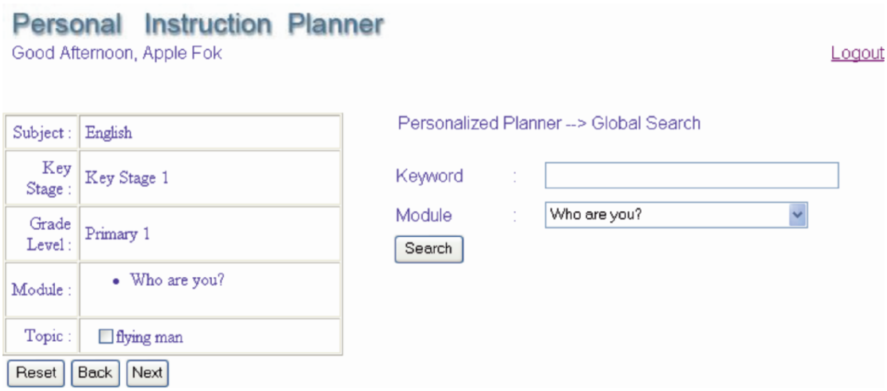

Fig. 13. Global search in PIP

A list of educational materials will be retrieved from the Web. The teacher can select relevant materials to add to the instruction plan (Fig. 14). Incorporated with different designed filters (i.e., different filtering mechanisms), high relevant result lists will be generated. Using the queries generator in PIP, it will generate/ extend user queries by adding the keywords.

After getting the retrieved lists from the global search engine, teachers can directly select and assign the resources to a particular instruction plan easily (Fig. 14) and these resources will be automatically annotated with corresponding description in the PIP. This record will be used for various mining purposes so as to perform recommendations, filtering and classification services.

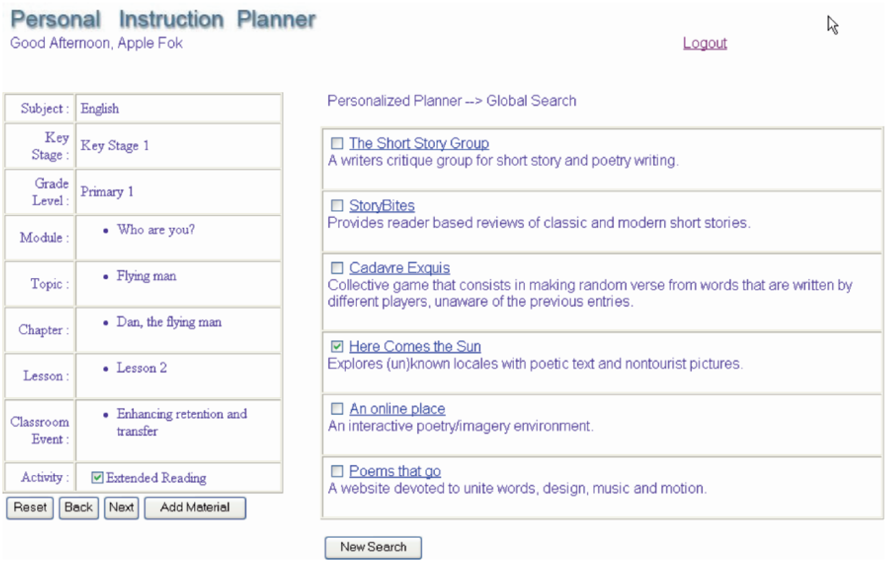

Fig. 14. Select suitable material for a particular learning activity/task

The Local Search function enables teachers to search for annotated LOs in Instruction Plans. Teachers can search for LOs in particular module, topic, lesson, learning activity or learning task. Figure 15 shows the search request based on Modules. Teacher can select item(s) by ticking the corresponding checkbox and then search for LOs by clicking the Search button.

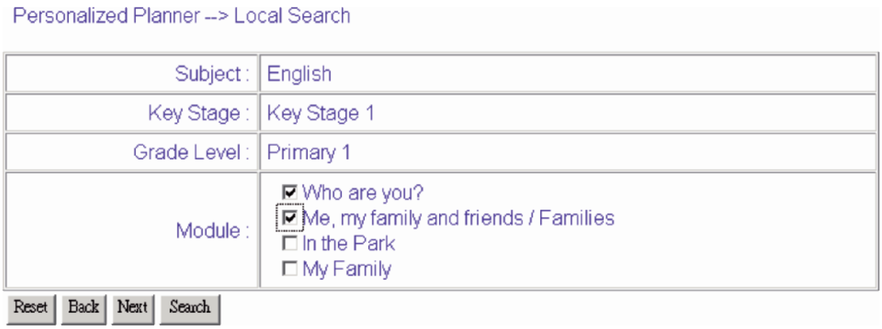

Fig. 15. Search for related learning objects in modules

The design and prototyping of PIP has demonstrated the applicability and usage of PEOnto to support several typical teaching or learning tasks. The development and refinement of PEOnto is a continuing and evolving process, PIP serves to highlight the possible future extension of PEOnto.

5 Conclusion

Using technologies to teach or learn nowadays is inescapable. To insure teaching quality, teachers are facing four main challenges (1) producing and annotating digitalized educational resources; (2) incorporating digital learning resources with appropriate pedagogies; (3) modifying, reusing, or improving existing educational resources effectively; and (4) storing, retrieving and sharing educational resources as well as teaching experiences efficiently. As tools are evolving rapidly to accomplish diverse personal demands, teachers have started to learn how to leave one's own paradigm of the educational process and face the challenges of new, complex, and threatening concepts that serve the purpose of collecting information, creating knowledge units, eliciting knowledge, repackaging knowledge, and finally delivering it in the most effective method possible. The general assumption of our work is based on the beliefs that teachers are capable of designing, selecting, organizing, and evaluating various educational resources independently for a particular teaching task. We believe the quality of each teaching material or resource is assured under the teachers' professional judgments. However, to eliminate the problem of mismatch between individual teacher's needs and resources required, collaboration between teachers is essential. Hence, teachers' teaching styles and experiences can be shown and shared through the use of the PIP. PIP will automatically generate annotated resources as semantic-driven LOs that can be reused more flexibly and accurately. PIP provides the test-bed for teachers to experience not only the potential values of using PE technology, but also the great invaluable experiences of integrating technology with the curriculum, the desired learning for students. In this chapter, we introduce and demonstrate a feasible implementation of the Personalized Instruction Planner to facilitate teachers to collaborate in using varied teaching/instruction techniques to design lessons or thematic units. The beauty of using an ontology-driven approach in PIP is sets of theoretical vocabulary items can be expressively described with closely related educational goals and strategies. Static metadata of LOs can be semantically transmits to offer meaningful personalization services in education. PIP allows sharable, reusable, and extensible education resources (the PE LOs), instructional presentation methods, and activities and evaluation projects to be searched and indexed for PE. Collaboration can benefit both teachers and students. The construction of PEOnto (an education ontology for PE), that underpins the development of the PES and its subsystem Personalized Instructional Planner (PIP), serves to help realize our education and research goal – personalized learning for whole-person development.

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Sequencing in Web-Based Education: Approaches, Standards and Future Trends

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Summary. Web-based education (WBE) has seen in recent years a significant increase both in its functionality as well as possible scenarios. After a first stage in which these systems offered mainly content management and course management capabilities, systems now offer solutions that cover pedagogical aspects such as activity sequencing. This chapter presents several approaches to the problem of adaptive sequencing. They are representative of the main initiatives for defining sequences of learning units that can be adapted to different users, with different capabilities and needs. All of them have some graphical background, but they focus on different issues use of well-known tools, use of simple metaphors like graphs, etc. The main two initiatives of standardization related to the sequencing problem (IMS Simple Sequencing and IMS Learning Design) are also examined. Finally, two approaches to social sequencing, an emerging trend inspired by the behaviour of social insects, are depicted.

1 Introduction

Web-based education (WBE) has seen in recent years a significant increase both in its functionality as well as possible scenarios. e-Learning systems are now present in an ever growing number of companies as well as educational institutions of all levels. After a first stage in which these systems offered mainly content management and course management

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capabilities, systems now offer solutions that cover pedagogical aspects such as activity sequencing. In this context, a learning activity may be described as an instructional event or events embedded in a content resource, or as an aggregation of activities that eventually resolve to discreet content resources with their contained instructional events [1].

When users of an e-learning platform are simply given access to a set of documents for each course, there is a high risk of being “lost in cyberspace” [2]. As important as having access to the proper documents, course activities and how they are organized within a course have a direct impact on the overall effect of the learning experience. Adaptive Hypermedia is a research area that focuses on how hypermedia can be changed according to the user needs. When applied to e-learning, these techniques are generally known as “personalized learning” or “adaptive educational hypermedia”. The idea is to customize learning material and activities and provide a personal environment for each learning [3]. This means adapting the learning content, its sequencing, and maybe more aspects of the learning experience [4].

The problem of adaptive sequencing is that of, given a set of learning activities, finding the best sequence for a particular student. There are students that prefer top-down approaches, that will learn more if general explanations are given first. Other students would rather take a bottom-up, starting with examples and abstracting general principles from them. Some learners will catch some concepts earlier, while others will take more time. The former will benefit from short sequences that do not bore them once they have learnt what they wanted to, and the latter will need a longer sequence (maybe with loops that repeat some of the activities).

This chapter presents several approaches to the problem of adaptive sequencing. They are representative of the main initiatives for defining sequences of learning units that can be adapted to different users, with different capabilities and needs. All of them have some graphical background, but they focus on different issues of the questions. Some give more importance to the use of tools that are known to the software and Web engineering community (Sect. 2). Others give preference to the use of simple graph metaphors that make it easier to define a path along the activities according to some rules (Sect. 3). Finally, in Sect. 4 an approach is presented in which the sequence of activities is not selected deterministically but stochastically. Although this leaves little space for individual adaptation at first, interesting results are obtained when swarm intelligence techniques are used, as explained in Sect. 6.1. All these approaches present some common characteristics (e.g. many use some kind of hierarchy), and all of them have some special characteristic (e.g. the functionality of UML-Guide user model, Sect. 2.1) or inspiration (e.g. the focus on reusability of sequencing graphs, Sect. 3.2) that makes them unique, and this is clearly explained when it is relevant.

There has been a big interest in the last few years for achieving some degree of standardization in the e-learning field. The problem of sequencing learning activities has been the subject of some initiatives, and they are explained in great detail in Sect. 5. Two initiatives are presented: IMS Simple Sequencing and IMS Learning Design. The first one is specifically designed to deal with the sequencing problem, but it is limited in scope as well as functionality. The second one is not designed specifically for this, but it offers some tools that are very useful and that can solve some of the deficiencies of the other specification. Both specifications are covered in great detail, paying special attention to the mechanisms that they offer to express sequencings that may have been designed using some other paradigms of the ones explained in the preceding sections.

Section 6 deals with one of the most promising trends today in adaptive sequencing: social sequencing. Recent years have seen the appearance of many engineering applications that are inspired by nature, specifically by the world of social insects. Some initiatives are appearing in the e-learning world that takes a similar approach. Two of them, representative of two different approaches, are presented.

Finally, it is important to note that there is an implicit assumption through most of this chapter. That is that the user of an e-learning system can be modelled in some meaningful way. All aspects of adaptive systems, and adaptive sequencing is no exception, rely on some technique or techniques for user modelling. It is beyond the scope of this chapter to cover user modelling, but the interested reader may check the references to see how the user is modelled in each of the initiatives described here. Moreover, there is a good overview in [5].

1.1 A Note About Terms: Sequencing or Navigation?

The concepts of sequencing and navigation are much related in the world of hypermedia systems. Sequencing stands for the order in which the documents are presented to/viewed by the user. Navigation stands for the process of moving from one document to another one.

As can be seen from these two definitions, the line between these two concepts is very thin, and usually blurry, especially in the field of adaptive hypermedia systems. As a matter of fact, in some cases they can be used as synonyms [6].

The usual distinction comes from the use of the word by the author, or from the characteristics of the system studied. Systems that are more focussed on direct guidance of the user (those that take the decisions about next documents based on what they know of infer about the user) generally use the term "sequencing". Systems that give more freedom to the user (that propose different choices to select, sometimes with recommendation about the best one) tend to use the term "navigation" instead.

In this chapter, we will use both terms depending on the scope or focus of the different sections. In those cases in which it will be important to distinguish between both meanings, it will be clearly indicated in the text.

2 UML-Based Sequencing

The Unified Modelling Language (UML) [7] is a graphical language for modelling software systems. There have been many other examples [8–10], but UML is the best known and most used nowadays. It is supported by the Object Management Group (OMG) that made it one of its standards.[1] UML can be used to visualize, specify, build and document a software system.

Since the first version of the standard, many elements have been added to UML in order to represent different entities. In fact, many of the criticisms that UML receives come from the fact that it has become extremely enlarged. On the other hand, its broad scope and the possibility of extending it through the use of profiles and stereotypes has made it very popular. UML is used today to model other systems that are not software-based like: business processes, system engineering, or organizational structures.

Some e-learning researchers with a software design background have used UML for the description of different e-learning tools, or for modelling some e-learning processes. We will focus in this section in those that have used UML for the definition of sequencing strategies applied to learning content. Two different, yet similar, approaches are presented in this chapter. Another approach that uses state diagrams for the definitions of different sequencing in hypertext and Web-based applications is described in [11].

[1] Specifications are available at www.omg.org (accessed Jun 2006).

One advantage of using UML for describing online educative systems is that it is a well known language for many software engineers, so they do not need to learn any additional tool. The main disadvantage is for those designers or teachers that do not have a technological background. UML is a complex language with a big specification; if they do not know UML in advance, the prospect of trying to learn it will be too much for most of them. Moreover, UML is a language designed for software engineering. In spite of its broad scope and extension capabilities, it may not be the best option for designing systems aimed at learning.

2.1 UML-Guide

UML Guide [12, 13] uses UML State Diagrams for modelling the user navigation though a hypertext or, more generally, a hypermedia system. The purpose of UML Guide is to build adaptive hypermedia systems (not only educational ones, but in a general sense). In UML-Guide, state diagrams are used for visualizing navigation maps, in which the nodes represent documents and the arrows (transitions) represent links between them.

Events raise transitions in a state machine. They include user-generated and system-generated events (the latter include time events). Guards can be used to constrain transitions depending on some rules. When a transition is raised, and before entering the new state, some actions may be performed. Additionally, actions may be performed *while* the transition is done (side-effect action). These actions process parameters (e.g. enabling guards) and update the user model.

In this approach, the user model is represented by a class diagram. The structure is similar to the one in the Adaptive Hypermedia Adaptation Model (AHAM) [14]. The user model incorporates various characteristics of the user, as well as data about the usage of the hypermedia application. In the class diagram, different classes represent user knowledge, user preferences, user goals, background, etc. Only the first one is compulsory. The other ones can be added if they are needed.

The user model has operations for reading the current state of user characteristics, as well as for updating their values. This is different to other approaches, in which the user model is seen only as data, and the operations are part of another aspect of the model.

The UML State Diagram can be exported to XMI. XMI is the OMG standard for exchanging metadata information via XML. It is commonly used for interchanging formats for UML models. Once the diagram is expressed in XMI, different techniques can be used to produce the sequencing map from it (XSLT, SAX/DOM, etc). The algorithm is explained in detail in [12].

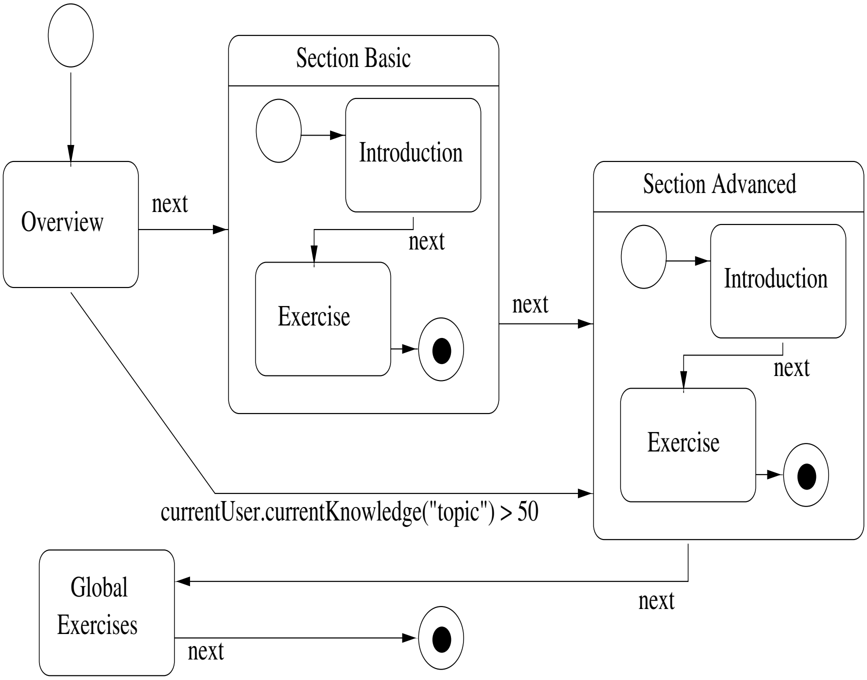

Fig. 1. Example of UML state chart for sequencing

2.2 CADMOS-D

CADMOS [15] is a methodology for the development of instructional systems, mainly focussed on the development of Web-based educational applications. Part of CADMOS is CADMOS-D [16], which is oriented at the design phase. Other phases comprise requirement capturing, implementation and evaluation.

CADMOS-D provides a process' model, focussed on the different steps and their temporal relationships and sequencings, and a product model, focussed on the outcomes of each step and the dependencies between them. The proposed model is defined as a UML profile [17]. This profile is specified by the extension of basic UML elements, the definition of additional semantics for the new elements, as well as the definition of syntactic constraints for the interconnection of these elements. The design model can be decomposed into three sub-models: conceptual model, navigational model and presentation model. This separation simplifies the design process. It also allows for the reusing of work; e.g. there is no need to change the content model to define a different sequencing strategy. For the purposes of this chapter, the most import model is the navigation model, and it is analysed in detail below.

In CADMOS-D the navigation design follows the conceptual design, so we must explain briefly the main concepts here. The conceptual model defines the learning activities that the students have to deal with, as well as the relationships between them. Usual pedagogical issues such as dependencies between concepts or learning goals, and knowledge hierarchies, are described in the concept model. The resources that are associated with the learning activities, if any, are also specified in the conceptual design.

In CADMOS-D, the conceptual model defines a default sequencing scheme (much in the same sense as IMS-CP [18] does): children concepts are to be covered after father concepts, and sibling concepts are to be covered from left to right as they are displayed in the UML map. This is a linear and static sequence, with no adaptation to the user.

Once the conceptual model is defined, the navigation model makes the correspondence between concepts (and resources, if any) and pages (nodes). It does so for relationships and links, too. Moreover, the navigation model is divided into a structure model and a behaviour model.

The navigation structure model defines the structure of the hypermedia system and specifies the actual Web pages and the resources associated to them. The structure is composed of:

- *Content*: the top-level container.
- *Container nodes*: that compose the hierarchy of the learning content (i.e. chapters, sub-topics, etc.).
- *Content nodes*: the actual pages of learning content.
- *Fragments*: similar to content nodes, but they can only be associated to resources in the conceptual level, while Content nodes can be associated to concepts or resources.
- *Access elements*: links that facilitate the navigation into the hypertext, like indexes or guided tours.
- *Links*: associative links [19] implementing relationships of the conceptual model; they are not structural links that allow the transition from one Web page to another.

The structure of the navigation structure model in CADMOS-D follows the structure of the concept model. Thus, it defines the same default sequencing: a pre-order traversal of the different containers, content nodes and fragments (children after parent, from left to right). This default sequencing is altered in the navigation behaviour model.

The navigation behaviour model defines the run-time behaviour of the system in terms of navigation. It is in this phase of the design that rules and optional transitions are created in order to allow for different sequencings, adapted to the characteristics of the user.

Container and content nodes from the navigation structure model are translated into states into the navigation behaviour model. Hierarchy is thus preserved: a hierarchy of navigational elements defined in the former corresponds to a hierarchy of nested states in the latter. Structure links in the navigation structure model correspond to links and events that fire them in the navigation behaviour model. Additionally guard conditions in the transition define, as it was the case in UML-Guide (Sect. 2.1), alternative navigational transitions. These alternative transitions are enabled or disabled depending on the characteristics of the student, thus adapting the sequence of states to him/her. Composite and content nodes have an attribute named *included*, to specify if they will be included (along with their descendants, if any) in the hypertext or not.

Once the full navigation model has been defined, the last step is the definition of the presentation model. The transition is very straightforward. Elements of the presentation model (namely HTML elements and CSS [20, 21] elements) are associated with the nodes in the navigation model. The presentation model is again divided in two: the presentation structure model that deals with Web elements such as windows, frames and elements; and the user interface model, that takes care of layout, colours, styles, etc.

In CADMOS-D, the user model consists of two different parts: the Overlay and the Stereotype. The Overlay model is the domain specific part of the user model. It defines the status of the learner's knowledge about the specific concepts covered by the learning material. The state of this model is frequently updated as a result of the interaction of the learner with the learning content. The knowledge is defined as a structure of concepts and this structure is built during the user's learning activities. In other words, the Overlay depicts the system's awareness of the current status of the user's knowledge about the domain of the specific application as it has been described in the Conceptual model, as explained above. The elements of the Overlay are called UserSchemes (following [14]). There can be one UserScheme element for each class of the Conceptual model.

The Stereotype (the name follows [22]) defines elements that are used to represent the predefined user knowledge profile. It describes the knowledge of the particular domain (novice, intermediate, expert, etc.) or corresponding to the user's preferences or learning style (top-bottom, bottom-up, text-oriented, etc.). The elements of this sub-model are called User.

In conclusion, CADMOS-D uses UML not only for defining adaptive sequencings of learning content units, but to define abstract entities as learning topics, concepts and relationships. For those e-learning researchers that already know the basics of UML, this is a sensible approach to the definition of educational hypermedia systems. In the case that a specific (and simpler) language appeared for the definition of adaptive educational hypermedia systems, most of the methodology could be used as such.

3 Graph-Based Sequencing

Defined in an informal way, a graph is a set of nodes or vertices linked by a set of edges or arcs. The arcs connect nodes two at a time. A graph can be undirected or directed.[2] In the latter case, an edge (called a *directed* edge) that connects node A to node B does not connect node B to node A.

Many problems of practical interest can be represented by graphs, either from the physical or from the cybernetical world. The link structure of a Web site could be represented by a directed graph: the vertices are the Web pages available at the Web site and there is a directed edge from page A to page B if and only if A contains a link to B. A similar approach can be taken to problems in travel, biology, computer chip design, communication networks and many other fields. The semantics of a graph can be enriched giving special meanings to its nodes or edges, or adding some restrictions (e.g., weights, conditions, etc.). Some graphs have become so important that they are known by a particular name, like finite automata [23] or Petri nets [24].

Graphs can be used to define sequencings of learning content. This section presents two approaches that have in common that they are based on a graph with some additional semantics specially designed for sequencing in e-learning. In Sect. 4 graphs are used to define sequencing stochastically, associating probabilities to the arcs.

[2] A directed graph is sometimes called a *digraph*.

3.1 Sequencing in AHA!

AHA! [25, 26] is a general-purpose Web-based adaptive framework for building hypermedia systems. It puts the focus on simplicity and allows many types of adaptation rules. It tries not to enforce any in particular, allowing complete presentation freedom for the system designer. Although, it can be used for any sort of system, most of its uses have been educational efforts of different kinds [27, 28]. AHA! is based heavily on the AHAM model [14].

The focus in AHA! is more on content adaptation rather than on sequencing adaptation. As a matter of fact, there is no such concept as "sequence adaptation" in AHA! There is only a level of navigation adaptation, using *link hiding* and *link annotation* that indirectly have an influence on the sequence of documents that the user can access. We will only cover here some of the aspects of the AHA! system that may be useful for other systems, as well as pointing out the similarities with some of other metaphors explained in the chapter.

There are two author tools for AHA! the Concept Editor and the Graph Editor [29]. The first one is a low-level tool in which the author defines predefined set of attributes and adaptation rules (of two types: *generate rules* and *requirement rules*) with each newly created concept, using a template. The latter uses a graph metaphor, similar to the one presented in Sect. 3.2. In the case of the Graph Editor the nodes in the graph are concepts, while the arcs represent different kinds of dependency rules between the concepts: knowledge propagation, prerequisite knowledge, etc. An automatic process transforms these high-level constructs into low-level adaptation rules. Thus, the result of the Graph Editor may be further refined with the Concept Editor.

The rules and relationships are then translated into the combined domain and adaptation model of AHA! [30]. This will enable or disable some transitions in the pages, according to the rules defined in the previous step. Although the focus here is clearly on the concepts and not on the sequence of learning material, this process brings similarities to the CADMOS-D methodology described in Sect. 2.2.

3.2 Sequencing Graphs

Another initiative based on graphs and specifically oriented towards sequencing is "graphs for sequencing" or "sequencing graphs" (SG) [31, 32]. SG have been designed specifically to model a learning strategy. This learning strategy allows the designer to express different sequencings of learning material that adapts themselves to the student's characteristics.

As in the previous section, in a sequencing graph every node is associated with an activity. Similarly to UML-Guide in Sect. 2.1, every arc in a sequencing graph represents a transition between activities. These activities are associated with online resources that can be anywhere on the Web.

SG were designed for their use in the intelligent tutoring platform SIT [33]. SIT is a platform that intelligent tutoring systems can be built upon. SIT puts the focus on adapting the sequence of resources to the user. Thus, tutoring systems built on top of SIT must implement some model of the domain they are tutoring and some sequencing strategy that adapts the sequence of activities to the student's capabilities and needs. SG were designed for developing tutoring systems in this context [34].

Sequencing adaptation in an SG is accomplished through *conditions* and *actions* associated to the arcs, and both express the relationship between the SG and the user's model. The student's model or *environment* contains all the information that the system has obtained from the student: which activities he/she has done, how long did it take to finish them, how well did he/she perform in the exercise regarding some section, how often does he/she connect to the system and so on. The environment is not monolithic, but divided into levels of hierarchy (see below).

Each arc has a condition associated with it. *Conditions* are boolean conditions, connected with AND, OR and NOT operators. These conditions are evaluated against the variables in the current environment. Conditions may check variables for equality against other variables or constant values. They can use basic arithmetical operations (addition, subtraction, multiplication, division), thresholds (greater than, less than) and max/min operations. When a condition is evaluated to *true*, the corresponding arc transition is enabled. If more than one transition is enabled, it is up to the application to decide which one (e.g. showing a menu to the user for manual selection) is to be followed.

Apart from that, every arc has a set of *actions* associated with it (maybe empty). These actions (PUT actions, different from SAVE actions, see below) are executed if the arc is selected and traversed by the student, and modify the current environment. The actions modify the value of a variable in the environment. This modification may be an assignment or a mathematical operation involving simple math: from addition to division, plus max/min operations.

Actions cannot add or delete variables from the environment. Variables in the environment are set when the graph is first entered (*init phase*) and they remain until the graph is left. Variables in the environment can be modified by the actions on the edges or by the activities themselves. The init phase must initialize all the variables that the activities list in their interface descriptions (see below). Otherwise, an error is produced at design time.

The activities can modify the variables in the environment (i.e. variables related to the result in the activity). Each activity node has an *interface* defined, declaring which values the activity can modify. Every variable that the activity modifies[3] but is not declared in the activity interface (and thus not correctly initialized at the beginning of the graph) is discarded. That way, those variables and values not specifically considered for sequencing at the design phase may not affect the sequence of activities, resulting in spurious steps.

It is important to note that SG were designed so that they could be used in life-long learning scenarios [35]. They were designed to be able to express arbitrarily long sequences of learning units yet not becoming unmanageable. Additionally, they were designed to promote reusability, much in the same sense as Reusable Learning Objects [36].

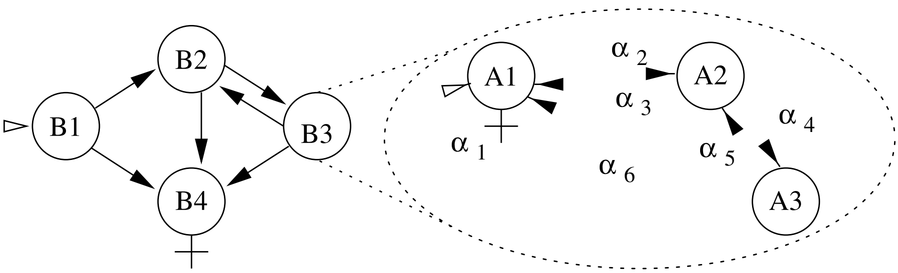

Fig. 2. Sequencing graph showing hierarchy

As a result of both these two requirements, SG are hierarchical. Hierarchical graphs have been used in many different fields with good results [37]. In the case of modelling sequencing strategies, hierarchy is a way to overcome the scalability problem. It can be easy to design a graph

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[3]The method used by the activities to modify the environment is left to the application. In the case of SIT, the variables and the new values are passed to the sequencer embedded in the HTTP response [33].

made of five activities, but designing a graph with 50 activities is not; a graph with 500 becomes very difficult to design and almost impossible to maintain. That is why SG have a hierarchical design, in which every node may be associated with a learning unit or with another SG of a lower level of hierarchy (see Fig. 2).

The algorithm for traversing the graph is as follows: when several transitions from a node are enabled (conditions in the corresponding edges evaluated to true) one of them is selected. If the next node in the graph is an activity, then deliver the activity to the student. If it is a container node, then go down to one of its *input nodes*.

Input nodes are those nodes in the graph that are selected as entry points from the upper level. In Fig. 2 they are marked with a white triangle. If there is more than one, one is selected in a non-deterministic way. When the student goes down a level, a new environment is created (and initialized).

In order to make real reutilization of graphs possible, the environment is not unique but there are as many environments for the user as levels of hierarchy he/she has gone down. Thus, there is no danger that a variable from the lower levels may overwrite the value of another variable with the same name in the upper levels. This is absolutely necessary if designers are to reuse modules (graphs) from other authors that they do not know in detail.

This is the way to go down a level in an SG: initialize environment with all the variables that you are going to use for finding the optimum sequence for the student; then, select one of the entry nodes. The entry node can be a learning activity, or it could be another container node, so the process must be repeated.

The way back up is through *output edges*. Output edges are edges pointing to the father node. They are depicted as crosses in Fig. 2. As any other edge, they have a boolean condition associated to them. They may have several actions, but the actions are different from those in other edges. Actions in output edges are SAVE actions (different from PUT actions, see above), and they store a value from the current environment into the upper level one. They specify the name of the variable at this level and at the upper level. This name must comply with the inter-level interface.

Thus, the interface between levels must be clearly defined. Every output edge has "SAVE" actions that store some of the variables from the current environment to the upper level one. The set of all the variables that can be *saved* from a graph is the *interface* of that graph, and must be documented along with it. This is the information that is used on the graph on the upper level to adapt the sequencing to the user after he/she has traversed the lower graph.

An example will illustrate this process. A module has a set of ten questions and three videos regarding the "discovery of the new world". The sequence of activities for the student will be longer or shorter depending on the accuracy of his/her answers. In the end, the module is finished when the condition in the output edge is satisfied ("knowledge > 50"). The output edge has two SAVE actions that save the values of the variables "number of tries" and "time_consumed", and the graph on the upper level will take its decisions depending on these two variables (and any other that may be present in that level's environment).

3.2.1 Other Hierarchical Approaches

The hierarchical structure of SG brings some similarities to some other inherently hierarchical approaches, like IMS Simple Sequencing (IMS-SS, Sect. 5.1), IMS Learning Design (IMS LD, Sect. 5.2) and CADMOS-D (Sect. 2.2), but there are key differences.

With respect to IMS Simple Sequencing (or IMS Content Package) the main difference is about the container or parent nodes. In the IMS specifications all the nodes have a resource associated to them, including *parent* nodes. This resource usually plays the role of "introductory content" to the resources that are to be delivered afterwards. On the other hand, in SG the *parents* are content-less, they are only containers for lower-level graphs that express the actual sequencing of activities (or other containers). The goal in SG is to improve reutilization, abstracting the content beneath a node with only an activity name. Thus, all the sequencing of activities can be detached cleanly, including any introductory content that may be needed. This works both ways: from the container to the containee and vice versa.

First, an SG can be ported to any other container node without any further change or modification. The container may use those variables present in the interface of the graphs (variables exported to the environment in the higher level using SAVE actions), but this is not mandatory. No additional material is needed either. The SG is atomic, a self-sufficient module.

Second, from the point of view of the higher-level container node, the graph underneath can change without affecting the rest of the graph. As long as the graph below maintains the same inter-level interface (the variables imported from the lower level to be used in adapting the sequencing in the upper level), the lower level graph can be modified or replaced without any change being necessary in the upper level.

With respect to IMS Learning Design, the similarities are fewer. IMS LD has got some hierarchical structures in its design, but they are intended for creating (more or less unordered) sets of activities rather than helping designing sequencing for large groups of activities. In particular, the fact that in IMS LD a completed activity remains completed for the rest of the run presents many problems for non-linear sequencings (i.e. those involving cycles).

4 The Stochastic Approach

If the units of learning are seen as nodes in a graph, transition arcs between these nodes may represent hypertext links. This is the starting point for the work described in [38].

In this approach, probabilities are associated to every arc. These probabilities determine which will be the next learning unit to be delivered to the students. Units with a higher probability will be chosen more frequently than low probability ones. These probabilities are set by the pedagogical team of teachers that design the graph. There is a big difference here with previous approaches, where the decisions about what learning unit was to be delivered to the student where taken determinestically (at least partially) based on conditions, guards or rules.

Arcs that connect nodes are equivalent to restrictions in the sequencing of learning units. Probabilities associated with those arcs determine which transitions will usually be followed after each particular node. Taking into account both things, restrictions and probabilities, the sequencing of the students is specified stochastically.

Probability design step by step has one advantage and one disadvantage. The former is obvious. It is easier for the teachers to set some probabilities (weights) between some few activities one step ahead. (We must remember that the teachers are not supposed to have an engineering or mathematical background). In the medium and long run, the disadvantage of this method is that it is difficult to establish a stochastic sequence without proper analysis, and many errors may occur in the process [39].

It is important to note that in this approach (the only stochastic one as far as the authors know) there is a random choice of the next learning unit, but that is restricted to those nodes that are already connected to the current node. The probabilities are weighted so that they sum up one. There is no possibility of transitions to some other nodes, "creating" new transitions. Again, this makes the design easier for most teachers, but the possibility of having a truly random graph [40, 41] could lead to interesting results.

5 Standardization Efforts in Sequencing

The deployment of technology in learning activities has been shown to be promising and challenging at the same time. With the new scenarios offered by technology, learning can take place anywhere, anytime, and therefore learning management systems and learning material require high levels of adaptation, accessibility, interoperability and reuse.

Standards are a way to foster and promote these requirements at international levels. Several international institutions have procedures to deliver the best possible technical solutions to current technological problems. E-learning is one of the areas in which the effect of this standard is perceived not only as beneficial but also as crucial.

Institutions such as IEEE and ISO have numerous working groups elaborating standards to guarantee that learning management systems offer a common set of functionality and data representation framework so that learning material can be considered platform independent. An example of such effort is the Learning Object Metadata standard [42]. But there is a very important set of specifications and models aimed at providing a common background upon which to build really reusable material.

Other institutions produce specifications that are becoming de facto standards, like ADL or IMS. The main two related to sequencing are presented in this section: IMS Simple Sequencing and IMS Learning Design. The first one is specifically designed to address the problem of adaptive sequencing, but it is a bit limited in its scope. The other one has a much broader scope, but it does not focus on sequencing. However, it has attracted great attention from the e-learning community, even from those researchers interested in sequencing, because it offers possibilities that could solve some of the lacks of the other specification.

5.1 IMS Simple Sequencing

The IMS Simple Sequencing (IMS-SS) defines a method for defining the sequence in which a set of learning activities are to be presented to the student [43]. It incorporates rules that describe the flow or branching of activities according to some outcomes of the interaction between the user and the activities. Its goal is to be the meeting point between different learning management systems in terms of sequencing of learning content. Thus, the IMS-SS model is purposely neutral with regard to models of pedagogy and the use of instructional strategies.

The name *simple* in the specification does not mean that the specification is relatively short or easy compared to others from IMS. It is labelled as simple to denote that its scope is limited to some specific ways of defining sequencings (see Fig. 3): directed sequencing, self-guided sequencing and adaptive sequencing. Only the latter is important for the purposes of this chapter, and it is only supported by IMS-SS in a quite limited fashion.

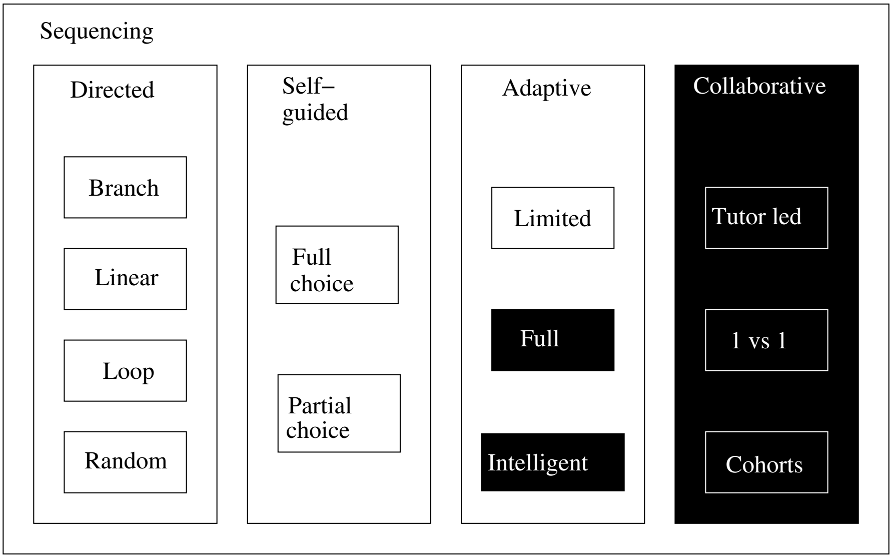

Fig. 3. Scope of IMS-SS (based on [43])

IMS-SS is designed to be integrated with IMS Content Package [18], the IMS specification about packaging of learning units (they can be seen as learning objects [36]). As a matter of fact, IMS-SS does not require Content Packaging. However, Content Packaging is currently the only defined mechanism for exchanging packaging instances in IMS. The IMS-SS information may be embedded in the IMS Content Package manifest or may be included in its own file.

The IMS-SS defines a whole sequencing process with several steps (called behaviours: navigation, termination, rollup, sequencing, delivery). For the sake of space, we have focussed in this section on the mechanism that IMS-SS gives the designer to define different sequencings that adapt to the student. Readers interested in the whole process may have a look at [44].

In the context of IMS-SS, a learning activity is a "pedagogically neutral unit of instruction, knowledge, assessment, etc. It can have sub-activities and may be nested to an arbitrarily deep level. Each activity may have a tracking status associated for each learner that is assigned to experience the activity. Activities can be attempted any number of times, or the number can be specified. They can be suspended, abandoned, exited normally, etc. All activities are performed within the context of a parent activity" [44]. It is important to note here that IMS-SS considers that learning activities are organized *hierarchically*. However, sub-activities are not considered to be part of the parent activity. Activities are always delivered one at a time, usually delivering the parent activity and then its sub-activities (see below). Activities may (and usually do) have auxiliary resources associated with them. In the case that a learning activity did not have any resource associated to it, the IMS-SS specification does not define any behaviour.

IMS-SS manages learning activities arranging them as a tree. Every node and every leaf in the tree is an activity. Any node in the tree may have any number of children nodes or leaves, so the branches do not need to be balanced. There is no relation between concepts such as lessons, courses, etc, and the depth of the nodes in the tree hierarchy.

The Simple Sequencing Specification defines the canonical traversal of the activity tree as pre-order traversal. Figure 4 presents a normal traversal of an IMS-SS tree.

The IMS-SS allows the designer to select if a set of sub-activities are to be sequenced in a guided fashion (without any intervention from the student) or if the student is expected to choose the next activity. This is done through the use of two properties at every node (not leaves): +sequencing control flow+ and +sequencing control choice+. The status of these two properties affects the sequencing of any sub-activity that is a direct child of the node. If the sub-activities have sub-activities themselves, they have to define their own policy. Additionally, some randomization can be selected both for the *flow* and the *choice* policy.

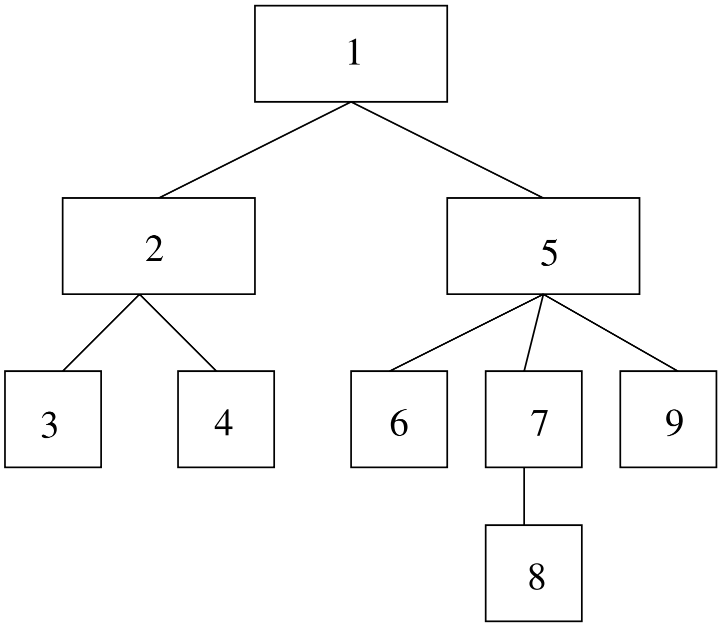

Fig. 4. Canonical traversal of an IMS-SS tree

This fact that a certain policy only affects children of an activity is very important in IMS-SS. An activity and its direct children are called a *cluster*. The scope of rules in IMS-SS does only affect clusters (directly, at least): they are defined at the parent, they affect the parent and/or the children, and they do not have any effect on either ancestors or descendants. Using the example of the last paragraph applied to Fig. 4, an activity (e.g. 1) can define that its sub-activities (children: 2 and 5) are to be delivered one after another (flow), while each of them defines that the user may choose between their sub-activities (grand-children: e.g. for 5, they are 6, 7 and 9).

The default traversal path can be modified through the association of sequencing rules created by a learning designer. Traversal is supposed to be triggered by the learner through navigational events or by the delivery system itself. Sequencing rules are evaluated at runtime and can be conditional based on tracking status. Rules that affect sequencing in IMS-SS can be of three kinds: limit rules, rollup rules and the so-called sequencing rules.

Limit conditions define constraints on the access to an activity (a node) based on conditions like time of day, time spent on the activity and number of attempts. Simple Sequencing processes may reference the limit conditions description for any activity in the activity tree. This may affect the sequencing (see sequencing rules below).

Rollup describes how the success or failure in children activity nodes of a cluster influences the sequencing of their parent activity and each other. Conditions that affect each of the sub-activities may have values like: satisfied, completed, attempted, etc. There can be more than one condition on any sub-activities, and they can be combined with a global AND (all conditions have to be met to fire the rule) or global OR (any condition met fires the rule). Every single condition may be negated (NOT satisfied, NOT attempted, etc). Additionally, any sub-activity may be marked as not to be taken into account (i.e. optional activities with no effect on the global sequencing). The rollup rule can be fired if all the conditions on the children are met, or any of them, or none of them, or if more (or less) than some percentage of them have been met. When the rule is fired, it has a direct effect on the parent activity of the cluster. Actions can set the status of the parent to: satisfied, completed or any of its opposites. This can have an effect on the sequencing (see sequencing rules, below).

There are three types of sequencing rules in IMS-SS: preconditions, post-conditions and exit conditions. All of them can be associated to the same kind of conditions, but they take different actions on the sequencing. The conditions evaluate several aspects about the activity (many of them can be modified with regard to limit conditions and rollup rules). Examples are: some objective is satisfied or completed, some objective is satisfied or completed up to a threshold, the limits of attempts or the time spent on it has exceeded some threshold, etc. More than one condition may be set for each activity, and they can be combined with a global AND (all conditions have to be met to fire the rule) or global OR (any condition met fires the rule). Every single condition may be negated (NOT satisfied, NOT attempted, etc.).

Preconditions' actions are used when traversing the activity tree to identify an activity for delivery. Preconditions are evaluated before delivering the current activity. Their associated actions can be:

– **Skip:** Skip current activity during a *flow* sequencing process; indirectly, this skips all descendants of this activity.
– **Hidden from choice:** Hide the current activity from the set of activities that are presented to the user to choose.
– **Disabled:** Combines the effect of the former two actions.
– **Stop forward traversal:** Stop walking the activity tree, in a forward direction.
– **Ignore:** No action.

Post-conditions actions apply when an attempt on the current activity finishes. They can be[4]:

- **Exit parent:** Exit the parent activity.
- **Exit all:** Exit from the system.
- **Retry:** Try again the activity.
- **Retry all:** Try again all activities in the cluster.
- **Continue:** Continue. Please note that next activity in the tree may not be the next activity to be delivered to the student, depending on preconditions.
- **Previous:** Go to previous activity. Please note that previous activity in the tree may not be the next activity to be delivered to the student, depending on preconditions.
- **Ignore:** No action.

Exit actions apply after an attempt on a descendent activity terminates. They can be:

- **Exit:** Unconditionally terminate the activity.
- **Ignore:** No action.

The fact that IMS-SS does not have a generalized student's model is its main limitation. It is possible to store in the scope of IMS-SS some information about the user (e.g. time spent on some activity, or how many activities in a cluster he/she has successfully completed), but it is not possible to go beyond that and define/model abstract concepts (i.e. student prefers top-bottom approaches).

This may be the reason why most of the interest of the e-learning community has gravitated towards another IMS specification, IMS Learning Design (see Sect. 5.2). Although IMS Learning Design is not oriented specifically to address the sequencing problem, it gives some mechanisms to define sequencings. Besides, the properties of IMS Learning Design allow some user modelling semantics. Thus, there are many people from different fields working on IMS Learning Design, even those that are focussed on the sequencing problem.

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[4]The effect of the postcondition actions and the exit actions is a little simplified, because we have not covered in detail the Sequencing Process model of IMS-SS. The detailed behaviour of these actions is explained in [44].

5.2 IMS Learning Design

The IMS Learning Design (IMS-LD) specification has not been originally developed for the problem of sequencing. The goal of IMS-LD [45, 46] is to describe teaching strategies and/or pedagogical approaches, as well as promoting the interchange of them between learning management systems. Thus, it intends to document teaching strategies, establishing and adhering to prescribed procedures for assuring the consistency of that documentation.

The focus here is on encoding educational strategies in a consistent way (that could be understood by humans and computers). That way, the context of a learning unit, set of learning units, course or program can be managed separately from the content itself. This information would allow instructors to describe the instructional approach they use on their work associated with their content; this facilitates easy share and reuse with their colleagues of content that is designed for their particular instructional strategy and discipline. On the other hand, this information could be used to adapt or interpret learning content under an instructional strategy that is different from the one which it was designed for. Additionally, to have information about the pedagogical context of some learning content would also facilitate its adaptation between learning management systems.

The Learning Design allows different kinds of learning strategies to be described, while being agnostic with respect to them. Thus, it does not provide a specific vocabulary for describing different kinds of learning approaches. It uses its own metaphor for creating a meta-language that will be able to describe any approach instead. That is the metaphor of the script of a theatrical play, film or game [47]. The assumption is that a script is able to model all kinds of behaviours and interactions between actors that occur in the context of a defined environment. Thus, it is able to express all kinds of realities. It can be very strict and detailed or it can leave more space to improvisation. And more importantly, the script is a *high-level description* of the play, that focusses on some aspects but abstract from others: the scripts are written exactly the same independently of the company or actors that will actually perform the play, or if it is a comedy or a drama. In other words, the scripts can be *interpreted*.

IMS-LD implements a vocabulary with plays, acts, roles, activities and conditions that allegedly is able to express any pedagogical strategy. Acts are included into plays, and are means to synchronize different activities that occur simultaneously. Activities are performed by people playing a role. Roles are to be instantiated by real people, and are grouped into two built-in role families: student roles and teacher roles. Finally, conditions allow for some variability in the course of the play (*if* something happens, *then* this happens, *else* other thing happens). The whole package that includes the definition of a pedagogical strategy or learning design, along with the resources or services needed for it to develop, is called an *Unit of Learning (UoL)*. In IMS-LD, the process since a UoL starts until it is finished is called a *run*.

It is the conditions[5] of IMS-LD that are important from the point of view of this chapter, as they are the tools that determine different sequencings of activities. Conditions are evaluated against *properties*. Properties in IMS-LD can be:

- **Local:** They do not live beyond the scope of the current run.
- **Global:** The properties persist across multiple runs of the same UoL.

Additionally, the scope of properties in a UoL can be:

- **General:** They are attached to the UoL as a whole (e.g. maximum number of students that are allowed to play a role).
- **Role:** They are attached to all members of a role (e.g. maximum time that each student is allowed to complete an activity).
- **Person:** Personal properties that describe or affect one individual user (e.g. time that a student has been on the current act).

Although they can be used for different purposes, properties are the means for providing specific information about the learners. This makes it possible to adapt the current UoL to particular needs or capabilities of a student or group. The value, or change of value, of properties in a UoL fires the evaluation of conditions in IMS-LD. Properties have a name and an identifier, a type, a value and (maybe) some restrictions on the possible values that it can have.

Conditions are evaluated against properties. When the condition is met, some action takes place. Conditions are evaluated every time that the value of a property changes. There are three types of events that can change the

[5] In order to simplify the implementation of such a big and complex specification as IMS-LD, three levels (A, B, C) have been defined [48]. Each level adds some functionality to the previous level. *Properties* and *conditions* are defined in Level B. Level C defines *notifications*. For the sake of simplicity, the distinction between levels is overlooked in this section and IMS Learning Design will be explained as a whole.

value of a property, so they can be used to fire actions indirectly. These events can be provided by a timer (the UoL's runtime clock) that reaches a certain point in time. They can be provided by the user as well, for example, when he/she decides to finish an activity. Finishing of activities, acts or plays (for whatever reason) are events that may change the value of properties, too.

Conditions in IMS-LD are Boolean conditions, that can be combined with AND, OR and NOT operators. There are several issues that can be checked:

- Whether the current person is member of a role or not.
- If some activity, role part, act or play has been already completed.
- Whether a property is defined or not.
- If some property is equal to, or different from, some constant value.
- Any modification of the former using the basic mathematical operations (sum, subtract, multiply, divide) and thresholds (less than, greater than).
- Any question about the current time, the time the UoL was started, or time that an activity was accessed.

As it was stated above, conditions are evaluated every time the value of a property changes. The actions that can be performed by a condition are:

- *Change property value*: Changes the value of a property. This produces another re-evaluation of all the conditions. Conditions that were not met before may be validated after this property value change. The result can be the change of another property, producing a chain of connected conditions, each one firing the actions of the next.
- *Hide*: Hides a learning object or service, an environment, an activity or a play. If it was already hidden, there is no effect.
- *Show*: Shows a hidden learning object or service, an environment, an activity or a play. If it was not hidden, there is no effect. The combination of show and hide actions can be used to perform some kind of *adapting sequencing*. For example, two activities may be hidden for a particular student, resulting in an effective hop to the third one.
- *Complete*: Completes an act or activity. Because of the completion of an activity, act or play, some conditions may change. This would lead to another re-evaluation of all conditions. Thus, one condition may have an indirect effect on another one (e.g. if it completes an activity that modifies a specific property on completion, that has an effect on the other condition).

There is a last set of elements of IMS-LD that are important for sequencing. *Global elements* are XML extensions designed for XHTML resources. They enable properties to be accessed or modified from the activities. No other way is allowed for activities to modify properties, so only XHTML resources that make use of global elements can have an effect of sequencing during the run of a UoL. All other sequencing adaptation decisions must be taken before the UoL is instantiated and have effect for the whole run. It is obvious that this allow only for a limited degree of adaptation.

6 Future Trends: Social Sequencing

Although the solutions presented before allow for a sequencing to be adapted to different students, taking into account their differences (different goals, different needs, different capabilities, etc.) they are mostly static in their design (i.e. the graph or the state chart does not change over time). Besides, they rely on a human operator (i.e. teacher) to design or define the different possibilities for the students. It is the student who decides his/her own sequencing, either by own choice or by some mechanisms that he/she fires without being aware of; but it is the designer who must design the available sequencings for the students to choose from.

Therefore, all approaches presented share a common weakness: as the role of the human designer is central, a mistake affects the whole system. The negative effect on students may vary.

Human mistakes may be avoidable (e.g. errors when typing names of activities), but the sequencing designing process is bound to produce some unavoidable problems. Aside from the activities proposed by the teacher, students may as well discover and propose other activities of interest not considered so by the teacher. If the sequencing strategy depends entirely on the teacher, those activities that the teacher does not know will never be accessed (sequenced) by the students. This is a limitation that we are very used to, and that is accepted as normal, although the new possibilities brought to us by information technologies (specially the Internet) may give the opportunity to overcome it. Additionally, students evolve over time for several reasons (changes in formal curricula, different access to media and knowledge sources, etc.). A sequencing design that works very well today may not be as good tomorrow. These problems cannot be resolved by the teacher alone.

The answer to these problems is uncertain, but many research efforts are trying to take advantage of two of the main characteristics of the Internet:

small delays in communications independent of physical location and large number of users. Social systems try to emulate the behaviour of social groups in real life. The application of these techniques to the sequencing problem results in social sequencing systems. Two different approaches are presented in this section, but all of them try to extract some information of the behaviour of the group of students and use it to improve their sequencing strategy.

6.1 Ants and Pheromones

The behaviour of ants is the best-known example of swarm intelligence. In many ant species, ants deposit a chemical substance called pheromone as they move from a food source to the nest. Ants do not communicate directly with each other, but they follow pheromone trails (leaving their own pheromones behind, so the trail is reinforced). Shorter trails are reinforced more, as the ants cross them more times for the same period of time, so they are followed by more ants. In the end, the path connecting the food source and the nest is optimized without any global knowledge of the problem by any of the agents. This process of indirect communication in a swarm is called stigmergy. Another example of a stigmergic process is nest building by termites, in which the insects are able to construct complex nests with arcs, hallways and ventilation systems following very simple and local rules [49].

Applying similar techniques to the sequencing problem can be applied using a probabilistic graph like the one described in Sect. 4. Nodes are pedagogical items, arcs are hypertext links (with their associated probabilities) and students play the role of ants that traverse the graph. In their way, they leave pheromones along the arcs they follow, indicating their grade of success [50].

The pheromones can be personal or group pheromones. Group pheromones are like the typical pheromones of any ant-inspired optimization heuristic. They are laid by the students as they go through the graph, and they are *added* to some value. In this case [38], they are added to the default pedagogic weight of the arcs (w_p). Thus, they modify the probabilities[6] of the different transitions from the current node. The group

[6]These probabilities are not real *probabilities* of an arc being chosen for the student to follow. In order to avoid stagnation of the system (getting caught in a local optimum), an algorithm borrowed from genetic algorithms [51, 52] is used to choose the arc.

pheromones can be positive (ϕ^{+}) or negative (ϕ^{-}). The former are laid when the student completes successfully one of the exercises in the graph. When the students fail, negative pheromones are laid.

Personal pheromones are laid by the student but they affect only his/her own sequencing. This is useful, for example, to avoid boring a student proposing the same exercise too many times. Personal pheromones are multiplicative, not additive. They are laid with a value and they tend to 1 as they evaporate (note that additive pheromones tend to 0 as they evaporate). In this case, the personal pheromones (called *history weight*, ϕ_{h}) are laid with a value of 0.1. This divides by 10, the probability for a student to be proposed an exercise he/she recently validated. Later, ϕ_{h} tends to one; the probability of the exercise to appear again increases with time, in the same way that the memory of the student is fading.

All these factors, along with some weights that must be calibrated for the system to work correctly, lead to the following equation:

$$\phi_{\mathrm{h}} \cdot (\omega_1 \cdot \omega_{\mathrm{p}} + \omega_2 \cdot \phi^{+} - \omega_3 \cdot \phi^{-})$$

that is the fitness function at every arc.

As in any other ant-based algorithm, pheromones must evaporate. Otherwise, bad decisions made in the early steps of the algorithm may negatively load the system for big periods of time. But in the case of an e-learning system it does not make sense to evaporate pheromones with time. The use of the system may vary greatly with time (e.g. before exams or during holidays). Calibrating the system so that it reacts correctly in all situations is infeasible [50]. Instead, the evaporation is performed with *use* instead of time. Every time a student (ant) goes through an arc, the pheromones on that arc are updated; at the same time, the pheromones in all the other arcs that start from the same node are diminished.

This ant-inspired approach to the automatic modification of graphs presents some problems. Human beings cannot be used as artificial ants that explore the whole space of available sequencings, including those that are very bad. They will complain if they detect that the sequencing proposed makes no sense. Besides, their learning will not be good. There is not an extreme altruism between human beings as there is in ants, where the group is fundamentally more important than the individuals. On the other hand, the technique has already proven that it can correct mistakes made by the teachers at design time [53]. Additionally, the analysis of pheromone values around the graph may detect extreme values that may indicate strange configurations in the graphs. Thus, this technique also has value as an auditing tool [54].

As a concluding remark, we would like to point out the two main differences between the technique described here and the common ACO applications in other fields [55]. First, there are personal pheromones that a student can lay. These pheromones only affect his/her own sequencing. Besides, they are a multiplicative factor in the equation, while pheromones are usually an additive factor in ACO. Second, the evaporation of pheromones does not occur with time but with use. Pheromone values are not updated after a certain unit of time, but after a new student (ant) goes through the arc. This is called, by the authors, *erosion*.

6.2 Swarm Link Annotation

Borrowing ideas both from the ant-inspired optimization algorithms [49] and from the collaborative filtering field [56], in [57] a technique is developed for going one step further in the sequencing adaptation based on SG (see Sect. 3.2). SG adapts the sequence of learning units to the student dynamically, but the graphs themselves are static and designed by one or several human beings. This has many problems as it has been stated in the introduction of this section. Thus, a process has been designed to readapt the sequencing graph to the behaviour of the students.

Some stirmergic capabilities have been added to the system. Successful paths are reinforced in order to guide students through the optimum path for their learning. The mechanism is similar to the one used by ants for reinforcing the paths leading to food sources with the use of pheromones.

When a unit is delivered to the student, his/her success or failure is recorded. If there was a success, information is stored about the actual activity and the former one. Thus, not only has every arc prerequisites to be accomplished by the student, but also information about how many students were successful when traversing it. It is important to note that these two sources of information are independent of each other: prerequisites are designed by a human teacher, pheromones are automatically left by students.

This information is presented to the student every time a unit is finished. All the available units are presented to him/her. Each of them has information attached, about how many students have gone to each of them starting from the same unit as the student has just finished. The total number of students that have gone there is also showed (see Fig. 5). That way, the student has the "ratio of success" for each unit, according to the data collected from his/her peers. As can be seen in the figure, the result brings some similarities to a collaborative filtering system, but applied to adaptive sequencing.

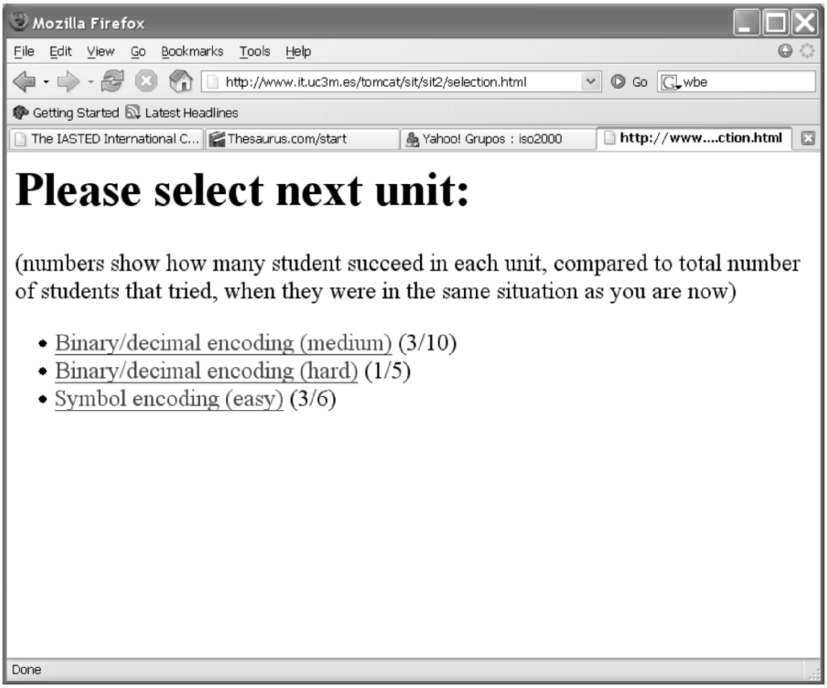

Fig. 5. Next activities in SIT and success information about them

A student who knows that he/she is above average compared with his/her classmates can select to do a unit that has a lower ratio of success but represents a higher challenge. A more modest student will be able to select those units in which many of his/her classmates were successful. This represents an additional degree of adaptation.

Its big advantage is that it is achieved in a distributed and automatic fashion, and gives a sensation of freedom and self-control to the students about its own learning, which is very positive.

The assumption is that learning paths will appear in the same way as natural paths are created in the wilderness, as more and more students use the system. These learning paths are created with no interference from the human teacher. They are created distributedly and automatically, using indirect communication between classmates. It is a stigmergic process.

As many collaborative filtering systems, the proposed strategy is suitable of being affected by the cold start problem. This means that, at first, there is no information on the arcs, so no information can be presented to the students. This is a big problem in recommender systems, as they need data to be useful to customers, and they need customers to use them to collect the data, but the users will not use a system that is not (yet) useful to them, producing a deadlock. In this case, this is unlikely to happen, because the system does not rely critically on this functionality. On the other hand, this approach is more appropriate for small numbers of students than the one presented in Sect. 6.1. Pure ant-inspired algorithms rely on big numbers of ants (users, agents, etc.) to achieve optimization robustly, avoiding chaotic or totally oscillating behaviour. When the number of users is not very big, this kind of approach gives some help to the students from an earlier point in time.

There are some issues to be concerned about. As with every other stigmergic process, there exists the possibility of local optima. This happens when students reinforce some paths in excess, so everybody follows the same paths, even if these are not optimal for them. This could happen as the first steps of aggregation that are almost random, but once a path is reinforced the process is positively reinforced and accelerated. A possible way to overcome this problem is the clustering of students, so a student only produces reinforcements on arcs for some of his/her mates, those that have similar capabilities and needs as him/her; this has the drawback of making the cold start problem even worse, as the system evolves more slowly. Additionally, a mechanism devised for the evaporation or erosion of the "pheromones" in the arcs may achieve the same effect. The results in [53] may be of help here.

This process of "student clustering" may be directed by the students themselves. The system presented in [57] shows only how students have performed so far as a group. If the names of students are shown (e.g. "A, B and F succeeded here"), next students have the opportunity of following those students (i.e. classmates) with whom they feel more identified. This approach may be very suitable for blended learning scenarios, but presents some social concerns (e.g. privacy) that have to be solved.

As it is stated in [57], next step in this direction would lead to analysis of paths taken by students. It could be possible to offer more precise information to the student for helping him/her in her decision. This information would be related not only to the last step, but a sequence of steps of some length. This shows some similarities to the approach described in [38], where pheromones are used to reinforce paths that are four exercises long. The question of how far should this path analysis or this pheromone diffusion goes has no answer yet. No studies have been conducted to find which grade of pheromone spreading is adequate for an e-learning application, as far as the authors know.

It is important to note that this swarming process is, in fact, independent of the SG. Thus, it could be used with any other sequencing mechanism in order to adapt it to the real behaviour of students.

7 Conclusions

The World Wide Web (WWW) has become the biggest source of educational material, and Web browsers have become a standard tool for information access. WBE has seen in recent years a significant increase in both its functionality as well as possible scenarios. E-learning systems are now present in an ever growing number of companies as well as educational institutions of all levels. In this context, the problem of producing good learning content is not the only one. Two other problems have achieved great importance: where to find good learning content and how to sequence it in order to maximize learning.

Many approaches to the sequencing problem have been presented in this chapter. Each of them focuses on a different topic and so addresses the problem in a different way. None of them is the definite solution to the problem, but they are varied enough so that every designer or researcher may use the one that most suites her tastes.

The main initiatives in the field of standardization of sequencing in WBE have also been covered. It has been shown that there is a lot of work ahead, as there are problems that have not been dealt with yet. Of the two specifications presented, one is too limited and the other is limited and not specifically designed for sequencing.

8 Resources

Key Books

– Koper R. and Tattersall, C. (eds). Learning Design: A Handbook on Modelling and Delivering Networked Education and Training, Springer, Berlin Heidelberg New York (2005)

Organizations

– IMS Consortium. *http://www.imsglobal.org/* (accessed on Feb 2007)
– ADL: SCORM. *http://www.adlnet.gov/scorm/index.cfm* (accessed on Feb 2007)

Key Conferences

– Adaptive Hypermedia. Last edition: *http://www.ah2006.org/* (accessed on Feb 2007)

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From Dungeons to Classrooms: The Evolution of MUDs as Learning Environments

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Summary. The history of MUDs (multiuser domains or dungeons) goes back to the 1970s. Primarily this is a history of role-playing games and text-based virtual realities. As the decades have passed, MUDs increasingly have been developed and deployed for a wide range of applications in education and the Science of Learning. As opposed to an historical recounting of the development of MUDs, this chapter describes the evolution of MUDs as they have influenced education and learning, from simple meeting and discussion places, to simulated learning spaces, to the current state of the art, which is Immersive Virtual Environments (IVEs) for Education.

1 Introduction

MUDs (multiuser domains or dungeons) have been with us since the 1970s. They are part of the fabric of Internet life, and have been more efficacious in building and sustaining social communities than many technologies we have seen come and go.

As will be explained in detail below, MUDs are multiuser places where people meet in virtual reality. Over the years a large number of MUD variations have emerged, under different names like MUSH, MUVE, and MOO, but the basic idea is the same – these are virtual places where people log on, take on a virtual persona, sometimes referred to as an avatar,

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and live a virtual life as a character in a virtual world. The possibilities for the characters are seemingly infinite: Butch McManly can log on as a 7 year-old girl, Poison Ivy can log on as Mr. Freeze, and regular mortals like us can log on to partake in an adventure or a learning experience that would never be available to us in the normal course of our lives.

This is the strange power of MUDs. You can visit impossible spaces, experience things not possible in real life (IRL), and be someone you could only dream of being IRL.

The MUD phenomena, and the history of MUDs, have been documentted many times over the years. We review a bit of that here. But our purpose is to trace the history and evolution of MUDs as they have been used for education within a Science of Learning context, which is a somewhat different story.

Over the years, educators have employed MUDs to create a number of educational opportunities: Meeting and discussion spaces for students, simulations for immersion in language learning, simulations for experiencing historical reconstructions, gathering spots for professionals to share ideas and teaching strategies, and in the current culmination of this evolution, immersive virtual environments (IVEs) for education.

This chapter traces the evolution of these systems from the distant past to the current state of the art as they have participated in education and the Science of Learning.

1.1 Technical Notes

There are some things to keep in mind while reading this chapter. First, MUDs are client–server systems, meaning the virtual environments are hosted on a single machine that many players access at the same time. Imagine the virtual environment as a wheel. The people are all out on the wheel rim while the simulation resides in the hub of the wheel. Client software is used to connect the people to the simulation. The client programs were text based in the early days as, indeed, all computing was.

In those olden days (before, say, 1983), there was no such thing as a mouse or a click. Programs were launched from the “command line,” produced text for users to read, and responded to commands typed into a text window. In the very early days, if you made a mistake in your typing, there was no backspace button to fix your command. Instead, you waited for an error message and then retyped your command again. Imagine, if you can, that everything done on a computer was accomplished through something resembling primitive text-only chat messaging. Imagine too, that programming in these simulated worlds was accomplished in the same way, without even rudimentary text editing such as you see in Notepad or Microsoft Word. In those days, you wrote and edited code using a “line editor” which let you list code, and replace lines that were stored in memory.

These “stone aged” systems still were in place when the MUD phenomenon took off in the early 1980s, and this explosion would never have occurred if not for pioneering efforts by people developing and distributing tools that others could use to build their MUDs. These advancements, and all the others, are described below.

2 Medicated Goo: The “Birth” of MUD

MUDs have their roots in interactive fiction programs written for mainframe computers in the mid-1970s. These interactive fiction programs, or “text adventures,” allowed the user to explore and manipulate a virtual world entirely through text commands. Users could perform movements or actions by typing commands such as “go west” or “open box,” and the results of their actions would be described for them by the MUD program. The first text adventures were “Colossal Cave Adventure” by Crowther and Woods in 1976 and “Dungeon” by Anderson, Blank, Daniels, and Lebling in 1977 [1], which was later sold commercially under the title Zork.

Text adventures were single-player games, that is, people who played a text adventure had the virtual universe to themselves. It was this limitation that Roy Trubshaw and Richard Bartle worked to remove in 1978–1979 when they created their own version of Dungeon for multiple users, called Multi-user Dungeon, or MUD [2]. Working in England at Essex University, Trubshaw and Bartle used a programming language known as MACRO-10. This version consisted of little more than the text-based ability to move around to different “rooms,” and to chat with other users on the system in real-time. Bartle wrote in his article, “How It Really Happened,” however, that this was not actually called a MUD. The subsequent version, also written in MACRO-10, was a little more sophisticated, and was referred to as an actual MUD. This version had at its core an actual database of user commands, rooms, and interactive objects.

The technology advanced rapidly, and after Trubshaw left Essex University, Bartle began working on additional functionality for the users. Before Trubshaw left the university, the MUD system code had already become unmanageable. Trubshaw rewrote the entire system in BCPL, a programming language that was the precursor of the now-ubiquitous C programming language. Then Bartle started to add features into the program, such as a point-scoring system, more advanced communication commands among players, and privileged characters like wizards [3]. More features enabled even greater popularity of the system, and this new form of virtual interaction took off.

Trubshaw and Bartle based their multiuser functionality on a shared database. This database was accessed by people logged into the same DEC PDP-10 minicomputer. Soon thereafter, MUDs were created that could be accessed in several different ways: via dial-in using a modem, or from any computer connected on a network, and finally, via any computer connected via the Internet.

There were several different MUDs created over the next ten years, but MUDs remained not much more than a technological gaming curiosity until a fundamental design change was introduced with MONSTER by Skrenta in 1988 [4]. MONSTER's invaluable contribution to MUD development was the ability to manipulate the environment while the game was still running. MONSTER became a benchmark in MUD evolution. Now players could "dig" new rooms, connect them with newly created "exits," and create a variety of player-defined objects, all while the game continued. Once new rooms and objects were created, they instantly were available to anybody connected to the game. The only major drawback to the original MONSTER was that it was written in the less popular Pascal language on the more obscure VAX operating system. However, in 1989, MONSTER was rewriteten in C for Unix by James Aspnes, a graduate student at Cernegie Mellon University. He called his work TinyMUD [3]. The TinyMUD variant of the MUD system became popular due to its simple game play, and also the fact that it was completely free to use.

TinyMUD was only up and running for seven months until it had to be brought down for overtaxing the host computer, but in that time the MUD-slide of the 1990s was born. TinyMUD gave inspiration to dozens of new MUD implementations, including TinyMush, PennMUSH, TinyMUCK and TinyMUSE, which were all based in some way on Aspnes' original TinyMUD source code. Other MUDs, such as UberMUD, TeenyMUD, and MOO [5] were written by people who played TinyMUD, but were not based on TinyMUD's source code. (See [4] for an overview.) Each of these expanded on TinyMUD's feature set, adding better networking abilities, better security, or expanded customization abilities.

3 From Text to Graphics: Habitat

All of the MUDs described above are entirely text-based games. These games catered to programmers and early computer users, who preferred simple text-based interfaces over graphical interfaces. In 1985, Randy Farmer and Chip Morningstar set about creating a MUD that a broader gaming audience might enjoy. Working for Lucasfilm, Morningstar, and Farmer [6] created Habitat, the first graphical MUD. Users connected to Habitat using a client program on the Commodore 64 personal computer. Habitat presented the MUD world to the user in a two-dimensional comic book style, with cartoon representations of users, a bright color palette, and user-entered chat messages presented in speech balloons. Today, graphical MUDs are known as Massive Multiplayer Online Games, and the subgenre of Massive Multiplayer Online Role-Playing Games (MMORPGs) are a multibillion dollar industry, including Blizzard Entertainment's "World of Warcraft" and Sony Online Entertainment's "Everquest" and "Star Wars: Galaxies."

4 Lahar in the 1990s: The Explosion of MUDs, MOOs, MUSHes, MUVEs, and TINY Things

Wikipedia (http://wikipedia.org/) defines *lahar* as "a type of mudflow… [that] is explosive in nature, moves quickly with little or no warning, and can have a long-lasting effect on people and communities." The explosion of textual-based virtual realities in the 1990s was like that – a lahar of MUDs.

In the beginning of the 1990s, personal computers were becoming more affordable to the middle-class, and, subsequently, more widespread. In 1990, Apple introduced the Classic, LC, and IISI. In 1992, Microsoft introduced Windows 3.1, selling 10 million units [7]. The fastest computers of those days had only tens or hundreds of megabytes of hard drive storage, 4–16 MB of RAM, and not more than a 60 MHz processor. These machines were not the graphical powerhouses that exist today, however, they sold very well and many users were tapping into this earlier and nascent version of the Internet to see what was out there.

At that time, the World Wide Web had existed for less than a decade, and there was no widespread access to the Web with a "point and click" browser interface, such as the user interface to which we are accustomed today. To go online, one needed to connect to a specific server and have a somewhat advanced understanding of the way in which the Web was organized. The specific server to which the user was connected (typically via ftp, telnet, or Gopher) generally required a paid subscription service such as the original Compuserve (later purchased by AOL), and the user could not easily browse. Users needed to have an idea toward doing something specific once connected. From the subscription service's business point-of-view, the problem was that people, especially those outside of academia, needed something interesting to do on these servers.

MUDs were one way to keep people coming back.

Once connected to a MUD, a person entered a completely alternate reality from that which they came. Although MUDs were text-based early on, the user experience was immersive nonetheless. By immersive, we mean that the person experienced being somewhere other than where they were actually physically located and someone else other than who they were IRL. After entering this alternate world, the person could become anyone they could dream up and they would become immersed in that character. This allowed a person to break from their daily routines and live out a separate life in a separate world. Early on, the majority of MUD participants were men and teenage boys, but that slowly changed as alternative worlds were created and an entire generation of children grew up in a world where MUDs are common-place. Today, girls and women make up over half of the online gamer group, and the majority of these females participate in role-play games, including MUDs [8].

In addition to their immersive qualities, MUDs also became popular because users could socialize in ways they never would in real life. An MUD world, due to its player anonymity, "tends to lower social barriers and encourage players to be more outgoing than in real life" [9]. While exploring rooms and manipulating objects, characters encounter each other, often are very friendly toward one another, and often strike up conversations.

These types of interactions typically do not occur quite so easily and leisurely in a real-world setting. This is one significant reason why users kept coming back to the MUDs. Moreover, the anonymity of the real person in these virtual worlds produces a feeling of personal safety, both physical and emotional, to the individual user, thus allowing people to express feelings or take actions that were not as accepted in the real-world. Examples of such feelings and behaviors include creating characters who are homosexual or bi-sexual, or creating characters that give the MUD player the opportunity to engage in gender reversal [9].

Many MUDs had a gaming/rewards-based feature to them to encourage long-term activity within the game. In some worlds, players battled against each other with the intent to kill or destroy the other character. By doing so, they would be rewarded with points. Of course, this created a competetive atmosphere, which some people craved. Unlike real life, physical fitness was not a criterion for success in hand-to-hand combat, which meant more people had a real chance at success.

Not all MUDs were competitive or filled with violence. The TinyMUD (noted above) rewarded its users with "pennies" if they visited other people's rooms in the world. TinyMUDs created a world where people would be rewarded by freely exploring without worrying about who might be lurking in the next room. This created a more social environment for players who either disliked or were bored with the violence of other MUDs, and it filled a niche for people who were interested in seeing what was through the next door.

For some users, MUDs became an environment in which an individual could gain considerable personal power (whether good or bad) that could not be obtained in the real-world. For example, some players had the capability to "toad" other players (turn another player's character description into that of a wart-covered toad) or even remove other players completely from the server [10]. A wizard is the usual example of such a powerful character in a MUD. These power-wielding players obtain a sense of power they could not get from reality by being able to vent their frustrations openly. Most wizards were not "evil." Most enjoyed teaching and helping people through their adventures in the MUD world, and could even "promote" other players to be wizards like themselves.

Finally, most MUD software was free and available to anyone who was interested. A person simply could download the software and double-click on the executable control to start the client. Often, these clients even had a predefined list of servers to make a connection. This allowed many people who might otherwise not be interested (or computer savvy) to develop a "what have I got to lose?" attitude.

In summary, MUDs exploded onto the scene in the 1990s and spread "lahar-like" for many reasons. The ability to safely role-play, be social, explore new worlds, be rewarded, exert power, and play for little investment were all very powerful forces that MUDs provided to anyone interested in joining. If not for this MUD-flow, we would not see the vast array of graphical-based realities today.

5 Virtual Discussion, Virtual Campuses

The next phase in the evolution of MUDs as learning environments involves the development of multiuser interaction in an online environment as a given strategy to community building, especially the concept of the virtual discussion, and its natural academic counterpart, the virtual classroom. These two technologies, along with their derivative concepts, have allowed participants to be teleported great virtual distances.

Early attempts at generating a virtual meeting place provided the foundations for modern virtual classrooms. The original MUD platforms can be viewed as a fusion of two already popular social forums. These were the BBS, or bulletin board systems, and the role-playing adventure games that were gaining popularity at the time, the most famous of which is probably Dungeons and Dragons.

As we have discussed, these early forms of the now-popular online community gathering place proved immensely popular. Users were able to interact with each other, as well as with the virtual world in which they were immersed. Remote participants were able to "meet" inside MUDs and go on adventures together or individually. The games provided goals and metrics by which a character could advance in skill and wealth, and was also used as a social forum for the users. This technology already was significantly ahead of the previous interactive champion, the telephone. Interacting in a virtual world, even in the early text-only versions of the technology, provided a much more fulfilling experience to the participants.

Despite their relatively advanced and modern features, the basic concepts behind the MMORPG games of today are the same as that of the original MUDs. The adventuring environments now consist of a fully 3D graphical world, with both sound and text communication between users, and between a user and the system. These games are so enthralling, that a backlash movement has emerged against what some perceive as an addiction to online gaming. Countless news articles tell of players whom have forsaken family, friends, jobs, and sometimes even their own lives to continue to play, as well as committed real-world crimes to gain advantage in role-playing games [11]. In actuality, of course, the vast majority of MMORPG players are just having a fun time gaming and socializing.

The more advanced versions of MUD technology in use today provide exceptional opportunities for people looking to create virtual learning environments. There are many examples of rather advanced online communities in use, including Donut MOO in Stark County, Ohio (a K-12 oriented learning environment), to the many various types used at universities all over the world. Examples of these include MundoHispano and MOOFrancais, both of which are hosted at the University of Missouri-St. Louis. These MOOs offer learning environments using the respective languages, Spanish and French. There are MOOville at the University of Florida, PennMOO at the University of Pennsylvania, and CafeMOO at the University of California, Berkley, as well as many others. These virtual learning environments supplement, and in some cases replace, the universal model of classroom-style teaching. Several of these environments are briefly discussed in the following section.

6 Writing Labs, Language Learning, Historical Reconstructions

The ability to create entire virtual universes that present an almost infinite range of functionalities and instructional capabilities is available to instructors today. Indeed, with a generation of students raised on video games and cell phones, speaking to them in their own language becomes of fundamental importance.

Several applications stand out as immediately amenable to the new ways of creating learning environments. Some of these include writing and composition instruction, learning a new language, and the creation of historical constructs in order to make the past appear "alive" to students studying history. These applications seem ready-made for virtual learning environments for many reasons. These include the natural displacement of location of the students and/or the instructor, the fact that many of these applications are very student-driven, such as writing, requiring only rough guidance from the instructor, as well as the problem of the subject matter no longer being available directly to the students, as in the case of the subject of history.

The early adopters of virtual teaching environments were business schools. As early as the 1950s, business colleges began requiring their students to compete in simulated business environments. This was accomplished by students feeding actual punch cards into the school's mainframe computer. The students' own programs would then compete with, and be evaluated against, other students' programs within the virtual system. These primitive methods have, of course, advanced considerably since then. The environments today routinely incorporate a graphically interactive world, sound, text, and vastly increased functionality and interactive ability. Today's MUDs and MOOs are truly interactive, artificial virtual universes.

The University of Pennsylvania employs a system called PennMOO. This MOO is loosely based on the geography of the campus of the university. It provides a virtual world in which students and teachers can "meet" and conduct educational activities. Though it is used in general for all of the university, one particular course is well structured for this type of learning style: their English 88 course. It features online assignments, virtual seminars, and virtual speeches, as well as an annual event known as the MOO Poetry Slam. This environment provides a technical emphasis to the introductory English course.

Another example of writing education being taught virtually is the CafeMOO environment developed at the University of California, Berkley. This artificial environment provides virtual office hours and other supplemental material. One of the most interesting uses, however, is that of the Humanities area of their English 108 course. Students have access to the same online facilities described above; however, the course itself emphasizes composition writing about the effects of technology on society. Required reading includes Microserfs by Douglas Coupland and WIRED magazine. Assignments are completed within the virtual world itself, which reinforces the purpose of the assignments.

The process of learning a new language is immediately ready for this type of enhanced learning. The best expertise is almost always from a foreign land (that of the language being taught), and it is difficult to disseminate this information without direct contact with these cultures. A couple of examples of online language educational environments include the MundoHispano environment and the MOOFrancais environment, both developed and maintained at the University of Missouri, St. Louis. MundoHispano is a language learning environment geared toward students whose native tongue is Spanish. Within this system there are thousands of "rooms" which represent over a dozen different countries. Each room is written by native speakers of the country it represents, thus acknowledging the many national and regional dialect differences within the Spanish speaking community. This gives participants the chance to interact with real native speakers and to communicate in terms of real-world conversation.

The MOOFrancais environment is similar, but on a smaller scale. There are over 100 rooms, each representing a different part of the city of Paris. Users can stroll virtually down various famous streets and interact with other users in French. This provides an immersive experience similar to the experience of physically traveling to the foreign country.

One of the more exciting subjects to be taught within this new paradigm is history, which is normally taught through reading and writing of prepared material with limited opportunities for hands-on or field trip experience (though trips to a local museum are common). This manner of teaching can be expanded using virtual worlds to include immersion in a simulated historical context.

An example of a system for studying history can be found in the Virtual Archaeologist/Like-A-Fishhook 3D Reconstruction, which "…[combines] immersive role-based technology with the principles and data of archaeology, ethnography, and history, … for teaching generations of students about all of these." [12]. Participants in this environment must interact with the people and geology of the time period through the virtual 3D game-like interface.

7 LambdaMOO, MacMOOse, MOOse Crossing, High Wired, and enCore

MUDs were extremely popular, but lacked flexibility for creating new virtual worlds for players to explore. Stephen White solved this problem by introducing MOOs (MUD, object-oriented), which implemented the attractive features offered by MUDs and provided players with the capability of creating new virtual environments to explore [13]. Pavel Curtis, an employee at Xerox PARC, recognized the work done by Stephen White and embraced his basic design to create LambdaMOO, a system that provided a MOO server with a MUD database [9]. LambdaMOO allowed developers to program in the MOO language to create tex-based virtual worlds. Since the MOO language is a noncompilation language and the LambdaMOO system has a small main memory footprint [14], developers can instantly view their new virtual worlds and program modifications. Another attractive quality the LambdaMOO server possesses is portability. LambdaMOO is capable of running on a number of operating systems, for instance, it can run on several types of Unix environments including Free BSD. It can also run in Windows and Macintosh environments. The most common Windows version is WinMOO [15].

On the client side, the most widely used Macintosh development implementation is MacMOOSE (http://www-static.cc.gatech.edu/fac/Amy.Bruckman/MacMOOSE/), developed by Amy Bruckman (discussed briefly later in this section). This is a client GUI interface that allows developers to program in the MOO language and to access properties and verbs of specified objects, which they can modify, add, and delete [16]. Since MacMOOSE provided these attractive usability features for programming, it was later embedded in the MOO client, tkMOO-light [17], which provided programmers the option of "graphical" programming using the MacMOOSE "out of band" protocol on Windows client machines or programming from the command line.

Users connect to LambdaMOO via telnet, ssh, or these MOO clients. Once connected, LambdaMOO provides the users with vast user control and freedom. Users have the power to create their own virtual rooms with furnishings. They also have accessibility where they can navigate from room-to room by providing text-based navigational commands. Users have the ability to view other users, their description, and location. A user can communicate with other users by "shouting," where all connected users receive the instant message, which is generally viewed as rude unless the message has system-wide implications, such as a server shut-down event. A user can also communicate with only the players residing within their current room or whisper privately to a specific user. LambdaMOO also provides emoting where users can express emotions and physical actions to other players. As a result of these appealing features, LambdaMOO increased the number of popular MOO hangouts available on the Internet [18].

LambdaMOO also provided researchers and software programmers with the ability to develop new exciting educational tools and software such as online writing centers, electronic classrooms, cyberspace campuses, and educational games. Educational tools and software implementing LambdaMOO can be text based or, with software extensions, graphical.

An example MOO educational system, the MOOSE Crossings (http://www-static.cc.gatech.edu/elc/moose-crossing/) was developed as a research project and than later as a doctoral dissertation by Amy Bruckman while attending MIT [19]. MOOSE Crossings provides educators with an additional tool to help students improve their reading, writing, and programming skills by using a learn through experience approach. Students become more engaged and interested in reading, writing, and programming by using their own creative imagination to develop virtual reality worlds using words and programming.

Another freely available tool, enCORE (http://lingua.utdallas.edu/encore/) is open source software that packages LambdaMOO and MacMOOSE utilities, created by Jan Rune Homevik and Cynthia Haynes [20]. EnCORE is an online system, with a server-side client, Xpress. Xpress is an optional GUI interface that allows users to view MOO environments. However, if users do not want to use Xpress, they can connect through telnet or the other available MOO clients. EnCORE follows the same learning approach emphasized by Bruckman, the learn-by-doing approach, which provides users with the means to create and modify objects and practice programming in an object-oriented language. It empowers educators by providing an educational tool they can use in collaborative learning, such as group projects or other methods such as distance learning or online conferencing.

Author's note. The textbook, High Wired: On the Design, Use and Theory of Educational MOOs [18], provides more information about MOOs and MUDs and the software and systems spawned from them It consists of collected essays from well-known individuals in the MOO and MUD community. This collection of essays provides answers to MOO and MUD-based questions and their usefulness in education. First, it covers the history of MUDs and MOOs and then provides a technical explanation, where readers can learn the step-by-step process for installing and setting up an MOO successfully. Afterwards, it provides the reasoning behind why MOOs are useful in education and MOO communities.

8 Professional Spaces

Professionally oriented MOOs have evolved alongside those in academia. These MOOs offer all of the same functionality and advantages of their educational counterparts, but are geared toward a more professional user. By offering more advanced services to an experienced clientele, the professional MOOs available today will often surpass their educationally oriented counterparts.

Professional MOOs offer a collaborative environment for people wishing to communicate with other people, when everyone involved has a rather advanced grasp of the topics discussed within the MOO. This is in contrast to the educational MOOs, in which a large number of users who are relatively naïve in the given subject receive instructions from a few users who are very knowledgeable in that subject. For instance, in the case of the TAPPED IN system, the focus is on educational professionals (teachers, lecturers, etc.) and getting them to share knowledge, skills and techniques.

There are many examples of this type of MOO, both mature (fully functional), and in development. Most of these revolve around a central theme, usually an academic field of research. A few of these are MediaMOO, BioMOO, and the TAPPED IN system. Within these environments, experts and professionals share information on research projects, as well as general information and the latest developments within the respective fields. Often, these meeting places are invitation only, and the requirements for membership generally include a relatively advanced standing within the field (for instance, graduate student, researcher, teacher, etc.). This is done to assure a higher level of expertise among the participants, which can in turn foster further advances in the field without having to "catch anyone up."

The first of these, MediaMOO was developed by graduate students for graduate students. It is associated specifically with media-related disciplines and the research being conducted within those fields. This project was started in 1994 by Bruckman while a graduate student at MIT (previously discussed in this chapter) and is now hosted at Georgia Tech. According to the MediaMOO Web page, "MediaMOO is a professional online community for media researchers. It is a place to come meet colleagues in media studies and related fields and brainstorm, to hold colloquia and conferences, and to explore the serious side of this new medium." The requirements for membership are simply that one needs to be working on research in a media-related field. "The requirement that members be actively involved in research is more rigorously enforced, as this is a professional community." [21]. Discouraging people with only a passing interest in the subject matter ensures the content of the MOO will not be diluted in some way.

Another example of a professional MOO is TAPPED IN. This system, created by SRI International, is geared toward education professionals who can collaborate and share ideas and techniques. It is not for students, but rather a place for teachers and educators to refine their knowledge. Members include an international community of K-12 teachers, librarians, teacher education faculty, and education researchers. These professionals collaborate on professional development programs and informal workgroup activities with other members from all over the globe.

Within this virtual environment, educators can plan and conduct projects with colleagues and students, participate in (or lead) topical discussions, conduct and attend courses, find resources, experts, and new colleagues, serve as resources for other educators, or try out new ideas in a safe supportive environment (http://tappedin.org/tappedin). The TAPPED IN system has many ways for its members to collaborate, including custom-mized virtual buildings with public, group, and personal rooms [22]. There are various methods by which users can communicate with each other. These include virtual meeting rooms, private messaging, discussion boards, and a built-in message delivery system similar to email. Of immense convenience is the feature that provides for file and URL storage within the virtual meeting rooms.

Another example of the many professional MOO projects being developed is BioMOO. This MOO is an ongoing project of the BioInformatics Unit of The Weizmann Institute of Science in Israel. BioMOO is a professsional community of Biology researchers. "It is a place to come meet colleagues in Biology studies and related fields and brainstorm, to hold colloquia and conferences, to explore the serious side of this new medium." [23]

This resource is a forum for professional biology researchers. The members create colloquia and conferences, as well as share research ideas and information and brainstorm about biology and related fields. This MOO claims to be the most technologically advanced MOO of its type. "The BioMOO is one of the most successful MOO for communities of researchers. On a technical level, it has one of the most (if not the most) enhanced environment. Unlike the MediaMOO, it offers a WOO environment using interactive maps, databases with very simple search systems, etc." [23]. A "WOO" is a World Wide Web connection to an MOO. The most successful application of BioMOO has been online seminars. These are particularly amenable to the online meeting format and have proven productive and efficient. Transcripts of these seminars are recorded, and can be accessed via the Internet by anyone.

In addition to its core function in the fields related to biology, BioMOO also operates as the virtual campus for the Global Network Academy (GNA). The mission statement of this nonprofit organization is to open the academic world to anyone, anywhere. BioMOO provides the online virtual meeting spaces used by GNA to reach students all over the world who are then provided with social networking resources as well as advice and instruction.

The future for these and similar systems is bright. As network speeds, computing capacity, and sensory peripherals (user input devices) improve, the virtual collaboration experience is likely to improve. Already, great strides have been made in eliminating the physical-distance barriers between people. In the future, we can expect to see increases in these immersive technologies as a means of staying connected to one another in professional and personal realms. The potential for bringing together different ideas from different parts of the globe in a synergistic, cooperative manner is seemingly limitless. Having disparate experts in disparate locations could become a problem of the past.

9 Immersive Virtual Environments for Education

Constructivist approaches to education hold that true learning occurs when learners construct their own meanings about a given topic. Such constructions are thought to occur best within authentic scenarios for learning. For IVEs, authenticity has two major components. First, at the system scenario level, authenticity means not duplication but reflection of the dynamics of practical contexts [24]. In this way, it does not matter that Planet Oit of the Geology Explorer (described below), is fictional. Second, authentic at the individual learning level means agreement by the student to participate in the simulation scenario by means of a social identity and its component status and role.

This is a style of learning in direct contrast to traditional classroom learning. It requires the student to act a part and to suspend disbelief in the unreality of the virtual context [25]. For some students, this nontraditional approach to learning at first can be disconcerting. Nonetheless, by assuming roles, students partake in a simulation that provides meaningful experiences at multiple levels within an educational setting. These experiences in the IVE are designed to take advantage of enculturative conditions within socially situated environments.

We view these IVEs for education as the natural evolutionary outcome arising from the historical progression described above. What follows is a description and discussion of the current state of the art in IVEs for education.

Author's note. The World Wide Web Instructional Committee (WWWIC) at North Dakota State University (NDSU) is a multidisciplinary group of faculty, staff, and students, working together to study learning in the context of multiuser virtual environments. The WWWIC group is composed of computer scientists, biologists, anthropologists, geologists, statisticians, and learning specialists. They WWWIC have developed a number of research artifacts, described below.

9.1 Dollar Bay

Dollar Bay is a fictitious seaside town intended to teach the principles and practices of retailing. To join the game, a player creates a character that is then assigned retail space and a starting budget. The player's goal is simple: Make more profit than other store owners in Dollar Bay. However, the simulation presents a formidable and invigorating challenge. The economic environment is sensitive to a number of factors, and players must adapt to changing market forces. Perceived demand changes as other players enter the market and the game simulates seasonal effects on consumer purchasing. Dollar Bay players must anticipate these and other trends along with socioeconomic factors in order to adjust their business and keep it thriving. Depending on the success of their business decisions, a business might fail and be reaped, or succeed, and be inducted into the Hall of Fame [26].

Dollar Bay uses an intelligent tutoring system to oversee and guide the student's learning experience. The overall goal of intelligent tutoring is to implement context-sensitive advice within multiuser distributed simulations to help provide effective learning experiences [27]. The tutor is able to both guide students having difficulties and identify students who have made lucky guesses and let them know they did not follow the proper process in getting to their answer. Dollar Bay uses both rule-based tutoring and case-based tutoring.

Rule-based tutoring in Dollar Bay functions by maintaining a simple set of rules about the domain, monitoring student actions for any indication of breaking one of the rules, and then visiting the student to present a warning. For example, one rule concerns whether a student has set their prices to an excessive markup. In such an instance, the tutor sends a message to the student informing them they may be setting their prices too high [28].

Case-based tutoring provides an analysis of student behavior based on selected attributes and classification and advice based on comparisons with previously stored student records. The case-based retrieval attends to attributes such as product spread and advertising quotients. This system provides the means to generate personalized lessons for each student participating in the Dollar Bay environment [29].

Dollar Bay is available to play at http://dbay.ndsu.edu.

9.2 Blackwood

The Blackwood project is the NDSU WWWIC's first attempt at creating a "next generation" role-based virtual environment for education – one where the pedagogical simulation will support cross-disciplinary content and a choice of roles to promote player interaction and collaboration. The project is intended to teach Microeconomics and American History through the simulation of a typical nineteenth century Western town.

Like Dollar Bay, Blackwood aims to provide an engaging context for immersive, role-based education in a platform that teaches business-oriented problem solving in a hands-on, learn-by-doing, pedagogical style. However, unlike Dollar Bay's static environment, Blackwood simulates the historical events surrounding a mythical small town in the American Old West during the early 1880s. By implementing these historically accurate events, users are able to experience the effects of history on the economic environment first hand.

The Blackwood game has players join the simulation and assume a specific role in the virtual environment. Instead of having all players vie for a portion of the same economic market, players choose a role and become providers of specific goods or services. For example, you can choose to be a blacksmith, leather worker, dry goods merchant, or a wagon maker. This allows players to compete for market share against other players or software agents trying to learn the same role in the simulated environment.

The game is designed to impart the time-independent principles of microeconomics and the practice of retailing within a historical context, and to promote the social and symbolic relations that sustain a business culture in the long term. As the simulation progresses, players learn their role in the environment and see the results of their actions as well as the impact of other player's actions within the constraints of the simulated world. Students are immersed in an authentic context, assigned authentic goals, given an opportunity to learn to operate in a historical context, and learn about culture and society while at the same time developing historical cross-cultural awareness and understanding [27].

To implement this comprehensive economic model with an authentic historical context, the simulation covers a six-year period from spring of 1880 to the spring of 1886 where events in the simulation track actual events that occurred in the 1880–1886 time frame, with one day equivalent to about three weeks in the simulation. The model's economic trends reflect the impact of western expansion, the discovery of mineral deposits, population fluctuations, weather, the introduction of new ideas and technology, and the coming of the railroads.

The Blackwood environment is populated by a number of software agents. Customer agents that represent the demand of consumer groups of the time: Settlers, Farmers, Ranchers, Soldiers, Laborers, Miners, etc. Merchant agents represent the supply of business in competition with human players. Employee agents see to the daily operation of the players' establishments and conduct the actual transactions with the customer agents.

The Blackwood project's home page is: http://lions.cs.ndsu.nodak.edu/~blackwood/.

9.3 The Virtual Archaeologist Project: Like-A-Fishhook

The Virtual Archaeologist project is an immersive three-dimensional (3D) educational environment that presents the science of archaeology in an intellectually engaging way by simulating the real-world conditions of an archaeology excavation. The goal is to develop an authentic simulation of an archaeological site where students experience the tasks and problems archaeologists have to face while conducting field research. The site chosen for the simulation is the Like-A-Fishhook village, located in central North Dakota in the United States. The village was occupied in the mid-1800s by members of the Mandan, Hidatsa, and Arikara tribes, known today as the Three Affiliated Tribes. Through the use of the Virtual Archaeologist, students can experience both the present day excavation as well as shift to the past, when the site was actually occupied, and see their discoveries in their actual context.

Archaeology is a discipline that relies on fieldwork, and students normally learn the conduct of archaeological research by taking a field course, but there are limitations to such courses. They can be expensive, often occur in remote locations and harsh conditions, and only a limited number of students can participate. Archaeology is also known as a "destructive" science and irreplaceable archaeological sites should not be used as training grounds for novices.

The goal of the Virtual Archaeologist is to overcome these restrictions and provide a means to teach students how to "think like an archaeologist" and learn to use the tools and resources available to researchers. To achieve this goal, the simulation consists of two environments representing two different time periods at the same location. The first is a representation of the modern day archaeological site and is the primary world in which the students will operate. This world consists of a 3D representation of the Like-A-Fishhook archaeological site, complete with models of actual artifacts environmental disturbances discovered. There, students are given a series of assignments and the tools and instructions necessary to carry out these assignments. Once the students have completed an assignment, they are given an opportunity to see their discoveries, in their historical context, by giving them a glimpse into the past.

The Like-A-Fishhook/Virtual Archaeologist home page is: http://fishhook.ndsu.edu/.

9.4 Geology Explorer

The Geology Explorer is one of the many multiuser IVEs produced by the WWWIC. In the Geology Explorer, players take on the role of a geologist sent to explore a mythical planet called Planet Oit. Through exploration, experimentation, and guided collaboration, students learn about geology through a process of scaffolded enculturation.

The Geology Explorer provides a vast array of geologically interesting areas to explore, with over 50 different locations and hundreds of different rock and mineral outcrops to identify using a variety of geologically relevant field instruments. Areas to explore include a variety of geologically interesting areas: Old Mountains, Young Mountains, Plains, Lake, Desert, Hills, and Seashore. There is also an interpretive module, where students apply higher order geologic knowledge to interpret how a landform was created. Students can explore numerous facets of geology education. However, simply showing them rocks and minerals will not necessarily teach them geology. They also need to know how to act like scientists – like geologists.

Geologists typically take a number of instruments with them into the field. These instruments provide a range of useful functions. Some aid in the identification of rocks and minerals, some provide information about rock formations and structures, still others are necessary to allow the geologist to get to and observe the environment.

A variety of these tools for student use are implemented in the Geology Explorer, so that it is possible to perform experiments as geologists would. For example, by using the Glass Plate, students can determine a rock's hardness, using the Pocket Transit; students can determine the strike and dip of a particular outcrop, which is useful in the interpretation of geologic landforms.

After giving students an area to explore and the tools needed to learn in that context, students need direction and instruction to maximize learning potential. The Geology Explorer directs students in two distinct, yet interdependent ways. Students are led through a series of progressively more difficult tasks, teaching them more and more about geology, and throughout these tasks; software agents tutor students on appropriate ways to approach certain tasks.

There are two main tasks in the Geology Explorer. The first, initial module is called the identification module. In this module, the student is asked to locate and identify a series of rocks and minerals. To begin with, rocks and minerals are relatively easy to find and identify. Players are given multiple hints to aid in the location and identification of their goal. Upon correctly identifying each rock or mineral, however, hints are faded, and the student is given progressively more difficult rocks and minerals. During this module, software tutors help students by pointing out what equipment the student will need to successfully identify their goal, showing the student what tests should be performed to come the correct conclusion, and explaining why their hypothesis is incorrect by pointing out contradictory experiments that would disprove its identity.

The second module is called the Interpretive Module. In this module, the student is asked to go to a different area of the planet, where an interesting geological phenomenon has occurred in the past. The student's job is to identify the outcrops in the region, create a geologic map of the area and, based on that map and other experimental data, determine the shortest length a tunnel could be driven through a particularly unstable rock area. Tutors in this module tell the students if they have missed outcrops that they should identify, help the students make a valid geologic map, and all of the tutoring help from the first module while identifying the underlying outcrops.

By giving them a vast area to explore, The tools needed to explore that area, and pedagogical support, students are able to enter the virtual world as novices, assume the role of a scientist, and come out knowing a great deal about the Earth, its geology, and how a geologist works.

The Geology Explorer Web site is: http://oit.ndsu.edu.

9.5 ProgrammingLand MOOseum

The ProgrammingLand Museum [30] is a text-based multiuser IVE, used in conjunction with a real life lecture to teach computer languages. In a real life museum, individual exhibits provide nuggets of information about a particular subject. In the ProgrammingLand museum, a series of rooms acts as those individual exhibits. To traverse these rooms, students follow a series of hyperlinks, looking at each exhibit and slowly learning more and more about the programming language being taught. As in a real museum, some of the exhibits include a hands-on activity, teaching the students how to apply the knowledge they have gained.

The ProgrammingLand museum currently has four different “wings” to explore, each covering a different programming language: C++, Java, BASIC, and LambdaMOO, the language employed by the museum itself. Instructors are able to track student progress through each of the wings, enhancing its use as a lecture tool.

The Web page for the ProgrammingLand Museum is: http://euler.vcsu.edu/pland.htm.

9.6 The NDSU Virtual Cell

In the NDSU Virtual Cell game, cellular processes are taught through simulations of the cellular processes and interactive goals. In order for students to learn the cellular process effectively, simulations require both speed and accuracy. Without these two qualities, obstacles are created to fun and learning, which may cause students to have negative attitudes toward the game.

Currently, the Virtual Cell server is transitioning from a LambdaMOO to JavaMOO server. Along with this transition come extensive modifications in how simulations are implemented. The most drastic change is moving the simulation from the server to the client. This alteration reduces network traffic between the client and server since the server no longer needs to update the client on the current state of the simulation. However, there still exists a small amount of communication between the server and client. The server provides information to the client on the number and type of molecules and complexes to reside within simulation. Once the server has supplied the initial information, communication ceases until the simulation has been manually stopped, paused, or rewound by the player or the simulation has finished on its own.

Another simulation improvement is having the client calculate the different positions for elements and molecules prior to running the simulation. This maintains simulation speed where the previous version calculated positions on the fly, causing some lag during the simulation.

Another modification addresses the creating and destroying of molecules and elements during the simulation. For example, in the Electron Transport Chain process, the NADH Dehydrogenase Complex removes two electrons from the NADH molecule. Now, the NADH molecule becomes NAD+ and two additional elements are created, electrons. During server side simulation, the electrons and NAD+ molecule would be dynamically created while the NADH molecule would be destroyed when needed. This was a complex process that created a noticeable lag in the simulation until the molecule(s) and element(s) were completely created/destroyed. In addition, destroyed molecules and elements caused another layer of complexity, due to its need for the garbage collector to collect elements after they were destroyed or remember which elements were destroyed to clean up at a later time. This is resolved by creating all required molecules and elements for the simulation before the simulation begins. Instead of destroying molecules, the molecules and elements simply become invisible and visible when notified by the client. Another improvement provides players with more control of the simulation by having additional control buttons, pause, and rewind. The rewind button allows the player to rewatch a part of the simulation they might have missed or did not understand.

These new modifications create a more robust simulation. It enables speed and timing accuracy of the elements and molecules in the simulation by eliminating obstacles in the way of fun and learning and reducing players' frustration with the simulation process. Yet, new problems arise with the transition from server to client side simulation. The current state of the client side simulation eliminates multiuser experiences, because client side simulation does not allow for two players to watch the same simulation as a result of them viewing different clients that hold different simulations. This takes away from player collaboration and players asking or providing advice to their peers. In order to allow players to view the same simulation, their clients need to know the identical simulation state event to start on. This can be achieved by one client providing information to the server and the server updating the other client.

The NDSU Virtual Cell Web site is: http://vcell.ndsu.edu.

10 Role Theory and Learning in WWWIC IVEs

WWWIC's IVEs continues to advance Science of Learning theory and practice. The approach adapted, extended, and implemented by WWWIC IVE developers is founded on a strong anthropological perspective. The disciplines of psychology and sociology, as well as education theory, drama theory, linguistic theory, and epistemological philosophy inform our dynamic perspective.

10.1 The Learning Paradigms Debate

To put the Science of Learning framework that is integral to the WWWIC IVEs in context, it is useful first to grasp the contemporary background of debate about learning and learning theory approaches and practices. Today there exist three major paradigms for learning and education frameworks. While initially focused on children and teaching, these paradigms have been extended in application to higher education and adult learning and are advancing knowledge about learning in virtual environments. These three paradigms are (1) the former status-quo model, known as the "instructionist," "instructivist," "behaviorist," "essentialist," "traditional," or "classical" model, (2) a transitional model, known as the "cognitive" or "comprehension" model, and (3) the model that has gained favor in recent decades, the "progressivist" or "constructivist" model, and its computer age subvariant, the "constructionist" model (for this last, see [31]). In this chapter, we refer to the first approach as the *instructionist model*, the next as the *cognitive model*, and the newer approach as the *constructivist model*.

These three approaches have been compared and contrasted in detail by others (e.g., [32]). Here they are generalized in broad terms and briefly compared in structural, functional, processural, and ideological terms. Arguably, these three models represent points on a continuum, with the instructionist and constructivist models discrete, and the cognitive model a transitional phase in the development from instructionist to constructivist approaches. Typically, learning situations combine various aspects of each of these models. That is, constructivist learning scenarios, themselves heavily influenced by the cognitive model, often take place as discrete learning activities within a traditional classroom institution. There exist many and varied practices and research based on these models and combinations of these models, but we deal here with idealized stereotyped synopses for the purpose of simplicity.

10.1.1 Instructionist Model

Structure. The learning environment is a formalized hierarchical setting of social actors defined as students and teachers, each with a set of tools appropriate to their rank. The student inhabits the social place of learner and subordinate, while the teacher inhabits the place of knowledge transmitter and authority. The educational environment is separate from the context within which professionals in a given domain act upon knowledge. That is, the student is exposed to information about a given subject but typically not involved in the practice of the subject itself. Evaluation typically occurs at the end of a series of lessons.

Function. The students are to learn new material and gain new knowledge, and prove the acquisition of this knowledge to the teacher.

Process. Linear. The teacher provides organized content through use of various tools and materials, including textbooks and audiovisual supplements. The student is the receptacle (*tabula rasa*) for that content, and typically uses tools of paper and pen or digital devices to gather the information provided by the teacher and the teaching materials. In other words, the teacher acts as an active transmitter, while the student acts as a passive receiver and signal repeater. Student performances in rote memorization, nomenclature use, acquisition of taxonomies of facts, and the ability to recognize these facts at any given moment are privileged. Evaluation of acquired knowledge is isolated from the field of practice; evaluation is retrospective in the sense of determining what the student *has* learned (rather than what the student *is* learning); and evaluation is done in batch mode rather than continuous and conterminous to the learning process. Evaluation usually is accomplished through formal examinations.

Ideological Basis. Repetition is key to learning. Recall and practice (changes in behavior) are evidence of learning. Learning is the addition of more and more information and associated skills into a solid whole. Cognitive ability principally is linked to age while cultural context is ignored or de-emphasized.

10.1.2 Cognitive Model

Structure. The learning environment is similar to the instructionist model.

Function. The students link new material to previous knowledge, thus readying themselves for the addition of new knowledge to be gained through activities that will solidify and expand the connections between what was previously known and what was recently learned.

Process. Linear within recursivity; an oscillation between linearity and circularity. The teaching processes are similar to the instructionist model. However, the student is not an automaton but recognized as a selective filtering agent who organizes and connects new knowledge to his or her own individual existing knowledge and knowledge structures. Most crucial to the model, the student will *retain* data significant to that individual, for whatever reason that significance exists. Feedback is important to the process both as a way to impel the recursive nature of cognition and as a way to affect or counter the sociocultural context of learning. In other words, the teacher acts as an active transmitter and feedback mechanism, while the student acts as an active (rather than passive) receiver. Short-term memorization is quickly lost, while long-term comprehension focuses on a subset of the input received. This occurs, in part, through the student's use of the classical student tool kit (note-taking, oral explanation, etc.) referred to by researchers as elaboration activities. Evaluation of acquired knowledge is similar to the instructionist model with the added emphasis on feedback from teacher to student.

Ideological basis. Thinking (cognitive processes) is key to learning. Recall, reconstruction, inference, and praxis (practical conduct) all are evidence of learning. The sociocultural context of learning will influence what is learned. Learning is the resolution of comprehended information into advanced knowledge. This involves the cognitive placement of the comprehended material into existing Webs or schemata of knowledge already organized by the student in her or his mind. Overall knowledge as well as knowledge structures simultaneously are modified, either enriched or changed, by this new knowledge.

10.1.3 Constructivist Model

Structure. The learning environment is a simulation of real-life contexts in which problems are embedded and knowledge is gained, used, and (re)created (commonly referred to as situated, genuine, or immersive environments). Hierarchy exists but is not the only powerful factor – structures may be vaguely defined, problems typically have duration and complexity, and problems may reformulate into new variations. Often the student is placed at the rank of entry-level professional among a cohort of other entry-level participants – cooperation and shared consequences exist. Evaluation of acquired knowledge is ongoing through feedback mechanisms and student reflexivity.

Function. The students are to learn new material and gain new skills through both tactical uses of knowledge and strategic approaches to gaining knowledge.

Process. Linear within recursivity; an oscillation between linearity and circularity. Role-play and collaborative construction of knowledge. Evaluation through peer communication, self-assessment, and feedback from expert agents, as well as normative testing, is continuous and conterminous to the learning process.

Ideological basis. Cognition is adaptive, recursive, reflexive, and socio-culturally situated. Learning and practice are active social processes occurring within relevant enculturating contexts. The student is presumed to be the active constructor of knowledge. When learners dynamically engage with new resources and data in ways that require reflection and cooperation, new knowledge can be gained and acted upon. Pragmatism, especially in the sense of learning-by-doing, is the guiding principle, with the idea of "scaffolding" to increasing levels of complexity driving the learning process. The computer age subvariant of this approach is the *constructionist* school. Constructionist approaches involve students actually creating games and other educational materials as the vehicle for learning. Inverting the equation of a student learning by playing a game, constructionists argue students learn by creating the game or other materials themselves.

The basic premise of constructivist learning theory as informed by cognitive theories (heavily influenced by the work of Swiss psychologist and philosopher Jean Piaget) is that individuals piece together understanding by reference to their own comprehension of materials and to their own individual experiences, a process involving, among other factors, qualitative transformation of individual understanding (see [33] for an edited volume considered to be the mainstay of the constructivist approach. For criticisms of the approach, see [34, 35]).

Our version of the constructivist approach attempts to align both the socially situated nature of knowledge and the individual construction of knowledge through the use of immersive role interaction in an authentic virtual scenario setting. MUDs lend themselves to immersive experiences, and the WWWIC research agenda has focused on capitalizing on this through promoting roles within exploratory science learning experiences. In this way, performance and construction of knowledge are primarily under the control of the student, with evaluation of student learning occurring both within the IVE as immediate feedback through embedded assessments and interaction with intelligent agents or tutors, as well as later, post-IVE, through more traditional retrospective quantitative and qualitative analyses by the instructors. The driving theoretical parameters in the WWWIC IVEs for student learning are performance of role, authentic scenarios, and enculturation processes.

10.2 Role Theory

Since the 1960s, roles and role-playing have become an increasingly important component of the "progressive education" or cognitive and constructivist paradigms. While roles are commonly used in a variety of teaching situations, from elementary education to on-the-job training, the theory behind roles is rarely articulated. Here we summarize briefly role theory: what roles are, how they work, and what can be expected from them.

Roles really are a component of social identity. *Social* refers to the material and symbolic interaction of the individual and the group. *Social identity* is a theoretical construct defined by status and role and is part of the theory of social organization. *Social organization* refers to groups of people interrelated in a particular arrangement and is based on ideas (shared generally by members of the group) about the group's membership and associated identities.

Social identity involves status and role. *Status* is the structural component of the identity; it refers to categories or taxonomies of group membership. Statuses, as social structural places within a group, typically have labels, such as mother, boss, significant other, student, geologist, white, Native American, woman, boy, rich, middle-class, educated, criminal, and so forth. Statuses are either ascribed or achieved. *Ascribed* status is assigned to a group member without the participation of that member, in other words, the individual has no control over the initial giving of that status to oneself. Typically, ascribed status deals with larger taxonomies in the social organization, such as ethnicity, class, or other attributes assigned at birth, depending on the social organization of the group under study. In the WWWIC IVEs, participants initially are given an ascribed status, but the remainder of their social identity is up to them. For example, in the Geology Explorer, participants initially are ascribed the status of Geologist.

Achieved status results from the actions of an individual, such as student, criminal, boss, and so forth. Achieved statuses are created within the IVE by the participants through their performance and reflection on that performance and the performance of others within the IVE. Achieved status is the primary social identity at work within IVEs, resulting in varying levels of prestige. Prestige refers to social value associated with functional and dynamic aspects of social organization, especially role.

An abstract construct or idea created and shared by a social group, a *role* is a general and flexible *set of rules for behavior associated with a particular status.* Hence, *role* is the *dynamic aspect of a social identity.* What makes role dynamic is that *it is performance of the status.* Performance of the status is the driving experience of students in IVEs.

For example, in the WWWIC IVE Geology Explorer, students take on the status of “geologist” and perform the role of “exploring geologist.” However, this role performance is not as straightforward as it appears. Roles are reflexive, involve self-reference during and after an act, and can affect the actor. Because roles are reflexive, they are dynamic, and open to improvisation, to self-assessment, and to shades and degrees of variation as created and practiced by an individual.

As students new to the Geology Explorer IVE adapt to that IVE and gain increasing comfort with their status and role, they will be focused on learning the IVE tools and a specific tactical approach to their role. In contrast, experienced students who have been in the Geology Explorer several times no longer may be concerned with figuring out how to move about or communicate with others within the IVE. They have mastered those types of activities, and so they may begin to focus on developing a strategic approach to complete the overall set of assigned problems. In so doing, these students become more advanced “exploring geologists” than the first-time users. These students often will self-assign a second status to themselves, that of advanced user, and associate with this new status a higher prestige than that which this student now associates with the brand-new user. In this way, the initial static social organization of the IVE is reconfigured to include achieved as well as assigned statuses. In this way, students effect a new social learning environment within the IVE. This newer social organization form works to make the students feel comfortable with their social identity within the IVE and advances their ability to reflect and analyze their performance based on on-going change. Students move from analyzing their utilitarian use of tools to creating a strategic approach to the problem set they are to perform.

To summarize, by relying on the dynamic and reflexive nature of role performance, IVEs teach more than “how-to” knowledge. Students gain not only a utilitarian tactical approach to a specific problem, but also a strategic approach to a class of problems. In this context, performance and construction of knowledge is primarily under the control of the student.

10.3 Performance Theory

In the WWWIC IVEs, student performance depends on ever-increasing knowledge and the ability to successfully interpret and practice the role associated with the virtual environment. Performance theory in anthropology describes how social actors use the dynamics of social interaction to create or produce outcomes on others and themselves.

Performances are reflexive, where learners learn about themselves [36, p. 81]). Performance theory is characterized by a concern with the productive force [37, p. 567]. Role performance directly affects the learning dynamics of a student in an IVE. More than mere goal-oriented "doing" of a task, role-based simulation learning is learning-by-performance.

Role performance learning is driven by individual experiences and "other-dependent learning" in both the virtual and real-worlds. Other-dependent learning involves "conditions of informally guided discovery" [38, p. 186]. "Others" in the IVE environment include software tutoring agents whose virtual behavior takes the form of powerful hints and occasional correction that is critical to other-dependent learning. Similar learning theory is found among business management theoreticians, who emphasize the role of people who are "third party brokers" and "go-betweens" [39].

In WWWIC IVEs, learners experience reflexive cognitive performative encounters. "Reflexive cognitive performative encounters" are social interplay that produce affects either on the performer or on the other social actors [40], such as when students are self-conscious of their language interactions and usage, and perceive their role as one "to display for others" a certain grasp of specialized concepts and language. For example, advanced students with experience and expertise may share with less-experienced students strategies for approaching and completing problem within the IVE. The teacher–student affects not only the performance of the less-experienced student, but also enriches his or her own understanding of the problems facing the IVE participant. This is similar to what educators discover as they teach a topic, that they themselves learn more about that topic through their interaction with students.

The performative aspect of the IVE experience allows us to move beyond simplistic analysis of whether or not a student's work is correct or incorrect and is indicative of change in learning levels [41]. For the virtual learner, performative social interaction develops and changes as the student progresses through levels of understanding and learning [42, p. 182]. This type of performative encounter has been observed in other learning situations, such as mathematics classes [43] and drama classes [44, 45].

Performance of social identity in the IVE, therefore, includes not only the accomplishment of set objectives, but also the enriching of the IVE environment itself. The socially situated learning environment is performed, not merely inhabited. Performance, therefore, creates the dynamic necessary to authentic learning scenarios.

10.4 Enculturation and Learning

Repeatedly, cognitive, and constructivist theoreticians stress that learning is socially and culturally situated. Just what does this mean? It means that learning is not divorced from the reality of a person's life and their place in the unfolding story of humanity's existence and condition. More specifically, it means that, fundamentally, individuals have individual agency, that is, they are able to think for themselves and decide for themselves what behavior and actions they will undertake. Such agency, however, is always located within a social context that has historical influence on the actor, reflecting both informal social norms and formal rules for action shared by a given group. This social context, its material, symbolic, and dynamic aspects, can be understood as enculturative conditions.

Enculturation classically refers to the processes by which a human group's ideas and behaviors are passed from one generation to the next. It is a fundamentally social process by which individuals adapt to their environment and learn to fulfill the function of their statuses (social identities) through the learning and performing of associated role behavior (rights, duties, and obligations). In contemporary anthropological usage, enculturation generally refers to the learning of a culture in terms of behavior and symbolic content, including belief systems [46]. Enculturation combines experiential, empirical, and propositional knowledge. It is an adaptive and cognitive experience that uses material context and content and symbolic context and content to bridge the gap between cognizance of new ideas and practice relying on those ideas. [Enculturation is sometimes given as a synonym for the sociologist's term "socialization." The difference in these terms is beyond the scope of this chapter, but it is important to note that we use the term enculturation because we are emphasizing not a conditioning process but an adaptation process.]

For instance, students accustomed to expensive private schools share a historical situation and worldview different from students in underfinanced public schools. Thus, in an IVE setting that brings people from such diverse backgrounds together, norms and rules are not evenly shared among members of the IVE social setting. On the one hand, hegemony of Western educational cultures means that much behavior by individuals in the IVE can be predicted. On the other hand, there is room for much variation in behavior patterns. Original thought and behavior that may be based on intent to do what is not considered socially "normal" can occur. From this, we get creativity. This creativity is not always thoughtful nor polite nor even successful in its intent, but when it is, originality and advancement can be produced that affects the whole group, not just the individual.

Therefore, IVEs developed by WWWIC work to promote an over-arching social situation by creating enculturating conditions intended to harness the creativity of individual agency and guide that creativity to efficacious outcomes. The enculturative conditions include, among others, the structural contents of the IVE itself, the structured and unstructured dynamic interactions among students and others, and the material and physical interaction of students with the system. Even in fairly passive interaction with an IVE, students are constrained to dealing with the enculturative conditions present.

The catalyst that transforms the virtual world and its component enculturative conditions into a learning experience is role performance. Because the virtual reality is embedded within everyday reality, the student's understanding of the virtual problem is transferable to real-world problems, using the same classes of psychological and social processes that are associated with individual learning through problem-exposure [47], unceremonious social coaching [38], and innovation diffusion within a cultural system [48]. It is the ability of the individual to adapt to a new cultural system by assuming a new social identity (role, status, and prestige) that drives the IVE [49]. This choice is conscious on the part of the students, whether or not they recognize all the ways in which the virtual system has been organized to filter their attention directly to learning practices through enculturative conditions.

In summary, we are building and enhancing learning environments that takes both collective activity and the individual experience into account. WWWIC IVEs have been engineered to provide enculturative conditions that focus the students attention on learning specific practices while at the same time comprehending strategic approaches to a given discipline. Unlike life in the classroom, there is little to distract the student from their performance. Furthermore, our work advances two theoretical stances in the Science of Learning (1) IVE cultures are not simply prototypes or mimicry of "real-world" culture. Through social interaction among learners inside the IVE, the IVE becomes a culture system just as "real" as cultures of the classroom. As such, it is available for critical study of learning structures and processes at both the individual and the system level. (2) IVE culture can be designed for learning sciences experimentation – we can develop hypotheses and engineer changes in the IVE culture to test hypotheses.

11 Software Tutors in WWWIC IVEs

While completing their goals within WWWIC IVE games, students may encounter difficulties. A tutoring system that provides guidance without deterring the student's ability to independently draw conclusions has been developed.

The current tutoring system consists of several software agents and a primary tutoring agent, identified as the Tutor Controller. The multiple software agents are goal-specific and handle independent tasks while the Tutor Controller distributes information regarding student activities and progress to the appropriate agent. Student history information is*** stored so tutoring agents may draw conclusions based on player activities, such as when students need help. Once an agent perceives a student needs help, the agent determines the type of help needed and chooses a remediation response. Typically, tutor responses are classified into several categories where each category represents a possible student behavior in attempting to complete the goal. For example, in the Organelle Identification module of the NDSU Virtual Cell game, one response category is a successful goal completion, where the players must choose the correct assay to perform an experiment on a subcellular organelle and then correctly identify the component. After a response has been issued, the response is used in selecting a remediation. The chosen remediation is displayed to the student, encouraging student thinking and guiding them toward using the resources of the Virtual Cell game. When repetitive student behavior occurs, the remediations become more detailed, providing additional insight for the student.

12 Technical Issues with Current IVEs

The aim of this advanced learning technology project is to move beyond the laboratory and venture into the realm of serious games and systems for real-world deployment. Research in this area is essential to this progress. To make these improvements, it is necessary to leave behind the rapid prototyping systems that got us here, and move on to more advanced learning technologies. This means moving beyond LambdaMOO [9] and onto the next generation of learning systems.

LambdaMOO is a dynamic, real-time, network-based simulation environment built on an object-oriented database, with an interpreted object-oriented programming language. The LambdaMOO platform was used for WWWIC's original suite of educational environments and has many fine qualities, including the ability to replace and compile individual methods on objects without recompiling any other parts of the application. LambdaMOO also features a fail-safe mechanism for canceling runaway processes but the overhead involved in monitoring all these executions is considerable and creates obvious inefficiencies in production systems. Further, and most serious from a performance point of view, the LambdaMOO execution environment is purely interpreted, unlike modern Smalltalk or Java environments; LambdaMOO is a basic byte-code interpreter without any support for just-in-time compilation or similar improvements. Due to the small size of its development community, it is unlikely that LambdaMOO will become competitive with other more popular interpreted languages.

Source code control is also a serious problem in development environments of this type. There is no facility for checking code in and out beyond a cumbersome and somewhat baroque system of ownerships and permissions. Nor is there is a facility for version control or change conflict resolution. In fact, LambdaMOO provides no built-in support for file handling of any sort. The only way to write and replace code is to enter it at the command line, or "send" code with one of the freely available editing clients. Therefore, all code in LambdaMOO is equivalent to the "stored procedures" implemented in a distributed database, where the state of the art is to fashion updates that are tested in a development "mirror" of the database and then uploaded to the "live" server during maintenance periods. In this mode of operation, source code and version control are relegated to external offline processes.

There are also no facilities in LambdaMOO for the type of development support that modern software developers expect: clickable reference to inspectable objects, visual interfaces for managing classes and methods, even editing applications with convenient indicators for bracket matching, and variable references. In addition to the issues already mentioned, there is no facility for synchronizing mirrored MOOs, and consequently no way to fully protect against a network outage. Nor is there a way to support a distributed approach where code and data are protected against all-too-common server crashes and network accidents. These common elements are increasingly necessary as applications grow and evolve, and LambdaMOO suffers from their absence.

13 JavaMOO Technology for Education

JavaMOO is a framework for building virtual worlds used for educational purposes, intended to replace LambdaMOO, which served as the implementation platform for WWWIC's original suite of educational virtual environments.

While LambdaMOO provides the essential functionality needed for building educational virtual worlds, it has many drawbacks that inhibited the development and distribution of large-scale environments. JavaMOO was written to address those drawbacks, and further facilitate the creation and deployment of educational virtual worlds.

The JavaMOO framework consists of (1) a suite of servers providing a reliable and robust environmental simulation and managing the interaction of dozens of connected students, (2) an application programmers' interface (API) for building an application-specific client that presents the state of the environment and allows students to interact with the environment and each other, and (3) a Data Collection Server which collects server information and tracks student progress in each game. All of these components and how they communicate with each other. This framework provides teachers with a self-contained package that is easy to set up and use, along with maintenance functions that allow instructors to track student progress, and WWWIC to monitor the status of the server.

The server of a JavaMOO virtual environment actually hosts a set of servers. The central component is the JavaMOO Server itself, which is responsible for executing the simulation, handling communication with clients connected to it, and communicating with the database to store and retrieve simulation and environment data. JavaMOO provides a set of foundation classes that form the base of the JavaMOO server. The game developer builds the simulated environment on top of this base. The foundation classes handle all the client communication and data storage, so the game developer does not need to worry about these features.

The JavaMOO server package comes with an SQL database, which the JavaMOO Server uses to store and retrieve simulation data. Account information is also stored in the database. While nearly any SQL server would work with our system, JavaMOO comes with the Apache Derby SQL database. By using an external database, JavaMOO has quick and reliable access to the data it needs.

Client/Server communication is handled using Java's Remote Method Invocation (RMI) system. In order for a client to connect to the JavaMOO Server, the server must first register with an RMI Server. The client then contacts the RMI Server to establish a connection with the JavaMOO server. Once this connection has been established, the RMI Server is no longer explicitly addressed.

The JavaMOO server package also comes with Tomcat, an HTTP server, which is used to host a Registration Server and a Media Server. The Registration Server is used by the client to create new accounts, and ask students to fill out surveys with demographic information and knowledge evaluation. This information is used to track student learning and provide data for larger studies. The Media Server holds images, animations, and other media used by the client. By storing these images on the central server, they do not need to take up storage on the client computers. This system also allows the game media to be updated without reinstalling a new client or rebooting the JavaMOO Server.

Together, these components make up the JavaMOO server package. A single server is created for each game being played by each class. Currently, this server is being tested by WWWIC as the future of IVE development.

14 The Future: Group Play

As to the future, we predict the next "big thing" in IVE research will be *group play*. Cooperative learning provides many benefits, both short and long term. In a cooperative environment, students depend on each other to do well and provide support in order to succeed themselves. Cooperative work increases self-esteem, time on task, and altruism while decreasing disruptive activity [50]. Giving students the opportunity to work in groups provides experiences in supporting skills useful throughout both personal and occupational lives. Brown, Collins, and Diguid [51] argue, "If people are going to learn and work in conjunction with others, they must be given the situated opportunity to develop those skills."

Group work in virtual worlds involves three components. First, students and/or teachers need the ability to create groups. Second, these groups need a variety of communication mediums, both synchronous and asynchronous, to allow exchange of information and ideas among present and not present group members. Third, goals must be available for groups to complete, evaluation must be ongoing and accurate, and rewards must be present for people who choose to form groups. Players with a group-centric set of goals employ constraints that map into Kagan's four primary principles for effective group learning: positive interdependence, individual accountability, equal participation, and simultaneous interaction [52].

15 Conclusion

The evolution of MUDs and MOOs extends back to the days of main frame computers, paper tape readers, punched cards, and so-called dumb terminals. This chapter has traced that evolution through the successive generations of MUD/MOO use, culminating in the state of the art as it exists today in education. IVEs for education holds the potential to alter the way students learn by doing. The IVEs described above provide a safe method for students to experience learning and learn through experience. These hold the further potential to bring learning opportunities to students that might otherwise lack the opportunity. One of the many opportunities involves computer mediated cooperative learning.

Cooperative learning provides many benefits, both short and long term. In a cooperative environment students depend on each other to do well and provide support in order to succeed themselves. Cooperative work increases self-esteem, time on task, and altruism while decreasing disruptive activity [50]. Giving students the opportunity to work in groups provides experiences in supporting skills useful throughout both personal and occupational lives. Brown, Collins, and Duguid [51] state it this way, "If people are going to learn and work in conjunction with others, they must be given the situated opportunity to develop those skills."

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The Development of an Approach to Learning Within the Middle Schooling Paradigm

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Summary. In this chapter, the key elements to facilitate success of an educational shift to learning within the middle schooling paradigm have been discussed. The aim of middle schooling at Kings Christian College is to provide a balanced and holistic education that meets the spiritual needs of all students as they grow to take their place in society. Effective middle schools provide a safe, supportive learning community and pastoral care is the umbrella under which all of the positive outcomes of middle schooling are achieved. This nurturing of young people according to an asset promotion paradigm, helps them to develop self-confidence, self-esteem and the capacity to contribute to the community. Since students at the middle level of schooling are working out who they are, their values, interests and abilities, they need a curriculum and learning activities that cater for this. If teachers and others involved in curriculum development organize middle years curricula so that there is a focus upon socially-relevant issues, then students are able to construct the views, attitudes and values that will lead them to behave as good citizens displaying socially-responsible behaviour. Thematic units in the middle years curriculum build students' values and interests while developing their understanding, giving them areas of particular expertise. The unified approach to teaching by using thematic units also connects learning with the real world and allows students to use skills from across the traditional curricular areas when solving problems. In our technologically advanced digital society, adolescents are substantially different from what they were in previous generations and this has profound implications for teaching and learning. Middle years students need interactive information, interactive communication and interactive resources as they process information and construct their understandings by being actively engaged in doing complex tasks. In order to use technology effectively

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to achieve positive learning outcomes, administrators need to prioritize the need for professional development and support for teachers. Teachers have an indispensable role to play in evaluating the use of technology in the classroom so that its use is pedagogically sound.

1 Introduction

The middle years is an important time of great change when students are developing out of childhood and undergoing substantial personal growth as they develop the skills, understandings, views, attitudes and values necessary for effective citizenry in the twenty-first century.

The seeds of success are sown during this developmental stage and therefore the years of education up to year 9 are important. As reported by Heggen [1], a study by the Australian Council for Educational Research showed that strong academic performance in year 9 was one of the keys to a successful result in year 12.

In middle schooling holistic education provides the building blocks upon which our students will build their values and understandings for the rest of their lives. A person's beliefs and then views and attitudes, form the basis of their thoughts, then emotions, which lead to actions. False beliefs trigger destructive thoughts [2]. In Christian schools such as King's Christian College we aim to "educate students in Christian leadership for tomorrow's generation". Therefore, we have a great need to replace false, potentially destructive beliefs with God's truth (as revealed to us through Jesus Christ).

The nature of beliefs, views, attitudes and values is a vital consideration for teachers. The eminent researchers Bloom, Krathwohl and Masia [3] questioned whether humans ever thought without "feeling" and emphasized the importance of the views and beliefs students bring to the classroom upon the understandings constructed by these students.

The aim of middle schooling is to provide a balanced and holistic education that meets the spiritual needs of all students as they grow to take their place in society. Effective middle schools provide a safe, supportive learning community. Within this community, pastoral care groups and curricula founded upon solid Christian values enables students to develop the optimism, views and understanding necessary to shape a sustainable future by dealing responsibly with the issues which will affect their lives.

Establishing middle schooling is not a search for an end point but rather an ongoing process of examining all school practices in light of the developmental needs of early adolescence. There are many ways of providing motivation and making meaning for middle years students as outlined by Walker [4]. These include:

– Connecting or integrating the learning areas by providing themes of interest to students in order to improve the likelihood of the content arousing their curiosity.
– Ensuring that students are sufficiently challenged by tasks that promote higher order thinking and the rich diversity of students' talents and abilities.
– Providing opportunities for students to work together to harness the energy that stems from their social relations with other young people.

Pastoral care is the umbrella under which all of the positive outcomes of middle schooling are achieved. At King's Christian College, our year 8 students are cared for in home classes where activities and worship provide the foundation for the students to develop strong friendships with others.

This nurturing of young people according to an asset promotion paradigm, such as the middle schooling paradigm, helps them to develop self-confidence and self-esteem. It represents a positive contribution to the future, as the approach self-perpetuates when the current young people have children of their own.

Middle schooling represents an effective way of meeting the needs of students at a stage of development where they are undergoing a great amount of change. It is a delicate balancing act to provide for a student's need for independence within clear and reasonable limits during the roller coaster ride of adolescence. Young people are listened to and have the opportunity to experiment with new ideas within established boundaries.

I envisage middle schooling as shown in Fig. 1. Since relationships are so important to middle level students, this is an ideal time for the development of leadership skills and peer support within a caring, Christian environment. Students "learn-to-learn" in their core subjects while they try out a range of elective subjects to see what subjects they enjoy and at which subjects they are especially able.

My vision for middle schooling might well be explained by reference to the parable of the leaven (Matthew 13:33). When a small amount of yeast is added to the flour under the appropriate conditions, fermentation occurs and the dough expands and rises to form delectable loaves of bread. Like the yeast, middle schooling should have a transforming influence helping students to grow in their relationship with God, so that they are prepared for their lives as vital participants in a changing world.

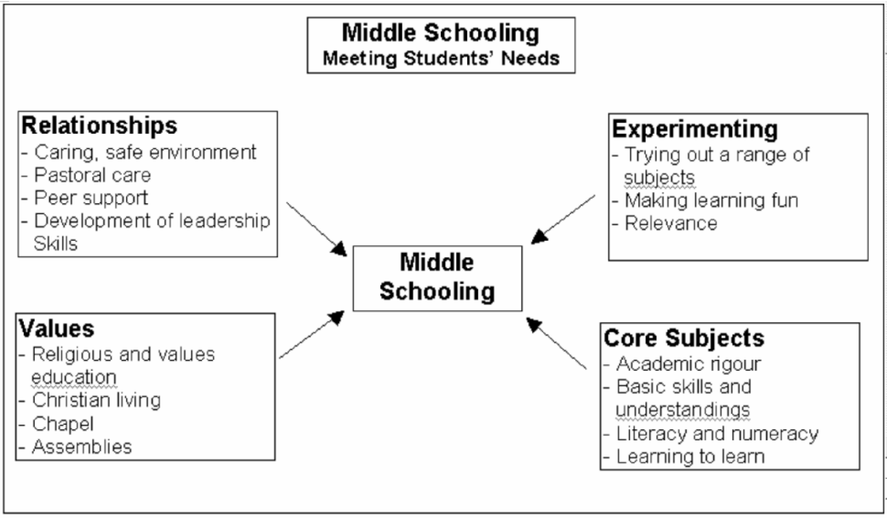

Fig. 1. Middle Schooling to Meet Students' Needs

2 Pastoral Care

The modern world is characterized by continuous change. This change has impacted substantially upon families and relationships within families. Perhaps at this time more than ever before, young people need strong support from schools during their passage to adulthood. Schools and families need to work closely together in order to provide this vital support. This support and care relates directly to the aims of schools with a strong Christian foundation.

In a middle school which encompasses year 7–year 9, a safe, caring environment where staff and students treat each other according to Christian principles enables students to develop all of the characteristics required for a happy, successful life as citizens in contemporary societies. Each student needs to be treated with respect and love following the commandment given by Jesus "My commandment is this: love one another, just as I love you". John 15:12.

The head of middle school provides leadership by guiding, inspiring and supporting the staff in caring for the students within the firm, clear boundaries of a behaviour support policy. The aim of this is to be consistent in the development of appropriate relationships between teachers, students, parents and Head of School. The model of leadership throughout this network of relationships is leadership by serving (Mark 10:43–44). As advocates of middle schooling have discussed, “Positive relationships, particularly between student and teacher, are critical for maximizing appropriate behaviour and achieving learning outcomes” [5, p. 8].

As head of middle school at St John’s Grammar School from 1999–2003, I was fortunate to have the opportunity to attend the AHISA Pastoral Care Conference in Brisbane in the school holidays in July 2002. The theme of the conference was “Family, Faculty, Fellowship and Fun – connections which count”. At the conference, the AHISA chair, Noelene Horton [6], argued that the adolescent years are characterized by the biggest shift in rules and friendships that people will face in their lives. As a consequence, the key for pastoral care is to provide opportunities for these relationships to develop between students as well as solid relationships between students and teachers. When we learn about friendships we learn about ourselves, so this is an extremely important focus for young people. As the Chinese philosopher Lao Tzu [7] said, “It is wisdom to know others”.

At the Pastoral Care Conference, one of the opening comments was that during the Sydney Olympics, there was not one serious crime committed in that city. It appears that this was because of the extremely positive spirit of cooperation and team support that was present in the community at the time of the games. A positive, encouraging environment within communities leads to support and empowerment of each other and the ability to cope with the little stresses that come with everyday life.

Therefore, in a Christian environment like those found in Christian Schools and in church schools with a strong Christian philosophy, we have the opportunity to work together to achieve great developments in understanding and coping strategies for the students. In addition to the regular cognitive learning outcomes, it is important to help students develop the learning outcomes from the affective domain such as the views, attitudes and values that help them to have the positive outlook, self-confidence and purpose that are necessary as Christian leaders in society.

Students at King’s Christian College are provided with opportunities to develop the faith that will help them to move past difficult times. Opportunities to explore and develop their spirituality are an essential part of the middle years experience. Acknowledgement of the importance of faith, hope and love underlies all that we do.

Unfortunately, not all young people have the same strong faith as the basis of their views of life. It is concerning that my study [8] of 1,278 young Australians in year 12 in 29 schools, found that a substantial proportion of these students did not hold overly positive views about what the quality of life would be like in the future. Forty percent of the young people believed that although more technology would make life easier, healthier and more efficient, this would cause more pollution, unemployment and other problems. Therefore, the standard of living may improve, but the quality of life may not. A further 8% of respondents believed that the standard of living for Australians would not improve with more technology, since we are irresponsible with the technology we have now; for example our production of weapons and using up our natural resources. A final 8% of quite disillusioned young people held the view that the standard of living for those who could afford to use technology could improve, but more technology would cut jobs and cause more people to fall below the poverty line. It would appear that these students needed help when they were in the middle years with developing positive life views, attitudes and hope for the future. These quite pessimistic views held by some young people point to the need to help students to look forward to the future with faith, so that they will be able to work with others to shape a sustainable future.

At King's in 2006, middle schooling initiatives, such as the year 9 extended experimental investigation of our school waterway, have enabled our students to understand that we are able to have a positive influence on the quality of our environment. It was wonderful to see our students working with staff from Waterwatch and Griffith University on the first stages of a longitudinal project to test our waterway. Students from King's will continue to work with community members from the Catchment Management Interest Group to have an impact upon our Gold Coast environment.

During Term 3, 2006, year 8 students also experienced an excursion to the mangroves that was great fun and enabled them to develop a positive attitude to the environment. A representative of the indigenous population explained that Aborigines have a relationship with the land and allowed students and staff (including me) to taste foods, such as the pig face plant, which are derived from the natural environment. It tasted a bit like a salty kiwifruit.

Clearly, the best possible way to achieve the academic and social outcomes and world views that schools aim for with their students is for the parents and teachers to work together. Blankstein [9] discussed the need for greater parental involvement in schools as one of the ways to ensure that failure is not an option for students. This cogent discussion of ways to promote greater parental involvement in schools and regular, meaningful two-way communication includes the following strategies:

- Providing information in regard to how parents can foster learning at home, give appropriate assistance and monitor homework.
- Informing parents of the expectations for students in each subject at each grade level.

– Providing opportunities for staff members to learn and share successful approaches to engaging parents in their child's education.
– Coordinating the use of parents' talents and interests within the school.
– Providing parents with current information regarding school policies, practices and both student and school performance data.

The most important factor influencing the outcomes of holistic education in the middle years is the quality of relationships. Grose [10] commenced his discussion of building relationships with students with "in the absence of a relationship you have nothing". Ways of building connection or rapport with students and parents, and consequently relationships include acts of affirmation, rewards, communication, acts of service and shared activities.

The relationship between teachers and students is generally with the teacher as mentor. Informal interactions in the school grounds, classroom activities and extra-curricular activities are valuable opportunities to further this relationship. This is essential for young people in Australia today, because we are one of the most mobile countries in the world in which many families rely increasingly upon schools as partners in the provision of consistent messages about boundaries and values for students. Therefore, we need to enable students and parents to have a strong bond with the school and a sense of belonging.

It is extremely important for middle schools to have a community of dedicated staff and supportive parents who are prepared to work together with the students to achieve the school aims. Parent networks in the schools, will facilitate fellowship and close associations and works within the communities.

Irvine [11] argued that most parents are on a search and rescue operation when they come to private schools with a Christian philosophy. In an overly-competitive society we have become so competitive that we can't nurture each other, and some parents are finding it difficult to nurture and understand their adolescent and teenage children. Parents who send their children to the traditional high-profile private schools are often at the top end of a competitive society and their kids compete with each other, which increases the pressure on kids, teenage depression and feelings of loneliness and isolation.

Schools should be the sites of holistic pastoral care that helps students to develop self-confidence, self-esteem and the capacity to contribute to the community. This nurturing of young people according to an asset promotion rather than a deficit-reduction paradigm is self-sustaining.

It represents a positive contribution to the future as the approach self-perpetuates when the current young people have their own children.

The philosophy of pastoral care in effective middle schools is founded upon the need to help young people develop:

1. Resilience – ability to beat the odds, bounce back, recover
2. Protection – resistance to health-compromising or future-jeopardising behaviour.

2.1 Building Resilience

There are some interesting and effective ways in which different Australian independent schools are trying to help students to develop the ability to bounce back after experiencing difficulties in their lives.

These include:

1. "Mind Matters" programme
2. "Programme Achieve"
3. Life skills developing activities
4. Pastoral Care within home groups and houses
5. Religious and Values development focus
6. Chapel/Assembly

Does continually providing students with a safety net really help them develop resilience? Certainly it is important for students to take responsibility for their own actions rather than allow parents to rush in to help them and make excuses for their children, as occurs in many schools.

I believe that it is clear that young people need to feel listened to and supported. There are a number of processes and strategies that can be employed in independent schools in order to shift the balance from vulnerability to resilience in learning and psycho-social development.

One way, as discussed by Nadge [12], is to engender a learning environment that promotes a positive self-image in students through an incremental approach that focuses upon effort and skill as well as the multiple intelligences:

- Experimental (learning on the job)
- Reflective (emotional – making meaning)
- Neural (How gifted you are)

As Nadge argued, reflective intelligence can be developed through problem solving, decision making and the cultivation of positive attitudes. In this model of linked learning and psycho-social development, cognitive and affective processes are closely linked.

The way in which teachers communicate with students is fundamental to enabling the development of positive relationships, promoting self-efficacy, optimism, or range of strategies and reasonable persistence.

It is important to remember that teachers have great power for inspiring young people and "making a difference in their lives". In order to do this, teachers must first be cared for and care for themselves. There needs to be a balance between the responsibility we bring to our roles as teachers and the need for enjoyment and stress release in some more child-like (playful) activities [13]. Family, faculty, fellowship and fun are all necessary components of our lives.

Providing students with the opportunity to explore and develop their spirituality is an essential part of the development of resilience. The importance of a faith to help both students and adults move past difficult times was clear from the AHISA Pastoral Care Conference, Brisbane, 2002 [14]. Faith enables students to look forward to the future with optimism rather than the fear that all will not be well. It enables them to feel good about themselves with the self-confidence required to take carefully considered academic risks in order to develop problem-solving skills. It means that students will not just passively accept what they believe is wrong, or false beliefs, but will proactively move forward to break free of false beliefs and work towards change [2].

In addition to these strategies to support students by shifting the balance from vulnerability to resilience in learning and psycho-social development, schools should have a co-operatively developed discipline or behaviour support policy. This establishes clear and consistent expectations of students. Consequences for inappropriate behaviour will, of course, occur in addition to the provision of counselling and appropriate support to help students manage their own behaviour. In this way our students will feel listened to and supported.

Middle school students need to be provided with wide ranging opportunities to develop their leadership skills. By way of example, the Peer Support Programme has enabled the leadership training of the schools in which I have been head of middle school or dean of middle schooling. Those students who applied to become Peer Support Leaders could further their own leadership capabilities while developing a capacity for supporting younger students in the school. Further leadership development opportunities are provided through participation in the Student Representative Council (SRC). Members of the SRC organize many successful events, including fundraising events such as teacher slave auctions and student awareness presentations for Assemblies. Everyone has a lot of fun during these events and teachers experienced many unexpected tasks. This sort of fun is extremely important in the development of a spirit of fellowship and fun within middle schools.

In Christian and church-based schools, issues relating to the development of spirituality and community responsibility can be explored in Chapel Service and Assemblies. These issues may include: globalization, resilience and elite athletes, recycling, preserving biodiversity, the plight of asylum seekers, the Australian culture, and representatives from groups such as The Royal Society for the Blind, The Gideons International and Anglicare. These occasions are extremely important for the development of values and other affective domain learning outcomes.

All of the avenues for caring for the students during the middle years conform very well with the recommendations in a report to UNESCO on challenges presented to education in the twenty-first century [15]. The author of this report, Delors, which is possibly one of the most significant reports on education in the past ten years, sees education as one of the means available to promote:

1. Personal and social development
2. A sense of common destiny through acceptance of the spiritual and cultural differences of people across the globe
3. Lifelong learning through teachers who act as catalysts to enable students to adjust to change

3 Curriculum and Pedagogy for the Middle Years

The psychologist Ericson, who wrote about the stages of development, termed the teenage years the “age of identity”. Since students at the middle level of schooling are working out who they are, their values, interests and abilities, they need a curriculum and learning activities that cater for this. As Schwartz [16] argued, the values of human beings affect the ways they organize their understandings of the world. If teachers and others involved in curriculum development organize middle years curricula so that there is a focus upon socially-relevant issues, then students are able to construct the views, attitudes and values that will lead them to behave as good citizens displaying socially-responsible behaviour.

3.1 Thematic, Transdisciplinary Units in the Middle Years

Thematic units in the middle years' curriculum build students' values and interests while developing their understanding, giving them areas of particular expertise. At King's Christian College, these units are pursued by students during the final three weeks of each term. At this stage the discussion of value-laden issues and the big questions of life are also an essential element of students' learning, and these issues can readily be explored in the thematic units.

Table 1 shows an outline of the thematic units that were first employed at King's Christian College in 2005.

Table 1. Transdisciplinary thematic units

Term	Theme	Task
1	Origins: Where did it all begin?	Students investigate the work of particular scientists and the impact of this work on our understanding of beginnings. They can choose to present their work as an oral presentation, role play, a report or a PowerPoint presentation.
2	Change: How has change occurred and what problems and benefits has this brought?	Newspaper articles written by students show how change has occurred in society.
3	Environment/Community/ World: What is good stewardship?	An excursion to the mangroves allows the gathering of data for a report on the impact of damage to the mangrove environment on the local economy and the lives of people in the community.
4	Preferred futures (choices): What is the role of humans in creating preferred futures?	A board game on a future scenario, developed by students, explores alternative energy generation sources and includes recommendations for preferred futures.

The review of the first thematic transcurricular unit by a teacher questionnaire that gathered teachers' responses to questions about the thematic unit is shown in Table 2. On the whole, the curriculum shift to develop thematic units was received positively by staff, given their extremely busy days.

It was considered very important to evaluate these units by gaining teachers' responses and involving them at each stage of the planning process, since Fullan [17] found that educational changes were more likely to succeed if teachers' views in relation to the change were collected and considered.

There were substantial positive outcomes or benefits of the thematic units that were identified by teachers in this evaluation. Perhaps one of the most effective of these was the professional development that teachers provided for each other as a consequence of needing to work together and communicate about the curriculum and student learning.

Table 2. Review of transdisciplinary thematic units

Question	Teacher Response
1. What are some of the positive outcomes/benefits of the transdisciplinary thematic unit?	Teacher 1 – More effective researching skills that can be learnt once and used in various subjects. Connecting material learnt in Science with material learnt in English, i.e. scientific method explained through a poster.
	Teacher 2 – Students had the opportunity to explore a challenging issue in a new and interesting way. Students had the opportunity to be creative and spontaneous in their approach to the task. Students learnt and practiced fairly difficult research processes that are significantly beneficial to higher learning. Working in groups some lower students were benefited by the direct support of more able/competent students. Students recognized the value of drawing on a range of knowledge areas and skills to attempt and complete task – task = reflection of future working conditions. Students also acknowledge that teachers work together in teams across subject areas and year level cohort.
	Teacher 3 – I think the combination of subjects has helped students with less assignment work, not so overloaded.
	Teacher 4 – Students seemed quite motivated by the task. They enjoyed the research time allowed them. It was a valuable lesson in extracting the correct information from the resources that they used (mainly Internet). Most worked cooperatively/very well, but there were a few instances where there was a disproportionate amount of work done by one or two members of the group.
	Teacher 5 – Good to show that all subjects link together in life. I think many students see them very separately.
	Teacher 6 – Students learning how to work together and be responsible for their work. Transdisciplinary work is excellent in terms of students learning how

	school relates to the real world and how subjects can connect. Teacher 7 – Staff communication – a few of the English/ History teachers discussed how assignments should be worded and then marked. Students do not know how to deliver an oral, but I explained I will give them some pointers, so development of skills is taking place. Teacher 8 – Peer tutoring, distribution of work, leadership skills, collaboration/brainstorming. Teacher 9 – Students learn that: there are many areas of common ground between each subject, and that it is not all about content, but more about learning skills. It gets staff working together and gives an insight into the importance of other disciplines. It gives students a better understanding of how their studies of various subjects all fit together to be relevant to the world they live in. Teacher 10 – Interesting to see what is done in English. Causes teachers in different disciplines to talk about students a bit more.
2. What were some of the problems/limitations/areas that require further development?	Teacher 1 – Planned time for work on project that matches the time required to complete. Guidelines for completing project (balanced with open-ended task). Scientific terms and ideas above some students (especially Internet resources). Teacher 2 – Some students found the task stressful. Some groups failed to coordinate group members effectively to produce adequate outcomes for assessment. Still having the problem of one student carrying the burden for the whole group. Students complained about lack of time and the requirement to coordinate each other and the task in a significant amount of their own time. This is stressful given the workload of all other subjects. Teacher 3 – I didn't have much cooperation or help from some teachers in other disciplines. Conflicting instructions were given to students. Teacher 4 – Clear expectations of the outcomes need to be established. There needs to be a more precise marking scheme. Teacher 5 – I found the Science marking criteria didn't match up with the finished product from the students.

	Teacher 6 – Lack of knowledge prior to the task. English/History teachers having a lack of understanding of scientific part, therefore the students achieving poor results. No real communication in regards to the outcomes the students are required to achieve. Teacher 7 – Students need more help as they didn't really know how to go about dividing up topic/ research etc. Teacher 8 – Staff communication could be improved. Communication to students as to how this will help them in the future. Some students in the groups did most of the work, while others watched. Teacher 9 – We must have greater access to computers with Internet and data projectors if we are to be able to help each other – VITAL. We need more time to discuss what we are doing, both as a whole group and with our Maths/Science/English/History colleagues.
3. How could these problems be overcome?	Teacher 1 – Dedicated time. Project integrated with intended outcomes. Guidelines – discussion, task planning from start to finish, monitored by teacher. Topic change/providing more simple information. Teacher 2 – It would help to have a meeting where the exact outcome requirements of the task were specified to ensure all classes are achieving the same thing and grades are monitored, i.e. cross-marking. I found setting deadlines for parts of the task to break down the hugeness of the task/culminating assessment, although no punishment for failure to submit as long as it was submitted by the final day. Teacher 3 – By getting together more often to talk about who's doing what. Making sure all the staff know what is expected of them. Teacher 4 – Time to share and discuss topics chosen first. In-service time allotted for planning topics, outcomes and marking scheme. Teacher 5 – Timing. Don't do this task at the same time as the Science Extended Experimental Investigation. Set aside a few lessons in Science to discuss the "scientific method". Meet with teaching partner to work out roles. Next time will be better. The problems were only because it was a first-timer. Not because it was a bad task. It was a great idea and a great task.

	Teacher 6 – More communication. All discipline teachers working together on the task. More time to understand the task, its outcomes and the best way to teach it. Teacher 7 – Students could be introduced to idea either in a year 8 group en masse, or by English/ History teacher. More prompts/access given to kids. More structured details (spoon feeding) to students. Teacher 8 – Documentation – log of what each student did at each group meeting. Staff meet maybe twice during this period for discussion. Staff meet prior to unit to clearly outline who does what. Teacher 9 – Expenditure of more money is the main one. I believe that at least two more computer rooms should be set-up and data projectors be installed in every computer lab, and that at least four more portable data projectors be purchased. Teacher 10 – Time, practice and experience develop and refine the unit.
4. What further professional development would you like to be provided within the area of developing transdisciplinary tasks to drive learning in the middle years?	Teacher 1 – Fortnightly staff meetings, 30 min – 1 hour (12 key teachers). Teacher 2 – None – completed the middle years pathway course at QUT. I have a clear understanding of what you are trying to achieve and knowledge of what is happening in all schools across Eastern Australia. Teacher 3 – I think more meetings together, more time together (see question 3). Teacher 4 – Time, as in question 3. Teacher 5 – More involvement in producing the task? Teacher 6 – Knowledge of the best way to support the students in their learning and how to encourage them to achieve their best results. Teacher 7 – More time to develop the thematic units. Teacher 8 – These are quite fresh in my mind as I am P-10 trained and we worked a lot with RAT's at university. Teacher 9 – More time to meet together and plan our thematic details.

Collaboration between teachers from different disciplines in regard to curriculum development led to an understanding of the importance of other disciplines, an approach to problem-solving using skills from the traditional disciplines and the need to help students develop skills, rather than such a predominant focus upon transmitting content. As Marzano [18, p. 27] has argued, “Schools should drastically reduce the amount of content teachers are required to address in class”. As discussed by Marzano, research has shown that American Science courses that covered a greater number of Science topics led to students who were outperformed in Science by Germany and Japanese students, who studied fewer Science topics in their courses. The thematic units stop duplication of content and favour the focus upon the necessary content, rather than covering all possible topics.

The unified approach to teaching by using thematic units also connects learning with the real world and allows students to use skills from across the traditional curricular areas when solving problems. As shown in Table 2, this was noted by many teachers in response to Question (1) in the review of the Transdisciplinary Unit. Teacher 1 believed that this approach fostered “more effective researching skills that can be learnt once and used in various subjects”. Teacher 3 noted that great benefit followed from the units in that “students recognized the value of drawing on a range of knowledge areas and skills to attempt and complete a task, which equalled a reflection of future working conditions”. Teacher 6 supported the transdisciplinary approach as “excellent in terms of students learning how school relates to the real world and how subjects can connect”.

As with any shift in curriculum and pedagogy, as the paradigm moves away from the traditional paradigm and towards the middle schooling paradigm, there were some problems and limitations experienced, especially in relation to time, communication and planning. Students needed clearer guidelines as to how to work in groups. These problems could be addressed by allocating timetabled planning time for the units led by a curriculum planning facilitator.

It is interesting that in the response to question 4 on the teacher’s view on what further professional development they would like, there were very different responses from the younger, more recently trained teachers. Teachers who had been trained quite recently in middle schooling were quite confident in regard to the transcurricular, thematic approach, while the others were wanting more time for planning and communicating in relation to the initiative.

Teachers’ concern about access to computers (As shown in Table 2) is being addressed by the college. In order to prepare students as informed active citizens who will provide leadership in society, it is essential that they develop a high standard of technological literacy.

3.2 Technology and Middle Schooling

In our technologically advanced digital society, adolescents are substantially different from what they were in previous generations and this has profound implications for teaching and learning. Middle years students need interactive information, interactive communication and interactive resources as they process information and construct their understandings by being actively engaged in doing complex tasks. Jukes [19, p. 6] extended his discussion of the need for today's digital kids to have access to technology in schools by suggesting that "this generation is equally as comfortable with virtual, screen-to-screen relationships as they are with face-to-face relationships".

It is fascinating to watch adolescents using technologies such as mobile phones and computers for communication, which is the foundation of their relationships. Since we are preparing our students for life in a digital world, we need instructional practices that are aligned with the real world. Computers and other digital technology should be used consistently as an integral part of teaching and learning. The use of technology by young people has even led to them having different neural pathways to process that same information when compared with older people [19]. Middle years students multitask as they receive and process digital communication while they are completing other related tasks.

Topics that might not otherwise be exciting and motivating for students can be made extremely interesting for students by using technology as a tool for learning. Edson [20] discussed a unit on the seven wonders of the ancient world that enthralled students since they showed their learning about the subject using clay animation in a DVD they produced about the seven wonders. The further benefit of this approach was the deep understanding of the topic that was developed by the students. As Edson concluded, technology was certainly making a difference in this classroom by addressing student disengagement.

In order to use technology effectively to achieve positive learning outcomes, administrators need to prioritize the need for professional development and support for teachers. In turn, teachers need to be committed to exploring new ways of integrating ICT tools so that they can be used effectively to promote deep understanding [21]. As Sutherland-Smith [22] argued, teachers have an indispensable role to play in evaluating the use of technology in the classroom so that its use is pedagogically sound. One way in which to do this is by teaching students to evaluate texts carefully. Scaffolding student learning is an important strategy to help them develop the skills of critical evaluation.

3.2.1 Scaffolding Students' Learning

Consideration of teachers' views in the evaluation of the transdisciplinary thematic units indicated that there was a need to scaffold students' learning, thereby guiding their thinking. It is especially important to support students in their learning in the formative stages as noted by teachers at King's, as it gives students more structured details, thereby guiding them in their learning from start to finish. Teachers said that students needed more prompts or guidelines to help them break down the topic and plan their response. In the second thematic unit, this scaffolding enhanced the learning outcomes achieved by students.

It has been argued that as middle-level students move from one phase of learning to the next, they require the support of scaffolding strategies to stretch them from one level to the next and enhance their chances of experiencing success [23]. Scaffolding needs to happen on a regular basis whenever new units or learning activities are developed. As has been indicated by the experience at King's, reflection upon the scaffolding used has many benefits and its gradual release has allowed the students to take the final responsibility for learning. This scaffolding also has the added benefit of aiding communication and professional development of teachers.

Scaffolding can be used across the disciplines in a generic form, as a strategy to assist the workshopping of particular assignments or as a way of teaching students on a one-to-one basis. There are many types of scaffolding but they generally include strategies such as:

– Guided writing; using frameworks, peer evaluation, explicit teaching
– Guided reading or viewing to help students to relate with the text using focus questions before, during and after the task and note-making frameworks
– Immersion where models or examples are provided to help students become familiar with features or structures of the text or item
– Joint construction where the teacher and students jointly construct the task using graphs, note-making, diagrams and writing
– Explicit teaching and feedback: Where the teacher is explicit about the steps involved and provides specific feedback to students [23, p. 40].

3.2.2 Teaching Students to Think

Students' learning is certainly supported by guiding their thinking or teaching them how to think. This has some similarities to the strategy of guided reading or viewing.

Teaching so that students learn how to think skillfully operates upon the general spirit of constructivism. It involves making explicit what has been implicit and making general what has been phrased in more restricted ways such as explaining, applying concepts and representing in new ways. If a student understands a scientific topic, they will be able to make predictions using this understanding. In middle school classrooms this requires student-centred teaching, as the students must be engaged so that they think with and about the ideas they are learning [24].

Clearly, a vital component of the assessment in these thinking-centred learning environments needs to be rich, open-ended assessment which provides consistent feed-back to students and promotes reflection.

Ways of teaching creative and critical thinking to students include asking a series of key prompting questions so that students exercise critical judgement and creative thinking. Key thinking questions to encourage skilful decision making include:

1. What makes a decision necessary?
2. What are my options?
3. What are the consequences of each option?
4. How important are the consequences?
5. Which option is the best in light of the consequences? [25]

As discussed previously, students' higher order thinking skills are also developed by transdisciplinary assignments where the skills of thinking are taught. This is extremely important for middle years students, since as Edward de Bono argued, thinking is a skill that must be learned [26].

4 Conclusion

In this chapter, the key elements to facilitate success of an educational shift to learning within the middle schooling paradigm have been discussed. I have been fortunate to have gained considerable experience in leading middle schooling as head of middle school at St. John's Grammar School in Adelaide and as dean of middle schooling at King's Christian College on the Gold Coast. As a consequence of this experience, it is clear to me that educators need to focus on the affective domain outcomes as well as the cognitive outcomes and the development of skills with middle years students.

When middle years students are cared for in a safe, stimulating environment they are able to develop the sorts of relationships, values, attitudes and understandings that will sustain them throughout the middle years and help them to become effective learners for life. Pastoral care is the umbrella under which the positive educational outcomes are achieved in the middle years, in that it focuses students on positive life experiences, rather than simply sheltering them from the world.

Relevant, meaningful curriculum and learning activities that provide opportunities for transcurricular understanding and skill development allow students to work together to suggest ways of solving social and environmental problems.

In this way, middle schools care for and educate young people in order to empower them to become informed and caring citizens who will have a vital impact in the world of tomorrow's generation. This is certainly significant in terms of developing a school culture that prepares young people to direct a sustainable future to which we can all look forward.

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Applying Data Mining Techniques to e-Learning Problems

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Summary. This chapter aims to provide an up-to-date snapshot of the current state of research and applications of Data Mining methods in e-learning. The cross-fertilization of both areas is still in its infancy, and even academic references are scarce on the ground, although some leading education-related publications are already beginning to pay attention to this new field. In order to offer a reasonable organization of the available bibliographic information according to different criteria, firstly, and from the Data Mining practitioner point of view, references are organized according to the type of modeling techniques used, which include: Neural Networks, Genetic Algorithms, Clustering and Visualization Methods, Fuzzy Logic, Intelligent agents, and Inductive Reasoning, amongst others. From the same point of view, the information is organized according to the type of Data Mining problem dealt with: clustering, classification, prediction, etc. Finally, from the standpoint of the e-learning practitioner, we provide a taxonomy of e-learning problems to which Data Mining techniques have been applied, including, for instance: Students' classification based on their learning performance; detection of irregular learning behaviors; e-learning system navigation and interaction optimization; clustering according to similar e-learning system usage; and systems' adaptability to students' requirements and capacities.

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1 Introduction

Within a decade, the Internet has become a pervasive medium that has changed completely, and perhaps irreversibly, the way information and knowledge are transmitted and shared throughout the world. The education community has not limited itself to the role of passive actor in this unfolding story, but it has been at the forefront of most of the changes.

Indeed, the Internet and the advance of telecommunication technologies allow us to share and manipulate information in nearly real time. This reality is determining the next generation of distance education tools. Distance education arose from traditional education in order to cover the necessities of remote students and/or help the teaching–learning process, reinforcing or replacing traditional education. The Internet takes this process of delocalization of the educative experience to a new realm, where the lack of presential intercourse is, at least partially, replaced by an increased level of technology-mediated interaction. Furthermore, telecommunications allow this interaction to take forms that were not available to traditional presential and distance learning teachers and learners.

This is e-learning (also referred to as Web-based education and e-teaching), a new context for education where large amounts of information describing the continuum of the teaching–learning interactions are endlessly generated and ubiquitously available. This could be seen as a blessing: plenty of information readily available just a click away. But it could equally be seen as an exponentially growing nightmare, in which unstructured information chokes the educational system without providing any articulate knowledge to its actors.

Data Mining was born to tackle problems like this. As a field of research, it is almost contemporary to e-learning. It is, though, rather difficult to define. Not because of its intrinsic complexity, but because it has most of its roots in the ever-shifting world of business. At its most detailed, it can be understood not just as a collection of data analysis methods, but as a data analysis process that encompasses anything from data understanding, preprocessing and modeling to process evaluation and implementation [16]. It is nevertheless usual to pay preferential attention to the Data Mining methods themselves. These commonly bridge the fields of traditional statistics, pattern recognition and Machine Learning (ML) to provide analytical solutions to problems in areas as diverse as biomedicine, engineering, and business, to name just a few. An aspect that perhaps makes Data Mining unique is that it pays special attention to the compatibility of the modeling techniques with new Information Technologies

(IT) and database technologies, usually focusing on large, heterogeneous and complex databases. e-learning databases often fit this description.

Therefore, Data Mining can be used to extract knowledge from e-learning systems through the analysis of the information available in the form of data generated by their users. In this case, the main objective becomes finding the patterns of system usage by teachers and students and, perhaps most importantly, discovering the students' learning behavior patterns.

This chapter aims to provide an as complete as possible review of the many applications of Data Mining to e-learning over the period 1999–2006; that is, a survey of the literature in this area up to date. We must acknowledge that this is not the first time a similar venture has been undertaken: A collection of papers that cover most of the important topics in the field was concurrently presented in [71].

The findings of the survey are organized from different points of view that might in turn match the different interests of its potential readers: The surveyed research can be seen as being displayed along two axes: Data Mining problems and methods, and e-learning applications. Section 2 presents the research along the axis of the Data Mining modeling techniques and methods, while Sect. 3 presents the surveyed content along the e-learning applications axis. This organization of the surveyed content should allow readers to access the information in a more compact and self-contained way than that in [71].

A deeper analysis and discussion of the actual state of the research in the field is presented in Sect. 4, highlighting its opportunities and limitations. Section 5 reports work on Data Mining in e-learning beyond academic publications. Finally, Sect. 6 summarizes the findings and draws some conclusions.

Most of the information provided in this chapter takes the form of tables of publications. We consider this the best (or at least the most compact) way to organize it and ease, in a guided manner, the access to the main contents.

2 A survey of Data Mining in e-Learning from the Data Mining Point of View

As stated in the introduction, we aim to organize the findings of the survey in different ways that might correspond to the diverse readers' academic or professional backgrounds. In this section, we present the surveyed research according to the Data Mining problems (classification, clustering, etc.), techniques and methods (e.g., Neural Networks, Genetic Algorithms, Decision Trees (DT), or Fuzzy Logic).

In fact, most of the existing research addresses problems of classification and clustering. For this reason, specific sections will be devoted to them. But first, let us try to find a place for Data Mining in the world of e-learning.

2.1 Where Does Data Mining Fit in e-Learning Processes?

Some researchers have pointed out the close relation between the fields of Artificial Intelligence (AI) and ML – main sources of Data Mining techniques and methods – and education processes [4, 26, 30, 49, 79, 85].

In [4], the author establishes the research opportunities in AI and education on the basis of three models of educational processes: *models as scientific tool*, are used as a means for understanding and forecasting some aspect of an educational situation; *models as component*: corresponding to some characteristic of the teaching or learning process and used as a component of an educative artefact; and *models as basis for design of educational artefacts*: assisting the design of computer tools for education by providing design methodologies and system components, or by constraining the range of tools that might be available to learners.

In [49, 85], studies on how Data Mining techniques could successfully be incorporated to e-learning environments and how they could improve the learning tasks were carried out. In [85], data clustering was suggested as a means to promote group-based collaborative learning and to provide incremental student diagnosis.

A review of the possibilities of the application of Web Mining (Web usage mining and clustering) techniques to meet some of the current challenges in distance education was presented in [30]. The proposed approach could improve the effectiveness and efficiency of distance education in two ways: On the one hand, the discovery of aggregate and individual paths for students could help in the development of effective customized education, providing an indication of how to best organize the educator organization's courseware. On the other hand, virtual knowledge structure could be identified through Web Mining methods: The discovery of Association Rules could make it possible for Web-based distance tutors to identify knowledge patterns and reorganize the virtual course based on the patterns discovered.

An analysis on how ML techniques – again, a common source for Data Mining techniques – have been used to automate the construction and induction of student models, as well as the background knowledge necessary for student modeling, were presented in [79]. In this paper, the difficulty, appropriateness and potential of applying ML techniques to student modeling was commented.

2.2 The Classification Problem in e-Learning

In classification problems, we usually aim to model the existing relationships (if any) between a set of multivariate data items and a certain set of outcomes for each of them in the form of class membership labels. Although plenty of classification methods that would fit in a Data Mining process exist, in what follows, we shall see that only a few techniques (or families of techniques) have been applied to e-learning.

2.2.1 Fuzzy Logic Methods

Fuzzy logic-based methods have only recently taken their first steps in the e-learning field [36, 39, 40, 81, 89].

In [81], a neurofuzzy model for the evaluation of students in an intelligent tutoring system (ITS) was presented. Fuzzy theory was used to measure and transform the interaction between the student and the ITS into linguistic terms. Then, Artificial Neural Networks were trained to realize fuzzy relations operated with the max–min composition. These fuzzy relations represent the estimation made by human tutors of the degree of association between an observed response and a student characteristic.

A fuzzy group-decision approach to assist users and domain experts in the evaluation of educational Web sites was realized in the EWSE system, presented in [39]. In further work by Hwang and colleagues [36, 40], a fuzzy rules-based method for eliciting and integrating system management knowledge was proposed and served as the basis for the design of an intelligent management system for monitoring educational Web servers. This system is capable of predicting and handling possible failures of educational Web servers, improving their stability and reliability. It assists students' self-assessment and provides them with suggestions based on fuzzy reasoning techniques.

A two-phase fuzzy mining and learning algorithm was described in [89]. It integrates an association rule mining algorithm, called *Apriori*, with fuzzy set theory to find embedded information that could be fed back to teachers for refining or reorganizing the teaching materials and tests. In a second phase, it uses an inductive learning algorithm of the AQ family: AQR, to find the concept descriptions indicating the missing concepts during students' learning. The results of this phase could also be fed back to teachers for refining or reorganizing the learning path.

2.2.2 Artificial Neural Networks and Evolutionary Computation

Some research on the use of Artificial Neural Networks and Evolutionary Computation models to deal with e-learning topics can be found in [53, 55, 87].

A navigation support system based on an Artificial Neural Network (more precisely, a Multi-Layer Perceptron, or MLP) was put forward in [55] to decide on the appropriate navigation strategies. The Neural Network was used as a navigation strategy decision module in the system. Evaluation has validated the knowledge learned by the Neural Network and the level of effectiveness of the navigation strategy.

In [53, 87], evolutionary algorithms were used to evaluate the students' learning behavior. A combination of multiple classifiers (CMC), for the classification of students and the prediction of their final grades, based on features extracted from logged data in an education Web-based system, was described in [53]. The classification and prediction accuracies are improved through the weighting of the data feature vectors using a Genetic Algorithm. In [87] we find a random code generation and mutation process suggested as a method to examine the comprehension ability of students.

2.2.3 Graphs and Trees

Graph and/or tree theory was applied to e-learning in [9, 13, 14, 29, 42, 47, 48, 95, 97].

An e-Learning model for the personalization of courses, based both on the student's needs and capabilities and on the teacher's profile, was described in [9]. Personalized learning paths in the courses were modeled using graph theory. In [47, 48], DT as classification models were applied. A discussion of the implementation of the Distance Learning Algorithm (DLA), which uses Rough Set theory to find general decision rules, was presented by [47]: A DT was used to adequate the original algorithm to distance learning issues. On the basis of the obtained results, the instructor might consider the reorganization of the course materials. A system architecture for mining learners' online behavior patterns was put forward in [13]. A framework for the integration of traditional Web log mining algorithms with pedagogical meanings of Web pages was presented. The approach is based on the definition of an e-learning system concept-hierarchy and the sequential patterns of the pages shown to users.

Also in [48], an automatic tool, based on the students' learning performance and communication preferences, for the generation and discovery of simple student models was described, with the ultimate goal of creating a personalized education environment. The approach was based on the PART algorithm, which produces rules from pruned partial DTs. In [97], a tool that can help trace deficiencies in students' understanding was presented. It resorts to a tree abstract data type (ADT), built from the concepts covered in a lab, lecture, or course. Once the tree ADT is created, each node can be associated with different entities such as student performance, class performance, or lab development. Using this tool, a teacher could help students by discovering concepts that needed additional coverage, while students might discover concepts for which they would need to spend additional working time.

A tool to perform a quantitative analysis based on students' learning performance was introduced in [14]. It proposes new courseware diagrams, combining tools provided by the theory of conceptual maps [63] and influence diagrams [75]. In [29, 42, 95], personalized Web-based learning systems were defined, applying Web usage mining techniques to personalized recommenddation services. The approach is based on a Web page classification method, which uses attribute-oriented induction according to related domain knowledge shown by a concept hierarchy tree.

2.2.4 Association Rules

Association Rules for classification, applied to e-learning, have been investigated in the areas of learning recommendation systems [18, 98, 99], learning material organization [89], student learning assessments [38, 45, 52, 54, 69, 70], course adaptation to the students' behavior [19, 35, 50], and evaluation of educational Web sites [21].

Data Mining techniques such as Association Rule mining, and inter-session and intra-session frequent pattern mining, were applied in [98, 99] to extract useful patterns that might help educators, educational managers, and Web masters to evaluate and interpret on-line course activities. A similar approach can be found in [54], where contrast rules, defined as sets of conjunctive rules describing patterns of performance disparity between groups of students, were used. A computer-assisted approach to diagnosing student learning problems in science courses and offer students advice was presented in [38], based on the concept effect relationship (CER) model (a specification of the Association Rules technique).

A hypermedia learning environment with a tutorial component was described in [19]. It is called *Logiocando* and targets children of the fourth level of primary school (9–10 years old). It includes a tutor module, based on if-then rules, that emulates the teacher by providing suggestions on how and what to study. In [52] we find the description of a learning process assessment method that resorts to Association Rules, and the well-known ID3 DT learning method. A framework for the use of Web usage mining to support the validation of learning site designs was defined in [21], applying association and sequence techniques [80].

In [50], a framework for personalized e-learning based on aggregate usage profiles and a domain ontology were presented, and a combination of Semantic Web and Web mining methods was used. The *Apriori* algorithm for Association Rules was applied to capture relationships among URL references based on the navigational patterns of students. A test result feedback (TRF) model that analyzes the relationships between student learning time and the corresponding test results was introduced in [35]. The objective was twofold: on the one hand, developing a tool for supporting the tutor in reorganizing the course material; on the other, a personalization of the course tailored to the individual student needs. The approach was based in Association Rules mining.

A rule-based mechanism for the adaptive generation of problems in ITS in the context of Web-based programming tutors was proposed in [45]. In [18], a Web-based course recommendation system, used to provide students with suggestions when having trouble in choosing courses, was described. The approach integrates the *Apriori* algorithm with graph theory.

2.2.5 Multiagent Systems

Multiagents Systems (MAS) for classification in e-learning have been proposed in [2, 28]. In [28] this takes the form of an adaptive interaction system based on three MAS: the *Interaction MAS* captures the user preferences applying some defined usability metrics (affect, efficiency, helpfulness, control and learnability). The *Learning MAS* shows the contents to the user according to the information collected by the Interaction MAS in the previous step; and the *Teaching MAS* offers recommendations to improve the virtual course. A multiagent recommendation system, called InLix, was described in [2]; it suggests educational resources to students in a mobile learning platform. InLix combines content analysis and the development of students' virtual clusters. The model includes a process of classification and recommendation feedback in which the user agent learns from the student and adapts itself to the changes in user's interests. This provides the agent with the opportunity to be more accurate in future classification decisions and recommendation steps. Therefore, the more students use the system, the more the agent learns and more accurate its actions become.

2.3 The Clustering Problem in e-learning

Unlike in classification problems, in data grouping or clustering we are not interested in modeling a relation between a set of multivariate data items and a certain set of outcomes for each of them (being this in the form of class membership labels). Instead, we usually aim to discover and model the groups in which the data items are often clustered, according to some item similarity measure.

We find a first application of clustering methods in [37], where a network-based testing and diagnostic system was implemented. It entails a multiple-criteria test-sheet-generating problem and a dynamic programming approach to generate test sheets. The proposed approach employs fuzzy logic theory to determine the difficulty levels of test items according to the learning status and personal features of each student, and then applies an Artificial Neural Network model: Fuzzy Adaptive Resonance Theory (Fuzzy ART) [10] to cluster the test items into groups, as well as dynamic programming [22] for test sheet construction.

In [60, 61], an in-depth study describing the usability of Artificial Neural Networks and, more specifically, of Kohonen's Self-Organizing Maps (SOM) [43] for the evaluation of students in a tutorial supervisor (TS) system, as well as the ability of a fuzzy TS to adapt question difficulty in the evaluation process, was carried out. An investigation on how Data Mining techniques could be successfully incorporated to e-learning environments, and how this could improve the learning processes was presented in [85]. Here, data clustering is suggested as a means to promote group-based collaborative learning and to provide incremental student diagnosis.

In [86], user actions associated to students' Web usage were gathered and pre-processed as part of a Data Mining process. The Expectation-Maximization (EM) algorithm was then used to group the users into clusters according to their behaviors. These results could be used by teachers to provide specialized advice to students belonging to each cluster. The simplifying assumption that students belonging to each cluster should share Web usage behavior makes personalization strategies more scalable. The system administrators could also benefit from this acquired knowledge by adjusting the e-learning environment they manage according to it. The EM algorithm was also the method of choice in [82], where clustering was used to discover user behavior patterns in collaborative activities in e-learning applications.

Some researchers [23, 31, 83] propose the use of clustering techniques to group similar course materials: An ontology-based tool, within a Web Semantics framework, was implemented in [83] with the goal of helping e-learning users to find and organize distributed courseware resources. An element of this tool was the implementation of the Bisection K-Means algorithm, used for the grouping of similar learning materials. Kohonen's well-known SOM algorithm was used in [23] to devise an intelligent searching tool to cluster similar learning material into classes, based on its semantic similarities. Clustering was proposed in [31] to group similar learning documents based on their topics and similarities. A Document Index Graph (DIG) for document representation was introduced, and some classical clustering algorithms (Hierarchical Agglomerative Clustering, Single Pass Clustering and k-NN) were implemented.

Different variants of the Generative Topographic Mapping (GTM) model, a probabilistic alternative to SOM, were used in [11, 12, 94] for the clustering and visualization of multivariate data concerning the behavior of the students of a virtual course. More specifically, in [11, 94] a variant of GTM known to behave robustly in the presence of atypical data or outliers was used to successfully identify clusters of students with atypical learning behaviors. A different variant of GTM for feature relevance determination was used in [12] to rank the available data features according to their relevance for the definition of student clusters.

2.4 Other Data Mining Problems in e-Learning

As previously stated, most of the current research deals with problems of classification and clustering in e-learning environments. However, there are several applications that tackle other Data Mining problems such as prediction and visualization, which we review in this section.

2.4.1 Prediction Techniques

Prediction is often also an interesting problem in e-learning, although it must be born in mind that it can easily overlap with classification and regression problems. The forecasting of students' behavior and performance when using e-learning systems bears the potential of facilitating the improvement of virtual courses as well as e-learning environments in general.

A methodology to improve the performance of developed courses through adaptation was presented in [72, 73]. Course log-files stored in databases could be mined by teachers using evolutionary algorithms to discover important relationships and patterns, with the target of discovering relationships between students' knowledge levels, e-learning system usage times and students' scores.

A system for the automatic analysis of user actions in Web-based learning environments, which could be used to make predictions on future uses of the learning environment, was presented in [59]. It applies a C4.5 DT model for the analysis of the data; (Note that this reference could also have been included in the section reviewing classification methods).

Some studies apply regression methods for prediction [5, 27, 44]. In [27], a study that aimed to find the sources of error in the prediction of students' knowledge behavior was carried out. Stepwise regression was applied to assess what metrics help to explain poor prediction of state exam scores. Linear regression was applied in [5] to predict whether the student's next response would be correct, and how long he or she would take to generate that response.

In [44], a set of experiments was conducted in order to predict the students' performance in e-learning courses, as well as to assess the relevance of the attributes involved. In this approach, several Data Mining methods were applied, including: Naïve Bayes, kNN, MLP Neural Network, C4.5, Logistic Regression, and Support Vector Machines. With similar goals in mind, experiments applying the Fuzzy Inductive Reasoning (FIR) methodology to the prediction of the students' final marks in a course taken at a virtual campus were carried out in [62]. The relative relevance of specific features describing course online behavior was also assessed. This work was extended in [25] using Artificial Neural Networks for the prediction of the students' final marks. In this work, the predictions made by the network were interpreted using Orthogonal Search-based Rule Extraction (OSRE) a novel rule extraction algorithm [24]. Rule extraction was also used in [72, 73] with the emphasis on the discovery of interesting prediction rules in student usage information, in order to use them to improve adaptive Web courses.

Graphical models and Bayesian methods have also been used in this context. For instance, an open learning platform for the development of intelligent Web-based educative systems, named MEDEA, was presented in [88]. Systems developed with MEDEA guide students in their learning process, and allow free navigation to better suit their learning needs. A Bayesian Network model lies at the core of MEDEA. In [3] an evaluation of students' attitudes and their relationship to students' performance in a tutoring system was implemented. Starting from a correlation analysis between variables, a Bayesian Network that inferred negative and positive students' attitudes was built. Finally, a Dynamic Bayes Net (DBN) was used in [15], for modeling students' knowledge behavior and predict future performance in an ITS.

In [90, 91], a tool for the automatic detection of atypical behaviors on the students' use of the e-learning system was defined. It resorts to a Bayesian predictive distribution model to detect irregular learning processes on the basis of the students' response time. Note that some models for the detection of atypical student behavior were also referenced in the section reviewing clustering applications [11, 94].

2.4.2 Visualization Techniques

One of the most important phases of a Data Mining process (and one that is usually neglected) is that of data exploration through visualization methods.

Visualization was understood in [68] in the context of Social Network Analysis adapted to collaborative distance-learning, where the cohesion of small learning groups is measured. The cohesion is computed in several ways in order to highlight isolated people, active subgroups and various roles of the members in the group communication structure. Note the links between this goal and that of atypical student behavior described in previous sections. The method allows the display of global properties both at individual level and at group level, as well as to efficiently assist the virtual tutor in following the collaboration patterns within the group.

An educational Data Mining tool is presented in [57, 58] that shows, in a hierarchical and partially ordered fashion, the students' interaction with the e-learning environment and their virtual tutors. The tool provides case analysis and visualizes the results in an event tree, exploiting MySQL databases to obtain tutorial events.

One main limitation to the analysis of high-dimensional multivariate data is the difficulty of representing those data faithfully in an intuitive visual way. Latent methods (of which Principal Component Analysis, or PCA, is perhaps the most widely known) allow such representation. One such latent method was used in [11, 12, 94] to display high-dimensional student behavior data in a 2-dimensional representation. This type of visualization helps detecting the characteristics of the data distributions and their grouping or cluster structure.

2.5 Other Data Mining Methods Applied in e-Learning

Not all Data Mining in e-learning concerns advanced AI or ML methods: traditional statistics are also used in [1, 32, 74, 77], as well as Semantic

Web technologies [34], ontologies [46], Case-Based Reasoning [33] and/or theoretical modern didactical approaches [6, 7, 41, 96].

Although it could have been included in the section devoted to classification, Naïve Bayes, the model used in [78, 84], also fits in the description of general statistical method. An approach to automate the classification process of Web learning resources was developed in [78]. The model organizes and labels learning resources according to a concept hierarchy extracted from the extended ontology of the ACM Computing Curricula 2001 for Computer Science. In [84], a method to construct personalized courseware was proposed. It consists of the building of a personalized Web tutor tree using the Naïve algorithm, for mining both the context and the structure of the courseware.

Statistical methods were applied in [8, 56, 64]. In [64], the goals were the discovery and extraction of knowledge from an e-learning database to support the analysis of student learning processes, as well as the evaluation of the effectiveness and usability of Web-based courses. Three Web Mining-based evaluation criteria were considered: *session statistics*, *session patterns* and *time series of session data*. In the first, basic statistics about sessions, such as average session, length in time or in number of content requests were gathered. In *session patterns*, the learning processes were extracted from navigation and request behavior. Finally, in the *time series of session data*, the evolution of session statistics and session patterns over a period of time was analyzed. All methods were applied to Web log entries. In [8], a personalized learning environment applying different symmetric and asymmetric distance measures between the students' profiles and their interests was proposed. In [56], tools for the analysis of student activity were developed to provide decision makers and course developers with an understanding of the e-learners needs. Some statistical analyses of the learner's activities were performed.

An experiment combining a MAS and self-regulation strategies to allow flexible and incremental design, and to provide a more realistic social context for interactions between students and the teachable agent, were presented in [6]. In [41], a model called Learning Response Dynamics that analyzes learning systems through the concepts of learning dynamics, energy, speed, force, and acceleration, was described. In [7, 96], the problems of developing versatile adaptive and intelligent learning systems that could be used in the context of practical Web-based education were discussed. One such system: ELM-ART was developed; it supports learning programming in LISP, and provides adaptive navigation support, course sequencing, individualized diagnosis of student solutions, and example-based problem-solving support.

MAS have also been applied to e-learning beyond classification problems. In [76], one called IDEAL was designed to support student-centered, self-paced, and highly interactive learning. The analysis was carried out on the students' learning-related profile, which includes learning style and background knowledge in selecting, organizing, and presenting the learning material to support active learning. IDEAL supports personalized interaction between the students and the learning system and enables adaptive course delivery of educational contents. The student learning behavior (student model) is inferred from the performance data using a Bayesian Belief Network model. In [66, 67], an MAS called Cooperative Intelligent Distance Learning Environments (CIDLE) was described. It extracts knowledge from domain knowledge and students' behavior during a learning discussion. It therefore infers the learners' behavior and adapts to them the presentation of course material in order to improve their success rate in answering questions. In [51], software agents were proposed as an alternative for data extraction from e-learning environments, in order to organize them in intelligent ways. The approach includes pedagogical agents to monitor and evaluate Web-based learning tools, from the educational intentions point of view.

In [33], a Case-Based Reasoning system was developed to offer navigational guidance to the student. It is based on past user's interaction logs and it includes a model describing learning sessions.

A system that evaluates the students' performance in Web-based e-learning was presented in [65]. Its functioning is controlled by an expert system using "neurules": a hybrid concept that integrates symbolic rules and neural computing. Internally, each "neurule" is represented and considered as an Adaline neuron.

Finally, in [17], Social Network Analysis was proposed as a method to evaluate the relationships between communication styles, social networks, and learning performance in a computer-supported collaborative learning (CSCL) community. The students' learning performance was measured by their final grades in the second semester of the CSCL course and was calculated through a combination of final exam score, group assignment evaluation, and peer-evaluation.

3 A Survey of Data Mining in e-Learning from the e-Learning Point of View

In this section, we present the surveyed research according to the e-learning problems to which the Data Mining methods are applied.

As mentioned in the introduction, and to avoid unnecessary redundancies, we now present in Tables 1–5 a survey of the available literature according to the different e-learning topics addressed in it. All tables include, column-wise, the following information: bibliographic reference, Data Mining problem addressed (DM objective), Data Mining technique used (DM technique), e-learning actors involved, and type of publication: Journal (J), International Conference (C), or Book Chapter (B).

Each of these tables summarizes, in turn, the references on one of the following e-learning subjects:

1. Applications dealing with the assessment of students' learning performance.
2. Applications that provide course adaptation and learning recommendations based on the students' learning behavior.
3. Approaches dealing with the evaluation of learning material and educational Web-based courses.
4. Applications that involve feedback to both teachers and students of e-learning courses, based on the students' learning behavior.
5. Developments for the detection of atypical students' learning behavior.

Table 1. Research works that perform students' learning assessment

Reference	DM objective	DM approach	e-learning actor	Type of publication
[56]	Statistical analysis	Basic statistical methods	Student and Staff	J
[36]	Classification	Fuzzy reasoning	Student	J
[37]	Clustering	Clustering, dynamic programming and fuzzy logic theory	Student and Teacher	J
[14]	Classification	Conceptual maps	Student and teacher	J
[1]	Statistical analysis	Metadata analysis	Student and Teacher	C
[38]	Classification	Concept effect relationship (CER) model	Teacher	J
[74]	Statistical analysis	Basic statistical methods	Student and Teacher	C
[32]	Statistical analysis	Metadata analysis	Student and Teacher	C
[52]	Classification	ID3	Teacher	C
[97]	Classification and visualization	ADT Tree	Student and Teacher	C

[64]	Classification	Basic statistical methods	Teacher	C
[68]	Visualization and clustering	Social Network Analysis	Teacher	C
[17]	Classification	Social Network Analysis	Teacher	J
[87]	Classification	Code generation and mutation.	Teacher	C
[81]	Classification	Neurofuzzy model	Teacher	C
[65]	Classification	Expert systems and Neural computing	Teacher	C
[53]	Classification	Combination of: k-NN, MLP and Decision Tree	Teacher	C
[54]	Classification	Contrast rules	Teacher	C
[69, 70]	Classification	Association Rules	Teacher	C; C
[13]	Classification	Association Rules	Teacher	C
[60, 61]	Clustering	SOM	Teacher	J; C
[35]	Classification	Association Rules	Student and Teacher	C
[45]	Classification	Association Rules	Teacher	C
[77]	Statistical analysis	Basic statistical methods	Student, Teacher and Staff	J
[85]	Clustering	Navigation path clustering ad hoc algorithm	Teacher	C
[48]	Classification	Decision tree-based rule extraction	Teacher	C
[59]	Prediction	Decision tree	Teacher	C
[3]	Prediction	Bayesian Network	Teacher	B
[44]	Classification and Prediction	Naïve Bayes, kNN, MLP-ANN, C4.5, Logistic Regression and SVM	Teacher	J
[5]	Prediction	Linear regression	Teacher	C
[27]	Prediction	Regression	Teacher	C
[57]	Visualization	SQL queries	Teacher	C
[58]	Visualization	SQL queries	Teacher	C
[62]	Prediction	FIR	Teacher	C
[25]	Prediction	FIR and OSRE	Teacher	C
[82]	Clustering	EM algorithm	Teacher	C
[15]	Prediction	Dynamic Bayes Net	Teacher	C

Although an important deal of research effort has been devoted to improve the students' e-learning experience (see Tables 2 and, partially, 4), even more has focused assisting online tutors' tasks, including the analysis and assessment of the students' performance and the evaluation of course materials (see Tables 1, 3 and 5, as well as, partially, 3.4).

Table 2. Research works that offer course adaptation based on students' learning behavior

Reference	DM objective	DM approach	e-learning actor	Type of publication
[29]	Classification	Consistency Queries (CQ) inductive inference machine	Student	C
[42]	Classification	Consistency Queries (CQ) inductive inference machine	Student	C
[93]	Prediction	Software agents	Student	C
[84]	Prediction	Ad hoc naïve algorithm for tutor tree	Student	C
[28]	Classification	Multiagent systems	Student	C
[9]	Classification	Graph theory	Student	C
[19]	Classification	IF-THEN rules	Student	
[2]	Classification	Multiagent systems	Student	
[50]	Classification	Apriori algorithm	Student	C
[8]	Classification	Distance measures	Student	C
[95]	Classification	Association Rules	Student	C
[35]	Classification	Association Rules	Student and Teacher	C
[55]	Classification	Neural Network	Student	J
[48]	Classification	Decision Tree-based rule extraction	Teacher	C
[72, 73]	Prediction	Prediction rules	Student	C; J
[33]	Classification	Case-based reasoning	Student	C
[31]	Clustering	HAC, Single-Pass and k-NN	Student	B
[47]	Classification	Rough set theory and Decision Trees	Student and Teacher	C
[66, 67]	Prediction	Multiagent systems and ID3	Teacher	C; C
[76]	Prediction	Bayesian Network	Student	J
[88]	Prediction	Bayesian Network	Student	C

The assessment of students is the e-learning issue most commonly tackled by means of Data Mining methods. This is probably due to the fact that such assessment is closer to the evaluation methods available in the traditional presential education. One of the e-learning topics with the least results obtained in this survey is the analysis of the atypical students' learning behavior. This is probably due to the inherently difficult problem of successfully establishing when the learning behavior of a student is atypical or not.

Table 3. Data Mining applications providing an evaluation of the learning material

Reference	DM objective	DM approach	e-learning actor	Type of publication
[98, 99]	Classification	Software agents and Association Rules	Student	C; C
[89]	Classification	Association Rules (integrating Apriori algorithm), fuzzy set theory and inductive learning (AQR algorithm)	Teacher	C
[39]	Group Decision methods	Group decision method, grey system and fuzzy theory	Student, Teacher and Staff	J
[40]	Classification and prediction	Fuzzy rules	Student, Teacher and Staff	C
[78]	Classification	Naïve Bayes	Teacher	C
[64]	Classification	Basic statistical methods	Teacher	C
[21]	Classification	Web usage mining: association and sequence	Teacher	C
[77]	Statistical analysis	Basic statistical methods	Student, Teacher and Staff	J
[83]	Clustering and Visualization	Bisection K-Means	Teacher	C
[23]	Clustering	SOM	Teacher	J

Table 4. Data Mining applications providing feedback to e-learning actors (students, tutors and educational managers)

Reference	DM objective	DM approach	e-learning actor	Type of publication
[98, 99]	Classification	Software agents and Association Rules	Student	C; C
[36]	Classification	Fuzzy reasoning	Student	J
[1]	Statistical analysis	Metadata analysis	Student and Teacher	C
[32]	Statistical analysis	Metadata analysis	Student and Teacher	C
[97]	Classification	ADT Tree	Student and Teacher	C
[35]	Classification	Association Rules	Student and Teacher	C
[18]	Classification	Apriori algorithm	Student	C
[47]	Classification	Rough set theory and Decision Trees	Student and Teacher	C
[86]	Clustering	EM algorithm	Teacher	C
[3]	Prediction	Bayesian Network	Teacher	B
[5]	Prediction	Linear regression	Teacher	C
[27]	Prediction	Regression	Teacher	C
[25]	Prediction	FIR and OSRE	Teacher	C
[62]	Prediction	FIR	Teacher	C
[11]	Clustering	GTM	Teacher	C
[15]	Prediction	Dynamic Bayes Net	Teacher	C

Table 5. Data Mining applications for the detection of atypical learning behaviors

Reference	DM objective	DM approach	e-learning actor	Type of publication
[90, 91]	Outliers detection	Bayesian predictive distribution model	Teacher	C; C
[12]	Outliers detection	GTM	Teacher	C
[94]	Outliers detection	GTM	Teacher	C

4 Discussion and Opportunity for the Use of Data Mining in e-Learning Systems

In this section, we analyze in some more detail the current state of the research in Data Mining applied to e-learning, highlighting its future perspectives and opportunities, as well as its limitations. On the basis of the research papers surveyed in this chapter, we can roughly characterize the aforementioned opportunities as follows:

4.1 e-Learning Courseware Optimization

The possibility of tracking user behavior in virtual e-learning environments makes possible the mining of the resulting databases. This opens new possibilities for the pedagogical and instructional designers who create and organize the learning contents.

In order to improve the content and organization of the resources of virtual courses, Data Mining methods concerned with the evaluation of learning materials, such as those summarized in Table 3, could be used. Classification problems are dominant in this area, although prediction and clustering are also present.

Some of the publications reported in Table 1 could also indirectly be used to improve the course resources. If the students' evaluation was unsatisfactory, it could hint to the fact that the course resources and learning materials are inadequate.

The Data Mining methods applied to evaluate the learning material in an e-learning course, summarized in Table 3, include: Association Rules techniques, Fuzzy theory and clustering techniques, amongst others. We think that a sensible starting point for the development of course material evaluation is the exploration of Web usage models, applying Association Rules to explore the relationships between the usability of the course materials and the students' learning performance, on the basis of the information gathered from the interaction between the user and the learning environment.

4.2 Students' e-Learning Experience Improvement

One of the most important goals in e-learning, and one of its major challenges, is the improvement of the e-learning experience of the students enrolled in a virtual course. As seen in Tables 1, 2 and 4, several publications have addressed self-evaluation, learning strategies recommendation, users' course adaptation based on the student's profile and necessities. Diverse Data Mining models have been applied to these problems, including Association Rules, Fuzzy Theory, Neural Networks, DT and traditional statistical analysis.

Applying Data Mining (text Mining or Web Mining) techniques to analyze Web logs, in order to discover useful navigation patterns, or deduce hypotheses that can be used to improve Web applications, is the main idea behind Web usage mining. Web usage mining can be used for many different purposes and applications such as user profiling and Web page personalization, server performance enhancement, Web site structure improvement, etc. [80].

Clustering and visualization methods could also enhance the e-learning experience, due to the capacity of the former to group similar actors based on their similarities and the ability of the later to describe and explore these groups intuitively. If it was possible to cluster similar student behaviors on the basis of students' interaction with the learning environment, the tutor could provide scalable feedback and learning recommendation to learners.

Combinations of Data Mining methods have demonstrated their potential in Web-based environments, such as the combination of multiple classifiers and Genetic Algorithms described in [53] and the neurofuzzy models put forward in [81].

4.3 Support Tools for e-Learning Tutors

The provision of a set of automatic, or semiautomatic, tools for virtual tutors that allowed them to get objective feedback from students' learning behavior in order to track their learning process, has been an important line of research on Data Mining for e-learning, as can be deduced from the information summarized in tables 1, 4 and 5. Based on the publications surveyed, the experimental tools developed with this goal in mind could be roughly grouped into:

1. Tools to evaluate the students' learning performance (Table 1).
2. Tools that allow performing an evaluation of the learning materials (Table 3).
3. Tools that provide feedback to the tutors based on the students' learning behavior (Tables 4–5).

Diverse Data Mining methods have been applied to assess the students' learning performance, including: Clustering, DT, Social Network Analysis, Neural Networks, Fuzzy methods, and Association Rules. In fact, this is perhaps the e-learning topic with more significant research advances in the field of applications we are surveying.

One of the most difficult and time-consuming activities for teachers in distance education courses is the evaluation process, due to the fact that, in this type of course, the review process is better accomplished through collaborative resources such as e-mail, discussion forums, chats, etc. As a result, this evaluation has usually to be carried out according to a large number of parameters, whose influence in the final mark is not always well defined and/or understood. Therefore, it would be helpful to discover features that are highly relevant for students' evaluation. In this way, it would be possible for teachers to provide feedback to students regarding their learning activities online and in real time. In this sense, GTM [12, 94] with feature relevance determination and FIR [25, 62] methodologies, have been applied.

From the virtual teacher standpoint, valuable information could be obtain from the e-mail or discussion forum resources; however there is still a lack of automated tools with this purpose, probably due to the difficulty of analyzing the learning behavior from the aforementioned sources. Such tool would entail the use of Text Mining (or Web Mining) techniques. Natural Language Processing (NLP) techniques would be of potential interest to tackle this problem in e-learning, due their ability to automatically extract useful information that would be difficult, or almost impossible to obtain, through other techniques. Unfortunately, NLP techniques have not been applied extensively in e-learning. Some exceptions can be found in [23, 31], where NLP and clustering models were proposed for grouping similar learning materials based on their topics and semantic similarities.

Another almost unexplored research path in Data Mining for e-learning, which, in the authors' opinion, bears a great potential, is that of the application of methods for the explicit analysis of time series. That is despite the fact that much of the information that could be gathered from e-learning systems usage takes precisely this form.

5 Data Mining in e-Learning Beyond Academic Publications: Systems and Research Projects

Beyond academic publications, Data Mining methods have been integrated into software platforms implemented in real e-learning systems. A general review of these types of systems: WebCT, Blackboard, TopClass, Ingenium

Docent, etc. [20, 92], commonly used in universities and higher education, showed two main types of platforms: The first type takes a course as the building block, while the second takes the organization as a whole. The former (e.g. WebCT, TopClass) normally does not make a distinction between teacher and author (course-developer). This way, such systems allow the teacher much flexibility but also assume that the teacher will create course materials. The latter (e.g. Ingenium, Docent), have clearly defined and distinct roles. Content can be developed outside the system.

All these systems claim to be innovative and stress the importance of content but, unfortunately, they hardly provide any information about which didactical methods and models they implement; it is therefore difficult to assess them. As far as adaptation is an integral part of the systems, it would require extensive customization. Most of the surveyed systems do support collaborative learning tasks; however they do not allow the use of any specific scenario. They allow collaboration but merely provide the basic tools for its implementation [93].

Several large research projects have dealt with the integration of Data Mining methods in e-learning (see Table 6). The ALFANET project consists of an e-learning platform that provides individuals with interactive, adaptive and personalized learning through the Internet. ALFANET includes a component to provide support to the interpretation and presentation of dynamic adaptive questionnaires and their evaluation at run-time, based on the student preferences and profile. The adaptation component applies ML techniques, Association Rules, and Multiagent architectures to provide online real-time recommendations and advice to learners based on previous users' interactions, the course structure, the contents characterization and the questionnaires' results.

The AHA! project was initially developed to support an on-line course to add adaptation to hypermedia courses at the Eindhoven University of Technology. AHA! is currently in its 3.0 version. One of its most important features is the adaptation of the presentation and navigation system of a course on the basis of the level of knowledge of a particular student. AHA! applies specific prediction rules to achieve the adaptation goals.

The LearningOnline Network with a Computer Assisted Personalized Approach (LON-CAPA) is an integrated system for online learning and assessment. It consists of a learning content authoring and management system that allows new and existing content to be shared and re-used within and across institutions; a course management system; and an individualized homework and automatic grading system. In LON-CAPA some Data Mining methods, such as k-NN, MLP Neural Networks, DT, Association Rules, Combinations of Multiple Classifiers, Genetic Algorithms, and K-means, are employed to analyze individual access paths though the material interaction behavior.

Table 6. e-learning projects in which Data Mining techniques are used

Project name	DM techniques applied	e-Learning Topic	University or institution	URL of the project
LON-CAPA	k-NN, MLP, Decision Trees, Association Rules, Multiple Classifiers, Genetic Algorithms and K-means	Assessment system and feedback to e-learning actor, Feature selection and clustering of students performance	Michigan State University, USA	www.lon-capa.org/
ATutor	Statistical analysis	Assessment system and student behavior tracking	University of Toronto, Canada	www.atutor.ca/
LExIKON	Consistency queries (CQ) inductive inference	Course adaptation to the students' navigational behavior	German Research Center for Artificial Intelligence, Technische Universität Darmstadt, and others, Germany	http://lexikon.dfki.de/
aLFanet	Software Agents, Machine Learning, Association Rules	Course adaptation to the students' navigational behavior	Universidad Nacional de Educación a Distancia and Open University of the Netherlands. Spain Portugal, Germany and Netherlands	http://alfanet.ia.uned.es/alfanet
AHA!	Prediction Rules	Course adaptation to the students' navigational behavior	Eindhoven University of Technology and Cordoba University. Netherlands and Spain	http://aha.win.tue.nl
WebCT	Statistical Analysis	Assessment system and student behavior tracking	WebCT	www.webct.com/
Blackboard	Statistical Analysis	Assessment system and student behavior tracking	Blackboard	www.blackboard.com/us/index.aspx

LExIKON is a research and development project with an innovative approach to knowledge extraction from the Internet. The underlying learning mechanisms invoke inductive inference of text patterns as well as inductive inference of elementary formal systems. A specific inductive inference method called consistency queries (CQ) was designed and applied to this purpose.

ATutor is an Open Source Web-based LCMS designed with accessibility and adaptability features. ATutor has also adopted the IMS/SCORM Content Packaging specifications, allowing content developers to create reusable content that can be swapped between different e-learning systems. In ATutor, the tutors can assign partial credit for certain answers and can view grades, by student, and for all students on all tests, even can get reports showing the number of times, the time, date, and the frequency with which each student accessed course content.

WebCT is a commercial e-learning suite providing a Course Management system and an e-learning platform. In WebCT, the tutors can create self-assessments and the system automatically scores multiple choice, matching, calculated, jumbled sentence, fill-in-the-blank, true-false and short answers type questions, and can display instructor-created feedback and links to relevant course material. The tutors can monitor students' activities in the e-learning system and get different reports about the tracking data of their students.

Blackboard is another commercial e-learning suite that allows tutors to create e-learning courses and develop custom learning paths for group or individual students, providing tools that facilitate the interaction, communication and collaboration between all actors. The system provides data analysis for surveys and test item, and the results can be exported for further analysis. The report includes the number of times and dates on which each student accessed course contents, discussion forums and assignments.

6 Conclusions

The pervasiveness of the Internet has enabled online distance education to become far more mainstream than it used to be, and that has happened in a surprisingly short time. e-Learning course offerings are now plentiful, and many new e-learning platforms and systems have been developed and implemented with varying degrees of success. These systems generate an exponenttially increasing amount of data, and much of this information has the potential to become new knowledge to improve all instances of e-learning. Data Mining processes should enable the extraction of this knowledge.

It is still early days for the integration of Data Mining in e-learning systems and not many real and fully operative implementations are available. Nevertheless, a good deal of academic research in this area has been published over the last few years. From the point of view of the Data Mining problems dealt with in the surveyed works, we have seen that these are dominated by research on classification and clustering. This is somehow unsurprising, given the variety and wide availability of Data Mining methods, techniques and software tools for both of them. From the e-learning problems viewpoint, most work deals with students' learning assessment, learning materials and course evaluation, and course adaptation based on students' learning behavior.

In this chapter we have presented a general and up-to-date survey on Data Mining application in e-learning, as reported in the academic literature. Although we aimed to make it as complete as possible, we may have failed to find and identify some papers, journals and conferences that should have been included. The authors apologise in advance for any such errors that may have occurred. We hope this chapter becomes useful not only for Data Mining practitioners and e-learning system managers and developers, but also even for members and users, teachers and learners, of the e-learning community at large.

7 Key e-Learning Resources

In this section, we synthesize, in a self-contained manner, some key resources for the e-learning community. Once again, the information is provided in the form of tables and includes: International journals and conferences specialized on e-learning; main e-learning discussion forums; main e-learning organizations; e-learning repositories; e-learning standards; key e-learning research papers, books and book chapters; and open source e-learning software.

The last years have witnessed the appearance of a rapidly increasing number of scholarly publications either devoted to e-learning or including e-learning within their scope, as well as the organization of specialized conferences in the field. Table 7 summarizes this information.

In Table 8, the main discussion forums concerning e-learning topics are listed, together with their corresponding URLs. Furthermore, many institutions delivering e-learning courses provide discussion forums to improve the interaction between their students and tutors.

Table 7. International journals and conferences specialized on e-learning or including it within their scope and main topics. Conference edition corresponds to that held on 2006

Scientific Journal	International Conference
ACM Journal of Educational Resources in Computing (JERIC), ACM	IASTED International Conference on Web-Based Education (WBE), on its 5th edition
Computers & Education, Elsevier	IEEE International Conference on Advanced Learning Technologies (ICALT), on its 6th edition
Education and Information Technologies, Springer-Verlag	International Conference of the Association for Learning Technology, (ALT-C), on its 13th edition
European Journal of Open and Distance Learning (EURODL), European Distance and e-Learning Network (online only)	International Conference on Artificial Intelligence in Education (International AIED Society), on its 12th edition
e-Learning, Symposium Journals (online only)	International Conference on Computers in Education, (ICCE), on its 14th edition
IEEE Transactions on Education, IEEE Education Society	International Conference on Engineering Education, (ICEE), on its 9th edition
International Journal of Artificial Intelligence in Education, International AIED Society	International Conference on Intelligent Tutoring Systems, (ITS), on its 8th edition
International Journal on e-Learning (IJEL), AACE	International Conference on Interactive Computer Aided Learning, (ICL), on its 9th edition
Journal of Educational Multimedia and Hypermedia (JEMH), AACE	International Conference on Web-based Learning, (ICWL), on its 5th edition
Journal of Information Technology Education (JITE), Informing Science Institute	MERLOT International Conference (MIC), on its 6th edition
Journal of Interactive Learning Research, (JILR), AACE	Society for Information Technology & Teacher Education, (SITE), on its 18th edition
Journal of Online Teaching and Learning (JOLT), MERLOT (online only)	World Conference on Educational Multimedia, Hypermedia and Telecommunications, (ED-MEDIA), on its 18th edition
User Modeling and User-Adapted Interaction (UMUAI), Springer-Verlag	World Conference on e-Learning in Corporate, Government, Health, & Higher Education (e-Learn), on its 11th edition

Table 8. e-Learning discussion forums

Name	URL of the forum
eLearning Forum eCommunity	http://elf.collabhost.com/logon.do
eLearning Forum vPortal	http://elearningforum.vportal.net/
The Common Room - eLearning Discussion Forum	http://bbs.odeluce.stir.ac.uk/index.php
Support Insight e-learning discussion forums (numbers 3, 13, 22)	http://www.supportinsight.com/snitz/default.asp
ASTD e-Learning Discussion Board	http://community.astd.org/eve/ubb.x/a/frm/f/6401041
VTU eLearning Center- Discussion Forum	http://forum.vtu.ac.in/index.php

In Table 9, the most important e-learning organizations, societies and interest groups are presented.

Table 9. e-Learning organizations

Name	URL of the organization
The eLearning Guild	http://www.elearningguild.com
Learning Economics Group	http://www.learningeconomics.org
Greater Arizona eLearning Association	http://www.gazel.org
New England Learning Association	http://www.nelearning.org
International Association for Distance Learning	http://www.iadl.org.uk/associations.htm
Consortium of College Testing Centers	http://www.ncta-testing.org/cctc/
Sloan Consortium	http://www.sloan-c.org/
Masie Center e-Learning Consortium	http://www.masie.com/masie/default.cfm?page=default
IMS Global Learning Consortium	http://www.imsglobal.org/
Association of Learning Technology (ALT)	http://www.alt.ac.uk/
British Learning Association	http://www.british-learning.com/
European Institute for e-Learning (EIfEL)	http://www.eife-l.org/
eLearning Alliance	http://www.elearningalliance.org
elearning Network	http://www.elearningnetwork.org/
Learning Federation	http://www.learningfederation.org/

In order to fast-track the access to what we consider the most successful experiments applying Data Mining techniques to e-learning problems, and the most interesting published information in the field, Table 10 shortlists some key research papers and, whereas Table 11 lists some main books and book chapters.

Table 10. Key e-learning research papers

Paper
Alpaslan F.N. and Jain L.C.: "Virtual Al Classroom: A Proposal", Proceedinds of the 1st International Workshop on Hybrid Intelligent Systems (HIS-2001) in Advances in Soft Computing, 2002, Springer, Germany, pp. 485–495.
Jain, L.C.: "Knowledge-Based engineering: An Innovative Teaching Approach," Proceedings of the 8th Turkish Symposium on Artificial Intelligence and Neural Networks, June 1999, pp. 15–19.
Rowland, J.G. and Jain, L.C.: "Artificial Intelligence Languages in Engineering Education," Proceedings of PRCEE, Adelaide, 1992, pp.201–206.
Fasuga, R., Sarmanova, J.: Usage of Artificial Intelligence in Education Process. In: International Conference for Engineering Education & Research, ICEER2005. Tainan, Taiwan (2005).
Kotsiantis, S.B., Pierrakeas, C.J., Pintelas, P.E.: Predicting Students' Performance in Distance Learning Using Machine Learning Techniques. Applied Artificial Intelligence 18(5) (2004) 411–426.
Margo, H.: Data Mining in the e-Learning Domain. Computers & Education 42(3) (2004) 267–287
Matsui, T., Okamoto, T.: Knowledge Discovery from Learning History Data and its Effective Use for Learning Process Assessment Under the e-Learning Environment. In: Crawford, C., et al. (eds.): Society for Information Technology and Teacher Education International Conference. (2003) 3141–3144.

Minaei-Bidgoli, B., Punch, W.F.: Using Genetic Algorithms for Data Mining Optimization in an Educational Web-based System. In: Cantu, P.E., et al. (eds.): Genetic and Evolutionary Computation Conference, GECCO 2003. (2003) 2252–2263.
Monk, D.: Using Data Mining for e-Learning Decision Making. The Electronic Journal of e-Learning 3 (2005) 41–54
Nebot, A., Castro, F., Vellido, A., Mugica, F.: Identification of Fuzzy Models to Predict Students Performance in an e-Learning Environment. In: Uskov, V. (ed.): The 5th IASTED International Conference on Web-Based Education, WBE 2006. Puerto Vallarta, Mexico (2006) 74–79.
Pahl, C., Donnellan, D.: Data Mining Technology for the Evaluation of Web-based Teaching and Learning Systems. In: World Conference on e-Learning in Corp., Govt., Health., & Higher Education. (2002) 747–752.
Sison, R., Shimura, M.: Student Modeling and Machine Learning. International Journal of Artificial Intelligence in Education 9 (1998) 128–158.
Tang, C., Lau, R.W., Li, Q., Yin, H., Li, T., Kilis, D.: Personalized Courseware Construction Based on Web Data Mining. In: The First international Conference on Web information Systems Engineering, WISE'00. IEEE Computer Society. June 19–20, Washington, USA (2000) 204-211.
Vellido, A., Castro, F., Nebot, A., Mugica, F.: Characterization of Atypical Virtual Campus Usage Behavior Through Robust Generative Relevance Analysis. In: Uskov, V. (ed.): The 5th IASTED International Conference on Web-Based Education, WBE 2006. Puerto Vallarta, Mexico (2006) 183–188.
Zaïane, O.R., Luo, J.: Towards Evaluating Learners' Behavior in a Web-based Distance Learning Environment. In: IEEE International Conference on Advanced Learning Technologies, ICALT'01. August 6-8, Madison, WI (2001) 357-360.

Table 11. Key e-learning books and books chapters (in chronological order)

Books and Book Chapters
Tedman, D. and Jain, L.C.: An Introduction to Innovative Teaching and Learning. In: Jain, L.C. (Editor) Innovative Teaching and Learning: Knowledge-based Paradigms, Springer, pp. 1–30, Chapter 1 (2000).
Horton, W.: Evaluating e-Learning. ASTD e-Learning Series, Pearson (2001).
Jain, L.C., Howlett, R.J., Ichalkaranje, N., and Tonfoni, G.(Editors), Virtual Environments for Teaching and Learning, World Scientific, Singapore (2002).
Bersin, J. The Blended Learning Handbook: Best Practices, Proven Methodologies, and Lessons Learned. John Wiley & Sons (2004).
Ghaoui, C., Jain, M., Bannore, V. and Jain, L.C. (Editors), Knowledge-Based Virtual Education: User-centerd Paradigms, Springer-Verlag (2005).
Rosenberg, M.L.: Beyond e-Learning: Approaches and Technologies to Enhance Organizational Knowledge, Learning, and Performance. John Wiley & Sons (2006).
Romero, C., Ventura, S. (Editors): Data Mining in e-Learning. WIT Press (2006).
Hammouda, K., Kamel, M.: Data Mining in e-Learning. In: Pierre, S. (Editor): e-Learning Networked Environments and Architectures: A Knowledge Processing Perspective, Springer-Verlag, (2006).

The deployment of an e-learning solution is a usually difficult process. Table 12 lists the best-known information repositories that may help to facilitate this task. In Table 13, we present a number of repositories containing learning objects ready to use in the development of e-learning courses. Learning objects are any digital resource that can be reused for learning or training, and constitute a valuable resource for e-learning course development.

Table 12. e-Learning information repositories

Name	URL of the document repository
Distributed eLearning Repositories	http://www.markcarey.com/elearning/distributed-elearning-repositories.html
Educational Resource Information Center – ERIC	http://www.eric.ed.gov/
Distance Learning Database	http://icdllit.open.ac.uk/
Database of Research on International Education	http://cunningham.acer.edu.au/dbtw-wpd/textbase/ndrie/ndrie.html
Education-line	http://www.leeds.ac.uk/educol/
Association for the Advancement of Computing in Education - AACE Digital Library	http://www.aace.org/
e-Learning Centre	http://www.e-learningcentre.co.uk
e-Learning Resources	http://www.grayharriman.com
Elearnspace	http://www.elearnspace.com
e-Learning Knowledge Base	http://ekb.mwr.biz
ASTD e-Learning Community	http://www.astd.org/astd/Resources/elearning_community/elearning_home.htm

Table 13. Learning objects repositories

Name	URL of the learning object repository
Multimedia Educational Resource for Online Learning and Teaching – MERLOT	www.merlot.org
Wisconsin Online Resource Center	http://www.wisc-online.com/
FERL: Learning Object Technology	http://ferl.becta.org.uk/display.cfm?page=307
ARIADNE - European Knowledge Pool System	http://www.ariadne-eu.org/
Campus Alberta Repository of Educational Objects – CAREO	http://careo.netera.ca/
Fathom Archive	http://www.fathom.com/
Lydia Global Repository	http://www.lydialearn.com/devwelcomepage.cfm
Scottish Electronic Staff Development Library	http://www.sesdl.scotcit.ac.uk:8082/main.html
Learning Resource Catalogue – LRC	http://www.lrc3.unsw.edu.au
Cooperative Learning Object Exchange - CLOE	http://cloe.on.ca/
Smete Digital Library	http://www.smete.org
Education Network Australia – EdNA	http://www.edna.edu.au/edna/go
MIT OpenCourseWare	http://ocw.mit.edu/index.html
Interactive Dialogue with Educators from Across the State- IDEAS	http://ideas.wisconsin.edu/
National Learning Network: Materials	http://www.nln.ac.uk/Materials
Global Campus	http://www.csulb.edu/~gcampus/

e-Learning systems require standards for their design and deployment. Educative organizations can also save time and resources, as well as guarantee their continuity, by adhering to a reliable and well-known set of standards. Some of them can be found in Table 14.

Table 14. e-Learning standards

Name	URL of the specifications
ADL SCORM	http://www.adlnet.org/index.cfm?fuseaction=SCORMDown
AICC (CMI Guidelines)	http://www.aicc.org
IEEE LTCS: LOM	http://ltsc.ieee.org/
MELD IT standards for healthcare education	http://meld.medbiq.org/meld_library/standards/index.htm
IMS	http://www.imsglobal.org/
Learning Systems Architecture Lab	http://meld.medbiq.org/primers/e-learning_standards_pasini.htm

An important issue for the development of e-learning environments is the existence and availability of open source software. In Table 15, the most popular, open source learning management systems are presented. Some of the software presented in this table has already been cited in Sect. 5.

Table 15. Open source e-learning software

Name	URL of the open source software
ATutor	http://www.atutor.ca/
Brihaspati	http://home.iitk.ac.in/~ynsingh/tool/brihaspati.shtml
Claroline	http://www.claroline.net/
COSE	http://www.staffs.ac.uk/COSE/
CourseWork	http://getcoursework.stanford.edu/
Didactor	http://www.didactor.nl/
Docebo LMS	http://www.docebo.org/doceboCms/
Drupal	http://drupal.org/
Fle3 Learning Environment	http://fle3.uiah.fi/
ILIAS	http://www.ilias.de/ios/index-e.html
LAMS	http://lamsfoundation.org/
.LRN	http://www.dotlrn.org/
Mambo	http://www.mamboserver.com/
Manhattan Virtual Classroom	http://manhattan.sourceforge.net/
Moodle	http://moodle.com/
MySource Matrix	http://www.squiz.co.uk/mysource_matrix
OLAT – Online Learning and Training	http://www.olat.org
Open Source Portfolio (OSP) Initiative	http://www.osportfolio.org/
Sakai	http://www.sakaiproject.org/
Wordcircle CMS	http://wordcircle.org/

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Data Mining of Virtual Campus Data

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Summary. As mentioned elsewhere in this book, e-learning offers "a new context for education where large amounts of information describing the continuum of the teaching–learning interactions are endlessly generated and ubiquitously available". But raw information by itself may be of no help to any of the e-learning actors. The use of Data Mining methods to extract knowledge from this information can, therefore, be an adequate approach to follow in order to use the obtained knowledge to fit the educational proposal to the students' needs and requirements. This chapter provides a case study in which several advanced Data Mining techniques are employed to extract different types of knowledge from virtual campus data concerning students system usage behaviour. The diverse palette of Data Mining problems addressed here include data clustering and visualization, outlier detection, classification, feature selection, and rule extraction. They concern diverse e-learning problems, such as the characterization of atypical students' behaviour and the prediction of students' performance. Different Data Mining techniques from the areas of Statistical and Machine Learning; Fuzzy Logic, and Inductive Reasoning are

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employed to tackle these problems. Strong emphasis is placed on the interpretability of the results, obtained through rule extraction, so that they can be fed back to the e-learning system in a practical an efficient manner.

1 Introduction

Any e-learning system is, by its own nature, likely to generate large amounts of information describing the continuum of the teaching-learning interactions almost in real time. All this information, gathered from diverse and usually heterogeneous sources, may be of no help by itself to any of the e-learning actors in its raw form. Actually, an excess of such information can become a liability for e-learning tutors and managers unless it is processed according to reasonable goals. Data Mining can provide the adequate tools for such processing; obtaining actionable patterns from large data repositories. The use of Data Mining methods to extract knowledge from the e-learning system available information can, therefore, be an adequate approach to follow in order to use the obtained knowledge to fit the educational proposal to the students' needs and requirements.

Virtual campus environments, such as the one that is the subject of this case study, are fastly becoming a mainstream alternative to traditional distance higher education. The Internet medium they use to convey content, also allows the gathering of information on students' online behaviour. Here, we focus on e-learning systems improvement through the analysis of the data generated by the virtual campus students, aiming to discover their system usage patterns.

The amount of research concerned with the mining of data generated by the usage of e-learning systems is still somehow scarce on the ground (see Castro et al., this book). In this study, we address two main problems concerning virtual campus students' behaviour: the characterization of atypical behaviour and the prediction of students' performance. Several Data Mining problems are concerned, namely: students' data clustering and visualization, behavioural outlier detection, students' classification according to course marks, data feature selection, and rule extraction. The latter becomes of paramount importance as we aim to place a strong emphasis on the interpretability of the obtained results; no matter how accurate these might be: unless they are translated into practical and efficient rules that system managers and tutors can act upon, it will be extremely difficult to feed them back to the e-learning system.

The rest of the chapter is structured as follows: First, in Sect. 2, we provide a detailed description of the data under analysis; they correspond to students of a particular course of the Center of Studies in Communication and Educational Technologies (CECTE, as Spanish acronym) virtual campus. This is followed by successive sections devoted to the different problems at hand. Atypical student behaviour is analysed using the Generative Topographic Mapping (GTM) [1] model for data clustering and visualization. Students' performance prediction and feature selection are dealt through Fuzzy Inductive Reasoning (FIR) [11] and Artificial Neural Networks. The models for rule extraction are Orthogonal Search-based Rule Extraction (OSRE) [4] and FIR. Finally, Sect. 5 concludes the study summarizing its findings.

2 Data from the CECTE Virtual Campus

CECTE is a partially virtual campus, offering postgraduate courses and continuous education (graduate, workshops and specific courses) to Latin-American students. The CECTE is part of the international Latin-American Institute of Educative Communication (ILCE), whose main goal is to offer postgraduate courses.

The ILCE was born in the General Conference of the United Nations Organization for Education Science and Culture, carried out in Uruguay in 1954. Its aim was alleviating the educative needs of the Latin-American region through the use of audiovisual media and technological resources. From inception, the ILCE has tried to apply the most up-to-date tools and technologies (from phonographic records to the Internet) to deliver high-quality distance courses. In February of 1979, ILCE obtained the status of International Organization with juridical personality, its own patrimony and autonomous administration.

Throughout its 50 years of existence, ILCE has undergone structural and technologic changes in order to maintain the high quality of its educative services, taking advantage of the computer, multimedia and telecommunications methodological breakthroughs, and staying at the forefront of the evolution of the distance education field. Moreover, ILCE has signed collaborative agreements with the most prestigious institutions, public and private, offering distance education services around the world, including the British Broadcasting Corporation (BBC), the Open Learning Agency (OLA), the University of British Columbia (UBC), the Public Broadcasting Service (PBS), and the Educational Management Group (EMG), to name just a few.

As previously stated, CECTE is the part of ILCE offering postgraduate courses and continuous education, including master and graduate degrees, workshops and specialized courses. At the moment, up to 2,000 students are registered in any of the offered programs. CECTE has developed 39 specialized courses addressed to educative, public and governmental institutions. The most demanded CECTE courses follow a hybrid, semi-presential model, in which students take courses online through the Web CECTE (WCECTE) but also attend weekly TV sessions through the National System of Educative Television (EDUSAT), which takes advantage of digitalized satellite, optical fibre and telephony technologies. Through WCECTE, students can access the course materials and communicate and interact with each other through an e-mail system and a discussion forum. Moreover, all weekly TV sessions are available to all students through WCECTE. The environment also includes an agenda, a news system, virtual classrooms, a digital library, interactive tutorials, and other related tools.

The educative model of CECTE comprises the interaction and communication between all actors involved in the teaching-learning process: Students, branch coordinators, advisors and tutors, mainly. An important characteristic of the CECTE educative model is the activities calendar, consisting of a list of activities and learning suggestions made by the module advisor.

Advisors are entrusted to deliver a specialized weekly session and interact, communicate, coordinate, and answer possible doubts from course tutors. Branch coordinators are entrusted to evaluate the branch activities and to check if students perform their assigned activities properly. The tutor is a very relevant actor, as he or she interacts directly with students, assigning learning activities, answering doubts, opening topics in discussion forums, evaluating the activities performed by learners, and verifying that the teaching-learning process is adequate, taking advantage of all the tools provided by WCECTE.

The evaluation process is based on a set of activities performed by the students, in both WCECTE and the physical branch. An important evaluation element in the course analysed in this chapter is the students' learning behaviour measured through the analysis of comments and homework posted by them to discussion forums. Two specialized discussion forums were used in the analysed course: general topics about the course and specific class plan topics comments.

Two novel evaluation topics, not often used in e-learning environments, were incorporated in the course: co-evaluation and experience report. In co-evaluation, the advisor grades how well the student evaluates the class plans of his/her course mates. The experience report is a student description of his/her perception of the course. It can be viewed as a self-evaluation of the student's own learning process.

For the experiments in this chapter, a set of 722 students, enrolled in the "Didactic Planning" graduate course, was selected. The course is addressed to second term high school teachers offering specialized subjects, namely Mathematics, Chemistry, Mexican History, Computer Science, English, as well as Reading and Writing, and Ethics and Values workshops. The students are meant to perform a set of activities throughout the course with the main purpose of learning new methods and strategies for planning the classes that they teach. This is the reason why these activities are centred on the so-called "class plan". A class plan is a document where a set of strategies are suggested to develop a teaching–learning session, taking into account different factors that appear in the educational process, such as students' characteristics, teaching style, teachers' experience, etc. The data features available for this study are detailed on Table 1.

3 Characterization of Atypical Virtual Campus Usage

The detection of atypical behaviour in a virtual campus is a research goal on its own. There is much to be learnt from atypical behaviour online, as it can provide clues about what might be failing in the e-learning system, or about virtual campus facilities that might have not been considered.

Here, we approach the discovery of atypical behaviour as a combination of data clustering and outlier detection. Unlike in classification problems (subject of coming sections of this chapter), in data clustering we are not interested in modelling a relation between a set of multivariate data items and a certain set of outcomes for each of them (being this in the form of class membership labels). Instead, we aim to discover and model the groups in which the data items are clustered, according to some item similarity measure.

If a clustering model is used as a Data Mining tool to characterize the groups of online students, we would expect this model to provide a sensible cluster structure despite the presence of data outliers. Outliers are loosely defined here as data items (corresponding to individual students) that are somehow removed from the most populated areas in data space. We assume that outlierness in this context corresponds to atypical student usage behaviours.

Table 1. Data features collected for the experiment

Feature	Alias	Description
Age of the student	AGE	Age of the student
Area of expertise	EXP	Area of expertise of the student (mathematics, chemistry, Mexican history, etc.)
Gender	G	Student's gender
Level of studies	STD	Level of studies (graduate, master, Ph.D., etc.)
Position of the student	POS	Position of the student as a teacher in his/her school
Percentage of the activities performed by the student	ACT	Percentage of the activities performed by the student with respect to the total activities of the course
Percentage of session assistance	ASS	Percentage of student's session assistance with respect to the total number of sessions of the course
Average mark of the e-mail	MAIL	Average mark obtained by the student in the activities sent by e-mail
Average mark of the co-evaluation	COEV	Average mark of the co-evaluation performed by the student of the class plan of other students. The advisor grades how well the student evaluates the class plans of his/her course mates
Average mark of the forum participation	F	Average mark of the student's forum participation (referring to topics related to the course)
Average mark of the forum class plan	FCP	Average mark of the forum class plan (referring only to topics related to the class plan exclusively)
Average mark of the final class plan	FC	Average mark obtained by the student in his/her final class plan
Average mark of the initial class plan	IC	Average mark obtained by the student in his/her initial class plan
Average mark of the experience report	ER	Average mark obtained by the student in the experience report. In this report the student evaluates his/her learning process and describes the main concepts learned
Average mark of the work in the branch	BR	Average mark of the work (activities) performed in the branch
Final mark	MARK	Final mark obtained by the student in the course

The model used in this study for simultaneous data clustering, visualization, and outlier detection, is called GTM [1], which is both a probabilistic alternative to the well-known Self-Organizing Maps (SOM) [8] (also referred to as Kohonen Maps) and a constrained mixture of Gaussians model. Gaussian mixture models are known to lack robustness in the presence of data outliers, and mixtures of multivariate Student *t*-distributions have been suggested as a more robust alternative [14]. In this study, the GTM is applied as a constrained mixture of Student *t*-distributions: the *t*-GTM [17], and used to detect atypical learning behaviour from the actions performed by the CECTE students. This outlier detection is part of a more general clustering process that aims to group students with similar navigational behaviour.

One of the most important phases of a Data Mining process (and one that is usually neglected) is that of data exploration through visualization methods. The interpretability of the clustering results provided by the *t*-GTM, even in terms of this exploratory visualization, can be limited for data sets consisting of too large a number of features. This situation is not uncommon for a wide range of real-world problems concerning clustering methods. Principled methods of feature selection have for long been the preserve of supervised methods. In comparison, feature selection for unsupervised learning has received far less attention. The interpretability of a clustering solution would be greatly improved by its description in terms of a reduced subset of relevant features. Recently, an important advance in feature selection for unsupervised model-based clustering was described in [10] for Gaussian mixture models and extended to GTM and *t*-GTM in [16, 18].

In this section, we first briefly introduce the GTM and its robust *t*-GTM variant. This is followed by the description of an unsupervised method for feature selection associated to it. Outlier detection, clustering, feature selection and visualization results are then, in turn, presented and discussed.

3.1 GTM in a Nutshell

The GTM [1] was originally formulated both as a probabilistic clustering model alternative to the heuristic SOM [8] and as a constrained mixture of Gaussian distributions. It is precisely these constraints what enables it for cluster visualization, overcoming a common limitation of generic mixture models. The GTM can also be seen as a non-linear latent variable model that defines a mapping from a low-dimensional latent (non-observable) space onto the observed data space. The mapping is carried through by basis functions generating a (mixture) density distribution. The functional form of this mapping for each variable d can be expressed as

$$y_d(\mathrm{u},\mathrm{W}) = \sum_{m}^{M} \phi_m(\mathrm{u}) w_{md}, \tag{1}$$

where $\boldsymbol{\Phi}$ are basis functions $\Phi(\mathrm{u}) = (\phi_1(\mathrm{u}),\ldots,\phi_M(\mathrm{u}))$ that introduce the non-linearity in the mapping; $\mathbf{W}$ is the matrix of adaptive weights w_{md} that defines the mapping; and u is a point in latent space. In order to provide an alternative to the visualization space defined by the characteristic SOM lattice, the latent space of the GTM is discretized as a regular grid of K latent points u_k. The mixture density for a data point $\mathbf{x}$, given Gaussian basis functions, can be written as

$$p(\mathrm{x}|\mathrm{W},\beta) = \frac{1}{K}\sum_{k=1}^{K}\left(\frac{\beta}{2\pi}\right)^{D/2} \exp\left\{-\beta/2 \left\|\mathrm{y}_k - \mathrm{x}\right\|^2\right\}, \tag{2}$$

where the D elements of $\mathbf{y}$ are given by (1). This density allows for the definition of a model likelihood, and the well-known Expectation-Maximization (EM: [2]) algorithm can be used to obtain the Maximum Likelihood estimates of the adaptive parameters (W and β) of the model. See [1] for details on these calculations.

3.2 Data Clustering and Visualization Using GTM

Model interpretation usually requires a drastic reduction in the dimensionality of the data. Latent variable models can provide such interpretation through visualization, as they describe the data in intrinsically low-dimensional latent spaces. Each of the latent points u_k in the latent visualization space – which in this study is a 2-dimensional space – is mapped, following (1), as $\mathrm{y}_k = \Phi(\mathrm{u}_k)\mathrm{W}$. The y_k points are usually known as *reference vectors* or *prototypes* and their dimensionality, in the case of this study, is that of the original CECTE virtual campus data, described in Table 1. Each of the reference vector elements corresponds to one of the observed features, and their values over the latent visualization space can be colour-coded to produce *reference maps* that provide information on the behaviour of each variable and its influence on the clustering results.

Each of the latent space points u_k can be considered by itself as a cluster representative (of a cluster containing the subset of course students assigned to it). For simplicity, we use for the GTM a cluster assignment method akin to that of SOM, which is based on a winner-takes-all strategy: Each data observation (student) is assigned to the location in the latent space (cluster) where the mode of the corresponding posterior distribution is highest, i.e. $\mathrm{u}_n^{\mathrm{mode}} = \arg\max_{\mathrm{u}_k} r_{kn}$, where r_{kn} is the probability of student n belonging to cluster k, and it is obtained as part of the EM algorithm.

3.3 Handling Outliers with *t*-GTM

General Gaussian mixture models lack robustness in the presence of data outliers. For the Gaussian GTM, as a constrained mixture model, the presence of outliers is likely to negatively bias the estimation of parameters W and β. To overcome this, several recent studies have suggested the use of multivariate Student *t*-distributions as a robust alternative to Gaussians. The GTM can equally be redefined as a constrained mixture of Student *t*-distributions: namely, the *t*-GTM [17]. Assuming now that the basis functions $\boldsymbol{\Phi}$ are *t*-distributions, the mixture density in (2) can be redefined as

$$p(\mathrm{x}|\mathrm{W},\beta,\nu) = \frac{1}{K}\sum_{k=1}^{K}\frac{\Gamma((\nu/2)+(D/2))\beta^{D/2}}{\Gamma(\nu/2)(\nu\pi)^{D/2}}\left(1+(\beta/\nu)\left\|\mathrm{y}_k-\mathrm{x}\right\|^2\right)^{-(\nu+D)/2}, \quad (3)$$

where $\Gamma(\cdot)$ is the gamma function and the parameter ν can be understood as a tuner that adapts the level of robustness (divergence from normality) for the mixture. Again, the parameters of this model can be estimated using the EM algorithm. Details can be found in [17]. As a result of replacing the Gaussians by *t*-distributions, the impact of outliers on the estimation of the model parameters is effectively minimized.

3.4 Unsupervised Feature Selection with *t*-GTM

The interpretation of the clustering results provided by the *t*-GTM can become extremely difficult – and even impractical – for high-dimensional data sets. Therefore, the development of a method for feature relevance determination (FRD) and a criterion for feature selection (FS) based on it should sensibly increase their interpretability.

Recently, a method for FRD in unsupervised model-based clustering with mixture of Gaussians models was presented in [10] and extended to the *t*-GTM in [18]. This method calculates an unsupervised feature saliency as part of the EM algorithm. Such saliency measures the relevance of a feature on the definition of the cluster structure yielded by the model. It could be argued that the presence of outliers in the data sample is likely to bias the estimation of this saliency: In Gaussian mixtures, too many mixture components tend to fit the atypical data; as a result, those features which define what is atypical in the outliers might be attributed too high a saliency. The use of *t*-GTM should discount the negative effect of data outliers.

Formally, the saliency of feature *d* (its relevance) is defined as ρ_d. A value of $\rho_d = 1$ indicates the full relevance of feature *d*. According to this definition, the mixture density in (3) can be rewritten as

$$p(\mathrm{x} \mid \mathrm{W}, \beta, \nu) = \sum_{k=1}^{K} \frac{1}{K} \prod_{d=1}^{D} \left\{ \rho_d p\left(x_d \middle| \mathrm{u}, \mathrm{W}, \beta, \nu\right) + \left(1 - \rho_d\right) q\left(x_d \middle| \lambda_d\right) \right\}. \quad (4)$$

A feature *d* is irrelevant, with *irrelevance* $(1 - \rho_d)$, if, for all the *t*-GTM mixture components, $p(x_d | \mathrm{u}, \mathrm{W}, \beta, \nu) = q(x_d | \lambda_d)$, where $q(x_d | \lambda_d)$ is a common density followed by feature *d*. Notice that this is tantamount to saying that the distribution for feature *d* does not follow the cluster structure defined by the model.

Once again, we can estimate the model parameters (most importantly, the relevance ρ_d) resorting again to Maximum Likelihood and the EM algorithm. Details can be found in [18].

3.5 Experimental Results and Discussion

The first part of the experiments concerns the identification and characterization of atypical (outlier) students. The *t*-GTM parameters W and w_0 are initialized to fixed values, following a standard procedure [1], that ensures the replicability of the results. The visualization grid of *t*-GTM latent centres is fixed to a square layout of 5×5 nodes (i.e., 25 constrained mixture components). The corresponding grid of basis functions ϕ_m is fixed to a 3×3 layout.

Following Peel and McLachlan [14], a given data observation *n* will be considered to be an outlier if the value of $\Omega_n = \sum_k r_{kn} \beta \left\| \mathrm{y}_k - \mathrm{x}_n \right\|^2$ is sufficiently large. Notice that r_{kn}, as previously mentioned, is the responsibility assumed by a cluster *k* for data observation (student) *n*. A histogram for this statistic is provided in Fig. 1, showing a reasonably well-defined structure that evidences the difference between a majority of students with low values of Ω_n and a minority with large values. The selection of a threshold to differentiate outliers from non-outliers depends on the restrictions of the analysis in a real context. In this study, for illustrative purposes, such threshold has been placed at $\Omega_n = 1.75 \times 10^7$, leaving 43 students (just below a 6%) as atypical cases or outliers.

We are interested in characterizing these atypical students. For that, we first visualize how the data have been mapped onto the *t*-GTM visualization space in Fig. 2 (top-left plot). The relative size of each cluster (square) is an indicator of the ratio of data observations assigned to that specific cluster by the model. Such assignment, as described in Sect. 3.2, is based on the modes $\mathrm{u}_n^{\mathrm{mode}} = \arg\max_{\mathrm{u}_k} r_{kn}$, which indicate which cluster bears maximum responsibility for a data point (student). The rather homogeneous cluster spread indicates that outliers do not dominate the mapping, which agrees with what is expected from the *t*-GTM definition. Instead, the mapping based on a Gaussian GTM (on the bottom plot) is clearly dominated by big clusters of students, restricted to a very specific area of the map and surrounded by small clusters corresponding to outliers.

Also in Fig. 2 (top-right plot), we can visualize where the outliers (according to the threshold in Fig. 1) have been mapped onto. With few exceptions, they are mostly on the left-hand side of the map; in other words, they have been located by the *t*-GTM model in a very well-delimited area. This localization simplifies their interpretation in terms of the *t*-GTM reference maps of Fig. 3. Let us focus on the four clusters on the top-left corner of the plot, which have a very strong outlier presence. Their interpretation according to the reference maps is quite straightforward: they are characterized by medium-to-very low values of all features but AGE, which is medium-to-high. This means that the *outlierness* of these particular students has to do with their low involvement with the virtual campus activity, which seems to be characteristic of the most mature students. It is also worth noting that the distribution of the main outliers over the map, as seen on the top-right plot of Fig. 2, resembles quite closely the distribution in Fig. 3 of the low values for the variables MARK, FC, MAIL and of the high values for AGE. These results are coherent with the online teachers' perception that the mature students lack expertise in the use of technology, at least at the beginning of the course.

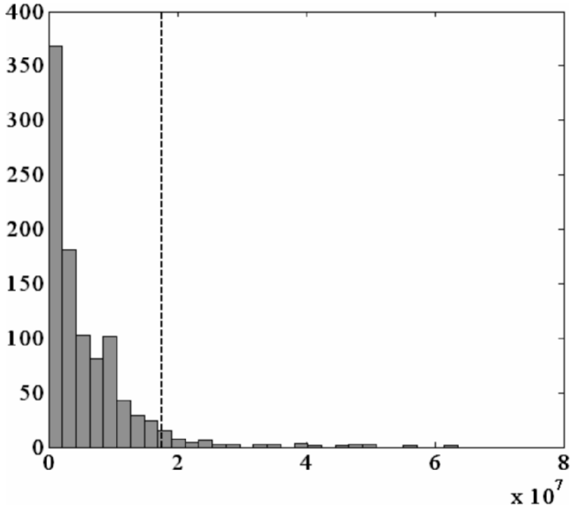

Fig. 1. Histogram of statistic Ω_n for the 722 students. An illustrative threshold is represented as a *dashed line*

The second part of the experiments concerns the estimation of the relative relevance of the data features. In this case, the values of the initial parameters are not fixed.

The feature saliency estimation results for the CECTE data are shown in Fig. 4. They neatly indicate that only one variable has consistently very high relevance: ACT. The average features (BR, F, FC and MAIL) and ASS have high but less consistent relevance. On the contrary, MARKS and, specially, AGE are clearly irrelevant in the definition of cluster structure. According to this, AGE influences cluster structure the least. With this new knowledge, we can now characterize the main outlier clusters described in previous paragraphs in a more parsimonious way: they are mainly defined by low to very low values of the average features, ACT, and ASS.

All these results show that useful knowledge can be extracted from the *t*-GTM combination of outlier detection, FRD and data clustering and visualization [19]. This knowledge could be fed back into the e-learning system in order to provide students with personalized guidance, tailored to their inhomogeneous needs and requirements. As a software tool embedded into the e-learning system, it would also help e-learning tutors to find patterns of student's behaviour.

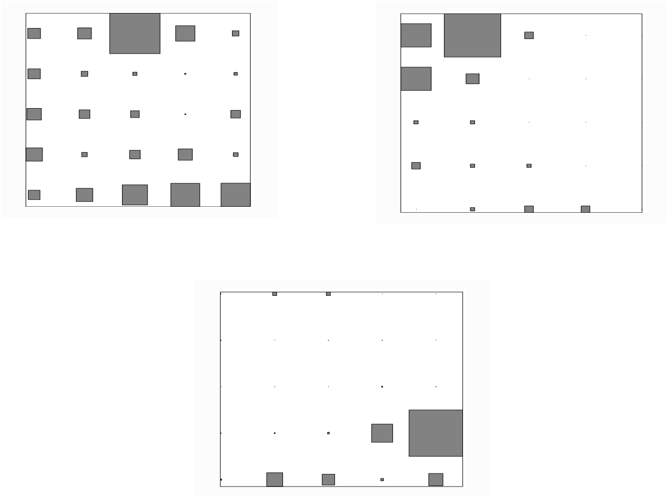

Fig. 2. Clustering of the 722 students on the *t*-GTM (*top-left*) and Gaussian GTM (*bottom*) 5 × 5 visualization spaces. On the *top-right* plot, only the *t*-GTM main outliers (43 students, according to Fig. 1) have been represented. For each plot, the size of the squares is proportional to the ratio of students assigned to the corresponding clusters by the model; therefore, squares of the same size in different plots do not necessarily correspond to the same number of students

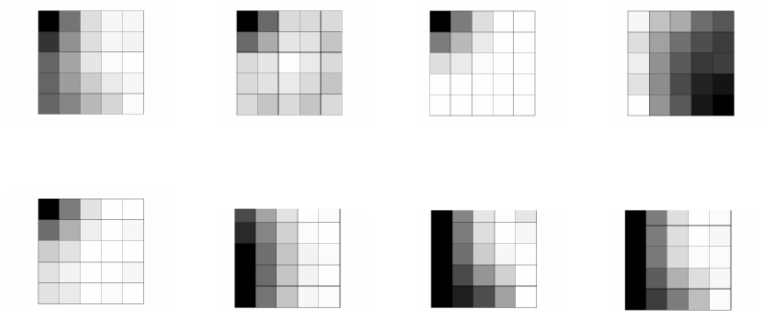

Fig. 3. Each cluster *k* in the 5 × 5 visualization space is associated to a reference vector $\mathrm{y}_k = \phi(\mathrm{u}_k)\mathrm{W}$. It consists of as many elements as features in Table 1. For brevity, only eight of them are displayed here: From *top* to *bottom* and *left* to *right*, reference maps for: MARK, ACT, ASS, AGE, BR, F, FC and MAIL. They are coded in grey-scale, from black (lowest values) to white (highest values). Given the correspondence between the layout of these maps and that of the clustering results in Fig. 2, the latter can be interpreted according to the former

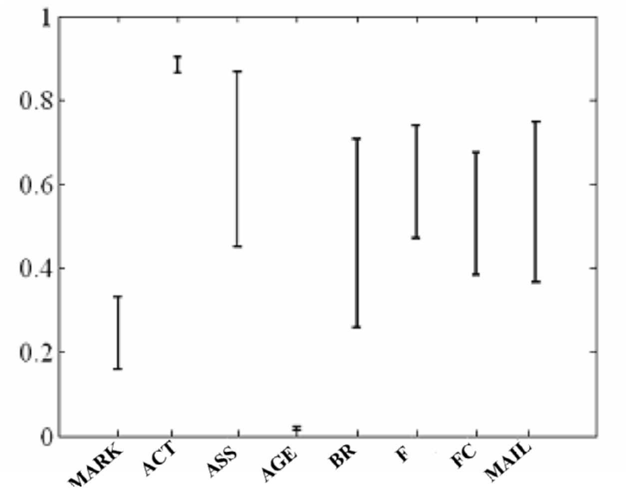

Fig. 4. FRD-GTM estimated values (represented by their means, plus and minus one standard deviation, over 20 runs of the algorithm) of the saliency vector ρ (see Sect. 3.4). Features with uncertain relevance (close to 0.5) show wider variations

4 Prediction of CECTE Students' Performance

In classification problems, we usually aim to model the existing relationships between a set of multivariate data items and a certain set of outcomes for each of them in the form of class membership labels.

One of the most difficult and time consuming activities for teachers in distance education courses is the evaluation process, due to the fact that, in this kind of courses, the review process should be done using collaborative resources such as e-mail, discussion forums, chats, etc. Additional problems are the usually high number of features involved and the complexity to define their influence in the final mark. Therefore, it would be helpful to reduce the dimensionality of the problem by identifying highly relevant features. In this way, it would be possible for teachers to provide feedback to students regarding their learning activities online and in real time. Moreover, the students' performance forecasting would become more interpretable.

In this section, we aim to predict the final mark of the users of the CECTE virtual campus. This prediction is understood as a classification problem, in which marks are grouped by intervals, each identified as a class. As explained in the introduction, we pay preferential attention to the interpretability of the results, trying to translate them into practical and efficient rules that system actors could use. To this end, classification is here intertwined with supervised feature selection and rule extraction.

4.1 Classification and Feature Selection with Fuzzy Inductive Reasoning

The methodological approach used to address the classification task is that of FIR. The conceptualization of FIR arises from the General Systems Theory proposed by Klir [7]. This modelling and qualitative simulation methodology is based on systems behaviour rather that on structural knowledge. It is able to obtain good qualitative relations between the variables that compose the system and to infer the future behaviour of that system. It also has the ability to describe systems that cannot easily be described by classical mathematics (e.g. differential equations), i.e. systems for which the underlying physical laws are not well understood. FIR consists of four main processes, namely: fuzzification, qualitative model identification, fuzzy forecast and defuzzification. Figure 5 describes the structure of the FIR methodology as applied in this study.

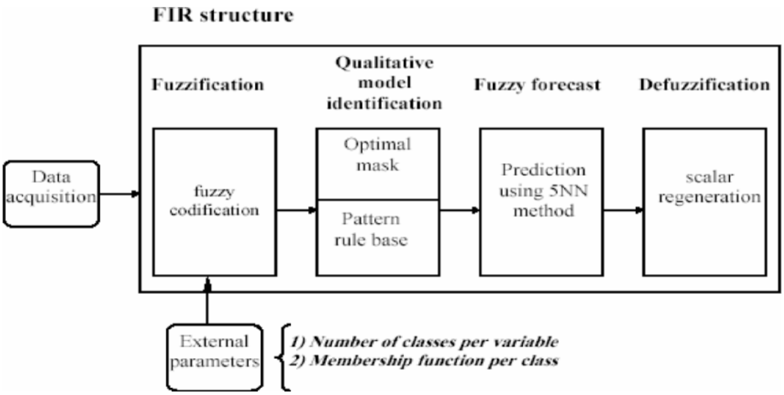

Fig. 5. Fuzzy Inductive Reasoning methodology

The fuzzification process converts quantitative data stemming from the system into fuzzy data. The qualitative model identification process is responsible for finding causal and temporal relations between variables and therefore for obtaining the best model that represents the system. An FIR model is composed of a mask (model structure) and a pattern rule base (behaviour matrix). Once the FIR model is available, the prediction system can take place using the FIR inference engine. This process is called fuzzy forecast. The FIR inference engine is a specialization of the k-nearest neighbour rule, commonly used in the pattern recognition field. Defuzzification is the inverse process of fuzzification. It allows converting the qualitative predicted output into quantitative values that can then be used as inputs to an external quantitative model.

Figure 6 illustrates the process of fuzzification by means of an example. A quantitative value is fuzzified into a qualitative triple, consisting of the class, membership, and side values. The side value, which is specific of the FIR technique and not commonly used in fuzzy logic, is responsible for presserving, in the qualitative triple, the complete knowledge contained in the original quantitative value.

Most fuzzy inference approaches preserve the total knowledge by associating multiple fuzzy rules consisting of tuples of class and membership values with each quantitative data value. In the example of Fig. 6, these rules would represent the temperature of 23° centigrade as being "normal" with likelihood 0.755 and being "warm" with likelihood 0.20. The point where two neighbouring classes match with a membership value of 0.5 is named *landmark*. In the example, the membership function of the class *Normal* is defined by landmarks {13,27}, being this pair the temperature values that specify the limits between the class *Normal* and its adjacent classes, *Fresh* and *Warm*, respectively.

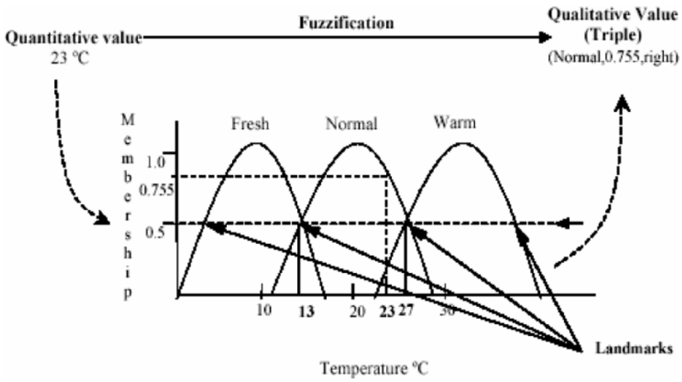

Fig. 6. FIR fuzzification process

The results of the fuzzification process are three matrices of identical size named qualitative data matrices, one containing the class values, the second containing the membership information, and the third containing the side values.

Let us now focus on how feature selection is embedded in the FIR methodology through the concept of masks. In FIR, a mask candidate matrix is the ensemble of all possible masks from which the best is chosen by either a mechanism of exhaustive search of exponential complexity, or by one of various suboptimal search strategies of polynomial complexity, as described in [6]. The mask candidate matrix contains elements of value −1 where the mask has a potential m-input, of value +1 where the mask has its m-output, and of value 0 to denote forbidden connections. A good mask candidate matrix to determine a predictive model for variable y_1 in the example of Fig. 7 might be, for instance:

t \ x	u_1	u_2	u_3	u_4	y_1	y_2
$t-2\delta t$	−1	−1	−1	−1	−1	−1
$t-\delta t$	−1	−1	−1	−1	−1	−1
t	−1	−1	−1	−1	+1	0

Each of the possible masks is compared to the others with respect to its forecasting power, which is maximal when the associate entropy measure is minimal. The Shannon entropy measure is used to determine the uncertainty associated with forecasting a particular output state given any legal input state. The Shannon entropy relative to one input state is calculated as

$$H_i = \sum_{\forall o} p(o \mid i) \log_2 p(o \mid i), \tag{5}$$

where $p(o|i)$ is the conditional probability of a certain m-output state o to occur, given that the m-input state i has already occurred. It denotes the quotient of the observed frequency of a particular state divided by the highest possible frequency of that state. The overall entropy of the mask is then computed as the weighted sum of the entropy over all input states:

$$H_m = -\sum_{\forall i} p(i) H_i, \tag{6}$$

where $p(i)$ is the probability of that input state to occur. The highest possible entropy $H_{\max}$ is obtained when all probabilities are equal, and zero entropy corresponds to totally deterministic relationships. A normalized overall entropy reduction H_{r} is defined as

$$H_{\mathrm{r}} = 1.0 - \left(\frac{H_m}{H_{\max}} \right). \tag{7}$$

H_r is a real-valued number in the range between 0 and 1, where high values indicate an improved forecasting power.

From a statistical point of view, every state should be observed at least five times [9]. Therefore, an observation ratio, O_r, is introduced as an additional contributor to the overall quality measure:

$$O_r = \frac{5n_{5x} + 4n_{4x} + 3n_{3x} + 2n_{2x} + n_{1x}}{5n_{\text{leg}}}, \tag{8}$$

where n_{leg} is the number of legal m-input states, n_{1x} is the number of m-input states observed only once, n_{2x} is the number of m-inputs states observed twice, and so on.

The overall quality of a mask, Q, is then defined as the product of its uncertainty reduction measure, H_r, and its observation ratio, O_r:

$$Q = H_r O_r . \tag{9}$$

The optimal mask is the mask with the largest Q value. An example of mask corresponding to Fig. 7 is

t \ x	u_1	u_2	u_3	u_4	y_1	y_2
$t-2\delta t$	0	0	0	0	0	−1
$t-\delta t$	−2	0	−3	0	−4	0
t	0	−5	0	0	+1	0

Each negative element in the mask is called an m-input (mask input). It denotes a causal relation with the output, i.e. it influences the output up to a certain degree. The enumeration of the m-inputs is immaterial and has no relevance. The single positive value denotes the output. The previous example mask contains five m-inputs. In position notation, it can be written as (6,7,9,11,14,17), enumerating the mask cells from top to bottom and from left to right.

Let us now address the second issue. How is the pattern rule base obtained from the mask? This process is illustrated in Fig. 7. The example mask can be used to "flatten" dynamic relationships into pseudo-static relationships. The left-hand side of Fig. 7 shows an excerpt of the quail-tative data matrix that stores the class values. It shows the numerical rather than the symbolic class values. In the example shown in Fig. 7, all the variables were discretized into three classes, with the exception of variable y_1 that was discretized into two classes. The dashed box symbolizes the mask that is shifted downwards along the class value matrix. The round shaded “holes” in the mask denote the positions of the m-inputs, whereas the square shaded “hole” indicates the position of the m-output. The class values are read out from the class value matrix through the “holes” of the mask, and are placed next to each other in the behaviour matrix that is shown on the right-hand side of Fig. 7.

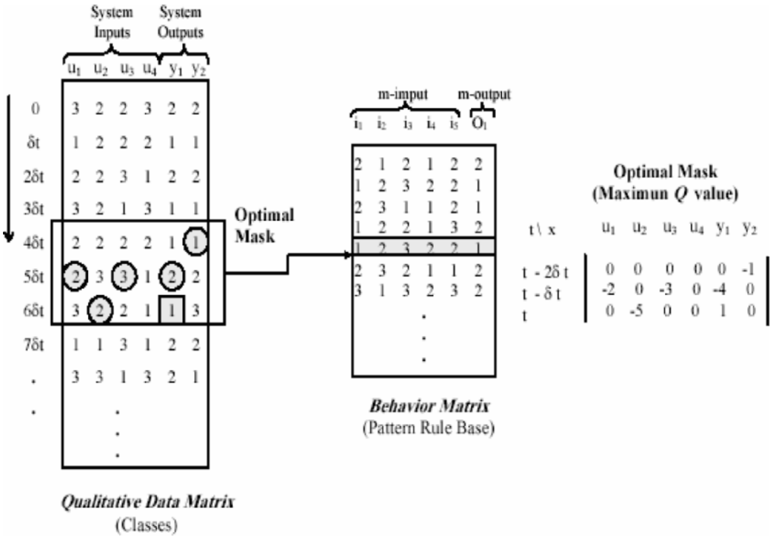

Fig. 7. FIR qualitative model identification process

Here, each row represents one position of the mask along the class value matrix. It is lined up with the bottom row of the mask. Each row of the behaviour matrix represents one pseudo-static qualitative state or qualitative rule (also called pattern rule). For example, the shaded rule of Fig. 7 can be read as follows: “If the first m-input, i_1, has a value of 1 (corresponding to high), the second m-input, i_2, has a value of 2 (corresponding to medium), etc., then the m-output, O_1, assumes a value of 1 (corresponding to high)”.

The FIR inference engine computes a distance measure between the input pattern, for which the output prediction should be obtained, and all patterns stored in the behaviour matrix that match (with regard to the class value) the input pattern. The predicted output is then computed as a weighted mean of the outputs associated with the *k*-nearest neighbours, i.e. those neighbours that exhibit the smallest distance measure in the input space. For a deeper and more detailed insight into the FIR methodology, the reader is referred to [12].

4.1.1 Experimental Results

In accordance with the previous theoretical description, the aim of these experiments was twofold. On the one hand, we aimed to identify FIR models that were capable of predicting students' performance. On the other hand, we were interested in determining which data features had the highest relevance from the students' performance point of view. To this end, a first set of experiments was carried out using sevenfold cross-validation. Each test set was composed of 122 data samples whereas the training sets contained 600 data samples.

Before the model identification process of the FIR methodology can take place, it is necessary to provide the "number of classes" parameter for each system variable (see Fig. 5). In these experiments, due to the reduced size of the data set available, the minimum possible number of classes was chosen to discretize each data feature. Table 2 lists these parameters. The gender (G), area of expertise (EXP) and position (POS) are nominal variables and, therefore, the minimum representation corresponds to the number of values that each one can take. The rest of the variables were discretized into two or three classes. The dependent variable (the one to be predicted), final mark (MARK), was discretized into three classes to allow a better discrimination between bad, regular and good students.

As described in Sect. 4.1, it is also necessary to define the membership function for each class of each system variable. This is accomplished by determining the landmarks associated to each class value. In these experiments the landmarks of the non-nominal variables were given by the experts (the course advisors).

Table 2. "Number of classes parameter for each feature

AGE	EXP	G	STD	POS	ACT	ASS	MAIL	COEV	F	FCP	FC	IC	ER	BR	MARK
2	7	2	2	15	2	2	3	3	3	3	3	2	2	2	3

The next step was the identification of the model. For the qualitative model identification process to take place, it is necessary to provide the mask candidate matrix. In this experiment, all features were considered. The candidate matrix proposed is of depth one (only one row), forbidding the creation of temporal relations between different samples, i.e. students. With the proposed initial mask, the qualitative model identification process computes the optimal and sub-optimal masks. The root mean square (RMS) error between the predicted output, $\hat{y}$, and the observed system output, y, was used to determine the validity of the model. This error is defined as

$$\text{RMS} = \sqrt{\frac{\sum_{i=1}^{N} (y_i - \hat{y}_i)^2}{N}}, \tag{10}$$

where N is the total number of data samples. We are now ready to validate the masks by allowing the fuzzy forecasting process of FIR methodology to predict the seven test data sets. The optimal mask encountered by FIR is

t\x	AGE	EXP	G	STD	POS	ACT	ASS	MAIL	COEV	F	FCP	FC	IC	ER	BR	MARK
T	0	0	0	0	0	0	0	0	–1	0	0	0	–2	–3	0	+1

Its associated quality measure has a value of $Q = 0.66$. This mask is then used to perform the prediction through the sevenfold cross-validation. The optimal mask reveals that the average marks of the co-evaluation (COEV), the initial class plan (IC), and the experience report (ER) are the most relevant features to predict the final mark of the course (MARK) for each student. The RMS errors obtained when using this mask to predict the 7 test data sets previously mentioned are shown in Table 3.

Table 3. RMS prediction errors for the 7 test data sets

Fold 1	Fold 2	Fold 3	Fold 4	Fold 5	Fold 6	Fold 7	Mean
0.6268	0.5239	0.5395	0.7038	0.4413	0.6743	0.6096	0.5884

The mean error value of 0.5884 shows that the optimal mask identified by FIR is able to capture accurately the students' performance using only the COEV, IC and ER variables. Figure 8 shows the best prediction signal obtained by FIR optimal mask (fold #5). Figure 9 shows the worst prediction signal obtained with the same mask (fold #4). From these figures, it is clear that the predicted signals follow very well the real signals, being able to forecast quite accurately low and high marks.

It is important to comment here that the three variables selected by the FIR modelling process (COEV, IC and ER), represent the 50% of the final mark evaluation (the weighted formula used to compute the final mark of the course is: MARK = 0.05*MAIL + 0.20*COEV + 0.05*F + 0.05*FCP + 0.20 *FC + 0.10*IC + 0.20*ER + 0.15*BR). Notice that there are some variables such as the final class plan (FCP) and work in the branch (BR) that, by themselves, constitute 35% of the final mark, yet they have not been included in the optimal mask. This is a relevant and interesting result, as it suggests that the information included in these variables already exists in the selected ones (COEV, IC and ER). Therefore, these variables are somehow redundant from the point of view of the final mark prediction.

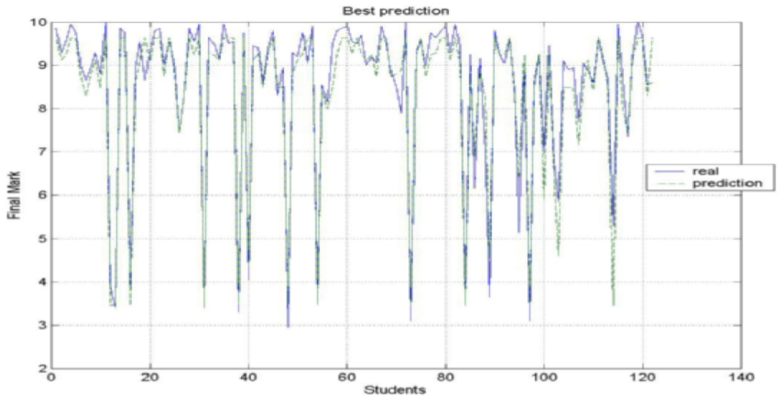

Fig. 8. Real and predicted signals of the MARK variable for fold #5 (RMS = 0.4413)

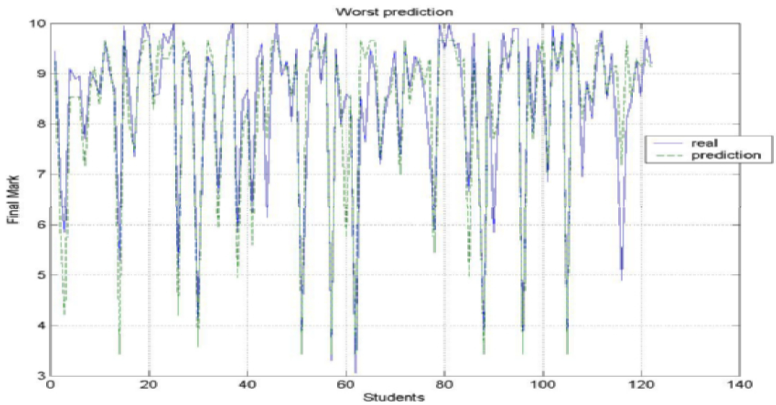

Fig. 9. Real and predicted signals of the MARK variable for fold #4 (RMS = 0.7038)

Another significant result is the selection of the co-evaluation variable as a relevant feature for the prediction of a student final mark. As described before, the advisor grades how well the student evaluates the class plans of his/her course mates. A student that is able to evaluate the work of other people is capable to evaluate correctly his/her own work and, therefore, to execute a good work or a good FCP. Therefore, the information conveyed by this feature is fundamental to predict the final performance of the student in the course. This conclusion has been corroborated by the 31 advisors responsible for the course, and previously published in [13]. It is also worth pointing out that co-evaluation is not a feature commonly used in the e-learning environment. However, its high level of predictive power is manifested in our experiments. Moreover, all the advisors agree that co-evaluation provides valuable leverage to reduce the barriers of distance education.

On the other hand, the experience report (ER) and the initial class plan (IC) also come up as relevant features for the prediction of the students' final mark. The experience report can be viewed as a self-evaluation of his/her own learning process. The average mark of the initial class plan variable is a binary variable that has a value of 0 if the student did not present the initial class plan and a value of 10 if he/she did. Both variables help to predict the peaks of the final mark signal, due to the fact that they contain information not provided by the COEV feature. To some extent, these results can be used by the advisors to adjust the equation that computes the final mark by modifying the weights of COEV and FC variables. At the very least, the data-based feature relevance results would help the course advisors to define a more accurate final mark equation.

It is also interesting to note that the variables that describe the personal attributes of the student, i.e. AGE, EXP, G, STP and POS, are not selected by FIR as relevant to predict the final mark. This makes sense because the work carried out by the students in the course is much more relevant than their personal information. However, we were interested in finding out which of the personal attributes gave us relevant information related to final grades. To this end, a new experiment was carried out in which only the first five features, corresponding to the students' personal attributes, were used in the mask candidate matrix with the main goal of predicting, again, the student final mark. In this case, FIR selected as relevant features the age of the student and his/her area of expertise.

The prediction error (RMS) obtained using this model was 1.893 and the prediction signal was able to follow quite well the minimum and maximum peaks, i.e. the bad and good marks. Although it is not possible to provide a definitive conclusion, it is clear from this experiment that the age of the student, in the first place, and the area of expertise, in the second place, are important personal aspects that influence students' performance. These results agree with some of the conclusions presented in Sect. 3 of this chapter, where GTM, a clustering model, was used to analyse atypical students' behaviour.

4.2 Rule Extraction from Classification Results

The interpretability of the mark prediction results shown in Sect. 4.1.1 would be improved by their description in terms of simple and actionable rules. This is accomplished in this case study through the application of two different methodologies: OSRE, a novel overlapping rule extraction method [4], and, once again, FIR.

4.2.1 OSRE

OSRE: [4] is an algorithm that efficiently extracts comprehensible rules from smooth models, such as those created by neural networks that accurately classify data. OSRE is a principled approach and is underpinned by a theoretical framework of continuous valued logic developed in [15]. In essence, the algorithm extracts rules by taking each data item, which the model predicts to be in a particular class, and searching in the direction of each variable to find the limits of the space regions for which the model prediction is in that class (Fig. 10, left). These regions form hyper-boxes that capture in-class data and they are converted to conjunctive rules in terms of the variables and their values (Fig. 10, right). The obtained set of rules is subjected to a number of refinement steps: removing repetitions; filtering rules of poor specificity and sensitivity; and removing rules that are subsets of other rules [3]. Specificity is defined as one minus the ratio of the number of out-of-class data records that the rule identifies to the total number of out-of-class data. Sensitivity is the ratio of the number of in-class data that the rule identifies to the total number of in-class data. The rules are then ranked in terms of their sensitivity values to form a hierarchy describing the in-class data. Testing against benchmark datasets [4] has showed OSRE to be an accurate and efficient rule extraction algorithm.

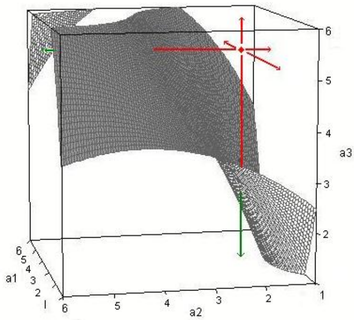

Fig. 10. *Left*: Illustration of orthogonal searching to find decision boundaries; *Right*: Hyper-boxes constructed from the search results

4.2.2 OSRE Results

The approach to the OSRE experiments was twofold: First, all data features from Table 1 were used in the classification task; second, only the three features selected by FIR, as reported in Sect. 4.2, were used. Two-layered Multi-Layer Perceptrons (MLP) were trained using error back-propagation and weight decay to inhibit overtraining. The data were split into two sets of 361 records, for training and testing the MLPs. In each case, the network parameters were selected by cross-validation and set, for the models using all the variables, to: Number of hidden nodes = 8; learning rate = 0.01; momentum = 0.9; weight decay = 0.01; for the models using the FIR selection of three features, all parameters but weight decay = 0.05 were the same. In all cases, the network weights were initialized with random values. Once the number of training epochs that minimized overtraining was determined, final networks were trained using all 722 data records. OSRE was used to produce a set of rules for each of the classes, shown in Tables 4–6. Each rule is a conjunction of the features and their values.

Interestingly, in the experiments using all features, those selected as the most relevant by FIR, namely COEV, IC, and ER, all figure prominently in the main rules generated by OSRE, especially for classes 1 and 3 (the low and high marks). Therefore, the rule extraction results indirectly validate, at least partially, the FIR selection. Classes 1 and 3 are extremely well captured by their corresponding rules. The students that failed (MARK < 5) are defined in very simple terms through low values of ER, COEV, FC and BR. The OSRE results using only the three features selected by FIR are quite consistent with those obtained using all features, while providing the most parsimonious rule descriptions of the MARK classes that can be obtained without compromising too much of the classification accuracy. results were validated by educative experts from CECTE [5].

Table 4. OSRE rules for Class 1 (MARK < 5). *Spec* stands for Specificity; *Sens* for Sensitivity; *PPV* is the Positive Predictive Value: the ratio of the number of in-class data that the rule predicts to the total number of data the rule predicts. *Top* table: Results for the full set of features. *Bottom table*: results for FIR feature selection

CLASS 1 (all features)		**For this rule only**			**For disjunction of ALL rules up to row *n***		
n	**RULE**	***Spec***	***Sens***	***PPV***	***Spec***	***Sens***	***PPV***
1	$(0 \leq ER \leq 6) \wedge (0 \leq COEV \leq 6)$	0.99	0.82	0.85	0.99	0.82	0.85
2	$0 \leq FC \leq 4$	0.99	0.82	0.87	0.98	0.92	0.78
3	$(0 \leq BR \leq 3) \wedge (0 \leq ER \leq 3)$	1	0.1	1	0.98	0.96	0.78
CLASS 1 (FIR feat. selection)		**For this rule only**			**For disjunction of ALL rules up to row *n***		
n	**RULE**	***Spec***	***Sens***	***PPV***	***Spec***	***Sens***	***PPV***
1	$0 \leq COEV \leq 5$	0.96	0.94	0.66	0.96	0.94	0.66

Table 5. OSRE rules for Class 2 (5 ≤ MARK < 8). *Spec*, *Sens* and *PPV* as in table 5. *Top* and *bottom* tables as in table 4

CLASS 2 (all features)		**For this rule only**			**For disjunction of ALL rules up to row *n***		
n	**RULE**	***Spec***	***Sens***	***PPV***	***Spec***	***Sens***	***PPV***
1	(0 ≤ FCP ≤ 7) ∧ (IC = 0)	0.96	0.35	0.64	0.96	0.35	0.64
2	(63.4 ≤ ACT ≤ 65.5) ∧ (69.7 ≤ ASS ≤ 100) ∧ (0 ≤ FCP ≤ 8) ∧ ER = 0	0.99	0.82	0.87	0.98	0.92	0.78
CLASS 2 (FIR feat. Selection)		**For this rule only**			**For disjunction of ALL rules up to row *n***		
N	**RULE**	***Spec***	***Sens***	***PPV***	***Spec***	***Sens***	***PPV***
1	IC = 0	0.94	0.43	0.66	0.94	0.43	0.66
2	(4 ≤ COEV ≤ 10) ∧ (0 ≤ ER ≤ 2)	0.99	0.33	0.93	0.94	0.66	0.69

4.2.3 Rule Extraction Using FIR

Starting from the description of FIR in Sect. 4.1, we now explain how rule extraction can be implemented as part of this methodology.

Table 6. OSRE rules for Class 3 (8 ≤ MARK < 10). *Spec*, *Sens* and *PPV* as in table 3. *Top* and *bottom* tables as in Table 4

CLASS 3 (all features)		**For this rule only**			**For disjunction of ALL rules up to row *n***		
N	**RULE**	***Spec***	***Sens***	***PPV***	***Spec***	***Sens***	***PPV***
1	(8 ≤ BR ≤ 10) ∧ (3 ≤ F ≤ 10) ∧ (1 ≤ FCP ≤ 10) ∧ IC = 10 ∧ (7 ≤ ER ≤ 10) ∧ (8 ≤ COEV ≤ 10)	1	0.86	1	1	0.86	1
2	(8 ≤ BR ≤ 10) ∧ (1 ≤ MAIL ≤ 10) ∧ (9 ≤ ER ≤ 10) ∧ (9 ≤ COEV ≤ 10)	1	0.65	1	1	0.91	1
3	(7 ≤ BR ≤ 10) ∧ (7 ≤ F ≤ 10) ∧ (5 ≤ MAIL ≤ 10) ∧ IC = 10 ∧ (7 ≤ FC ≤ 10) ∧ (7 ≤ ER ≤ 10) ∧ (5 ≤ COEV ≤ 10)	1	0.7	1	1	0.94	1
4	(6 ≤ FCP ≤ 10) ∧ (2 ≤ MAIL ≤ 10) ∧ FC = 10 ∧ (9 ≤ ER ≤ 10) ∧ (9 ≤ COEV ≤ 10)	1	0.47	1	1	0.95	1
5	BR = 10 ∧ IC = 10 ∧ FC = 10 ∧ (8 ≤ ER ≤ 10) ∧ (6 ≤ COEV ≤ 10)	1	0.49	1	1	0.97	1
CLASS 3 (FIR feat. selection)		**For this rule only**			**For disjunction of ALL rules up to row *n***		
N	**RULE**	***Spec***	***Sens***	***PPV***	***Spec***	***Sens***	***PPV***
1	(9 ≤ ER ≤ 10) ∧ (9 ≤ COEV ≤ 10)	0.91	0.73	0.96	0.91	0.73	0.96
2	IC = 10 ∧ (4 ≤ ER ≤ 9) ∧ (7 ≤ COEV ≤ 10)	0.91	0.39	0.94	0.82	0.95	0.95
3	IC = 10 ∧ (9 ≤ ER ≤ 10) ∧ (5 ≤ COEV ≤ 9)	0.93	0.35	0.94	0.82	0.99	z

The proposed method is an iterative process that compacts the pattern rule base identified by FIR. On the one hand, we aim to obtain interpretable, realistic and efficient behavioural rules, describing students' learning behaviour. On the other hand, we want to compact the rule base pattern in order to make more parsimonious and, therefore, speed up the prediction process. In order to preserve a model that is congruent with those previously identified by FIR, the proposed algorithm is based on its initial discretization, using only the mask features and the pattern rule base obtained (see Sect. 4.1). Therefore, the rules will maintain the landmarks initially defined.

The model can be summarized as a set of ordered steps:

1. *Basic compactation*. This is an iterative step that evaluates, one at a time, all the rules in a pattern rule base. The pattern rule base, R, is compacted on the basis of the "knowledge" obtained by FIR. A subset of rules R_c can be compacted in the form of a single rule r_c, when all premises P but one (P_a), as well as the consequence C share the same values. Premises, in this context, represent the input features, whereas consequence is the output feature in a rule. If the subset contains all legal values LV_a of P_a, all these rules can be replaced by a single rule, r_c, that has a value of -1 in the premise P_a. When more than one -1 value, P_{ni}, is present in a compacted rule r_c, it is compulsory to evaluate the existence of conflicts by expanding all P_{ni} to all their legal values LV_a, and comparing the resultant rules Xr with the original rules R. If conflicts, Cf, exist, the compacted rule r_c is rejected, and otherwise accepted. In the latter case, the previous subset, R_c is replaced by the compacted one r_c. Conflicts occur when one or more extended rules, Xr have the same values in all its premises, P, but different values in the consequence C.

2. *Improved compactation*. Whereas the previous step only structures the available knowledge and represents it in a more compact form, the improved compactation step extends the knowledge base R to cases that have not been previously used to build the model: R_b. Thus, whereas step 1 leads to a compacted data base that only contains knowledge, the enhanced algorithm contains undisputed knowledge and uncontested belief. Two options are studied: In the first one, using the compacted rule base R' obtained in step 1, all input features P (premises) are visited once more in all the rules r that have non-negative vales (not compact-ted), and their values are replaced by -1. An expansion to all possible full sets of rules Xr and their comparison with the original rules R are carried out. If no conflicts Cf are found, the compacted rule, r_c , is accepted, and otherwise, rejected. The second option is an extension of the basic compactation, where a consistent and reasonable minimal

ratio, *MR*, of the legal values LV_a should be present in the candidate subset R_c, in order to compact it in the form of a single rule r_c. This latter option seems sensible because, although a reasonable ratio was used to compact R_c in a single rule r_c, the assumed beliefs are minimal and do not compromise the model previously identified by FIR Instead, in option 1, beliefs are assumed to be consistent with the original rules; nevertheless, this could compromise the agreement with model identified, specially when the training data are poor and do not describe well all possible behaviours.

The obtained set of rules is subjected to a number of refinement steps: removal of duplicate rules and conflicting rules; unification of similar rules; evaluation of the obtained rules and removal of rules with low specificity and positive predictive value (PPV: see Sect. 4.2.2).

4.2.4 Experimental Rule Extraction Results Using FIR

The main goal of the rule extraction algorithm described is to endow FIR with a method to describe the analysed system using logical rules that are more comprehensive, readable, and which provide explanations (not only assumptions) that may be validated by domain experts, increasing confidence in the analysis. The experimental results obtained using the rule extraction algorithm described in the previous section are presented in Table 7.

We can see that the specificity and the positive predicted value reaches reasonable values for most rules separately, as well as for the whole set of rules. However, the sensitivity is quite low throughout. Only the sensitivity of rule 7 (highlighted in Table 7) is reasonably high, describing a very common pattern in the analysed data. The best results in this experiment correspond to the second option of the Improved Compactation method.

Although both of the rule extraction methods used in this section resort to the same evaluation metrics, they differ in the way results are presented. Whereas OSRE provides cumulative results for each class, the FIR experimental rule extraction method provides results for all classes together, for each individual rule and for the whole set of rules.

Notwithstanding the inherent difficulty of comparison, the rule extraction results obtained by the experimental FIR extension are, at least globally, not too different from those obtained by OSRE when only the features selected by FIR are used.

FIR obtains a set of seven rules based on its own feature selection. Looking more closely to the rules obtained by FIR and OSRE (with FIR feature selection), it seems that OSRE has a higher compactation capacity, at least for class 1. OSRE models class 1 by a unique rule with a single premise, whereas FIR needs two rules, with two and three premises, respectively. Comparing the set of rules obtained with both methodologies using specificity, sensitivity and positive predictive value metrics, it can be seen that for class 1, FIR rules have a higher specificity and PPV, whereas OSRE rule has a better sensitivity. The three metrics have similar values for both OSRE and FIR rules defining class 2. On the contrary, the OSRE rules obtain higher values in all the metrics for class 3.

The learning behaviour rules obtained by both algorithms were analysed and validated by educative experts of CECTE. They agreed that the obtained results were intuitive, realistic, and mostly consistent with their own perception of the CECTE course students' learning behaviour.

Table 7. Experimental rule extraction results using FIR for both training and test data sets. *Spec* stands for Specificity; *Sens* for Sensitivity; and *PPV* is the Positive Predictive Value: the ratio of the number of in-class data that the rule predicts to the total number of data the rule predicts

RULE	Out Class	TRAIN			TEST		
		Spec	Sens	PPV	Spec	Sens	PPV
IF 0<=IC<=5.1 AND 4.9<=COEV<=10 THEN 4.9<=MARK<= 7.9	2	0.96	0.38	0.7	0.95	0.37	0.71
IF 5.1<=IC<=10 AND 0<=ER<= 8.1 THEN 0<=MARK<= 7.9	1–2	0.84	0.51	0.57	0.84	0.43	0.55
IF 0<=COEV<=4.9 AND 8.1<=ER<=10 THEN 0<=MARK<= 4.9	1	1	0.11	0.78	0.97	0.08	0.2
IF 0<=COEV<= 4.9 AND 0<=IC<=5.1 AND 0<=ER<=8.1 THEN 0<=MARK<=4.9	1	1	0.07	1	1	0.08	1
IF 4.9<=COEV<= 7.9 AND 5.1<=IC<=10 THEN 7.9<=MARK<=10	3	0.95	0.03	0.58	0.87	0.04	0.42
IF 7.9<=COEV<=10 AND 8.1<=ER<=10 THEN 7.9<=MARK<=10	**3**	**0.75**	**0.81**	**0.88**	**0.83**	**0.81**	**0.91**
IF 7.9<=COEV<=10 AND 5.1<=IC<=10 AND 0<=ER<=8.1 THEN 7.9<=MARK<=10	**3**	0.78	0.16	0.63	0.8	0.15	0.62
TOTAL RULES		**0.93**	**0.34**	**0.76**	**0.92**	**0.33**	**0.74**

5 Conclusions

The possibility of tracking user behaviour in virtual campus e-learning environments makes possible the mining of the resulting data bases. This opens new possibilities for the pedagogical and instructional designers who create and organize the learning contents.

The presence of outliers in a data set can distort the results obtained from its analysis. Therefore, the data analyst should benefit from models that behave robustly in their presence. One such model, the *t*-GTM, has been introduced. It simultaneously provides robust data clustering and visualization of the results, which become intuitively interpretable. It also neutralizes the negative effects of outliers. Moreover, this model provides a method to assess the unsupervised relative relevance of the data features. Data from the CECTE virtual campus, corresponding to the students of a "Didactic Planning" graduate course, have been analysed using the proposed model. Students with atypical online behaviours (outliers) have been identified and characterized, using the extension of *t*-GTM for FRD. The results have shown that useful knowledge can be extracted from the *t*-GTM combination of outlier detection, FRD and data clustering and visualization. This knowledge could be fed back into the e-learning system in order to provide students with personalized guidance, tailored to their inhomogeneous needs and requirements. As a software tool embedded in the e-learning system, it would also help teachers to find patterns of student's behaviour.

In this case study, we have also addressed the problem of students' marks prediction, using the FIR methodology. The characterization of the students' online behaviour would benefit from a method capable of determining the relevance of the features involved in the analysed data set in terms of this prediction. One such method is also provided by FIR. The experimental results have shown that FIR was able to identify a good model to predict students' final marks and to determine the relevant features involved in the evaluation process. This knowledge could be used for real time student personalization guidance, and to help teachers in finding patterns of student behaviour. For this knowledge to have an intuitive and useful form, results have been described in terms of rules. The novel OSRE methodology and an extension of FIR have been applied here to obtain simple sets of rules describing the diverse levels of the students' performance.

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Technology and Pedagogy – How to Learn Technique

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Summary. A limitation of future development is the lack of ability to use technical equipment. To avoid this problem it is necessary to concentrate on pedagogy of technology – how to teach and learn technology? The paper also tries to break down some attitudes in both sides of teaching technology. The problem is mainly based on the lack of conversation and understanding between two sciences: Technology and Pedagogy. The aim of this paper is to help this conversation to begin and continue – this acts as a transmitter between these sciences. Paper explains basic ideas of both sciences with such language that the other is able to understand.

1 Introduction

Traditionally, technology and pedagogy are considered to be as far from each other as two issues can be. In common thinking, technology is a practical science or even only *doing* while pedagogy is a more humanistic science, *theory*. Superficially, they have nothing in common, and may even be viewed as highly dangerous concepts.

To many members of the general public, technology is seen as something to do with machines and equipment, while technical equipment is seen as difficult to use and expensive. Because of the insatiable need for energy, it is feared that technology will finally destroy the world or at least energy resources. At the same time some extreme viewpoints present pedagogy in terms of playing with human brains, brain washing and encouraging dangerous thoughts. It seems to be a route to manipulate humans to do unethical acts.

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A short check of publications from both sides of these sciences shows the existence of the barrier: pedagogues are not very interested in education of technology while technicians are not too keen on pedagogy. In technology the idea of pedagogy is the fact that *the student is responsible for the results of studies, and the teacher's task is just to make the information available*. Thus there is no need for good teaching in technology, just good students!

Before we determine how to teach technology, we have to dismantle the perceived barriers between these sciences and clearly define what is understood by technology and pedagogy. Technology is everywhere, or at least instances of technology are, for example mobile phones, cars, computers, coffee makers, vacuum cleaners, bicycles, pencils, overhead projectors, videos, barbeque grills, plus bioprocesses such as bread making and cooking.

Through this enormous range of technology, we can see similarities between all these items. They are all *tools*, helpers and things that make life easier. This is an important issue to remember when talking about usefulness and dangers of technology. As any tool, products of technology can be used in both good and bad applications. The basic nature of technology is thus to help, *to create tools for human beings*.

Pedagogy is the part of science, which concerns issues of learning and teaching. It develops theories and methods for better understanding of processes in learning and teaching. It also tries to implement these theories into the real life. Supporting this are scientific studies of the thinking and learning of human beings.

So after all, what really is the difference between these two sciences? They are both interested in improving and helping human activities. For this purpose they are both interested in target processes: pedagogy and processes of learning, technology and processes of doing.

Learning is in fact a very important issue in technology. Technical development is dependent on skills such as learning of natural sciences, developing a holistic view, realism and an attitude of *there are no problems, only challenges*. A person can have these skills by nature, as a talent, but these can and mostly must also be taught – and in a science called technology these are basic requirements for a profession.

Once technology has developed tools for easier life, there are also a few questions to be asked: Does the user of a tool know how to use it? Who and how to teach? How much does the user need to know?

To be able to live in a modern society, we all need to know something about technology. To be able to develop better tools some of us must understand technology well. To be able to understand at least some of technology we need to know how to teach and how to learn, we need pedagogy. To be able to use modern technology as a support of learning, pedagogy needs technology.

2 Technology – Challenge for Pedagogy

Technology, pedagogy, teaching of technology and using it as a tool for pedagogy as well as technology and human life have a long history together [5, 6, 8, 9]. There has been some discussion of technology and teaching of technology in Finland as well as around the world [1, 4–6, 8, 9, 15]. Normal citizens, people of areas other than technology, have not been too interested in this discussion – while only sensational themes have been in the news [15].

Around the world similar issues have been the bases of discussion: economics of education and production [1, 4, 6, 15], educational and social–political pressures [8, 9, 15, 23] as well as researchers' own interest as in [5, 17, 18] for example. When the discussion is based on researchers own interest the combination of technology and pedagogy is interpreted more widely than just school teaching and learning issues: pedagogy of technology also includes implementation and education of new applications and methods. With new developments in technology, the importance of pedagogy as a tool for motivating new users for correct and effective learning has arisen.

2.1 Attitude

Negative attitude towards technology and natural science is a serious problem [15, 22]: Attitudes of teachers, parents and the society can be seen in the results of school education. Studies have shown that, for example, sex or family background of the student has nothing to do with people's ability of thinking and development of thinking [15]. Also, it has been shown in the same studies that this kind of attitude can prevent a talented student from achieving well in his or her own area. For the social and personal life of a student this kind of limitation can be very destructive, resulting in the loss of a talented person for nothing.

Negative attitude towards technology is often caused by teachers and parents with their opinions about technology and subjects related to it [15], incorrect beliefs of talent and sex of the student [15, 22] or misunderstanding of the nature of technology which leads to ineffective methods of teaching and support of learning [5, 6, 8].

2.2 Limits of Learning

Problems in teaching and in learning of technology are not confined to university studies. A human being learns the basics of technological understanding in her or his earlier years, before school age. At the same time, attitudes towards learning in general plus attitudes to certain topics such as mathematics, physics, chemistry and technology, are also taught by the family and the society around the child. The talent of a person can be seen in every area at the same time. Thus, in fact, the problem of technology education is spread through all the years from early childhood to adulthood [8, 15, 21].

The Finnish Ministry of Education [15] have pointed out that attitudes of teachers can be seen in teaching results even though teachers cannot even recognise these themselves. For a young pupil the teacher has a great influence and thus she or he has a great effect on pupils' life even without any intention [8, 15, 22]. Still it must be noticed that this does not concern only one profession but the whole society since teachers just reflect the attitudes of the world around children [8, 15, 22] – the question is about our society, our attitudes and our opinions.

In Finland, the situation in the first school years is quite good: there are no division of pupils based on their sex in technological or science teaching [15, 22]. In the last years of comprehensive school and in high school, the attitudes of the society via parents and teachers do come up and children tend to behave as expected: they are divided into different goals, often based on their sex. Of course there are pupils who have courage enough to break these roles or who for some other reasons cannot fit into them. An important issue is the fact shown in research in Finland: ability of thinking, reasoning and solving problems is not connected to the sex of a person [15]. Thus each and every human is able to learn skills and knowledge needed in technical science [8, 15, 22].

In school, the biggest problem in equality of the sexes is connected tightly to valuation of learning results. The expectations of parents and teachers for learning as well as how seriously problems of learning are concerned are related to the sex of pupils and to the subject [15, 22]. Expectations of results in technology and science education for boys are often too low compared to their skills at the same time while their results of learning are valued more highly than they should be. This causes problematic behaviour, disturbances and boredom when boys do not get enough challenges and they notice that it is not necessary to do anything more. But this is only half of the problem. Achievements of learning for girls are less highly regarded than similar results of boys in science and technology education.

At the same time, problems in learning are not taken seriously: for boys problems are interpreted as a sign of individual thinking, own freedom and clever decision making while with girls they are a normal consequence of their sex. Thus in both cases, teachers and parents give themselves freedom not to meet real problems and challenges of the aim and the pupil [15].

It is interesting to notice that the situation is easily opposite in languages [15, 22]. The assumption in languages is that boys cannot learn languages and girls learn them easily. Again handling of problems and results of learning are based on the sex.

Thus with attitudes of teachers and parents, society, in fact we, cause different kinds of problems in learning while we believe we are helping pupils.

2.3 Talent

Talent is not always a pleasant gift, not to a talented person or teachers and parents around her or him. A talented person is a demanding student. She or he needs more and more interesting challenges, explanations, more knowledge, work and skill for the teacher. Of course, a not so talented, slow learning person has also demands for teachers, but basically staying in the same or similar tasks, repeating the same issue from day to day is enough. Thus the main difference can be seen easily: with talented students, a teacher's own professional knowledge is challenged to stay active and on time. The teacher must study more because of the talent of the student.

Problems arise when the talent of a person is in an area, which is not somehow suitable for teachers or for society around her or him. This can be seen in studies of learning experiences [15, 22] as well as in attitudes towards talented and problematic learners [15, 21]. It can also be seen in the recognition process of talented persons – there are not always the will or ability to see the talent.

As mentioned earlier, the society of a student has even more effect on learning results than genes [15]. This is reality in schools and families where parents have lower level education. Professions and education level in both good and bad cases seem to transfer to the next generation. To avoid losing capable workers (and tax payers) of future society this negative transfer must stop. While parents are not able, the teacher's ability to recognise and support the talents of a student is even more important [15, 21, 22].

Society's attitude to a person does affect her or his ideas of her or his possibilities in life. This can lead to incorrect positive and negative thoughts. At the same time, as the research has shown, a person's own ideas of her or his capability have a great impact on learning results and finding of skills [22]. Thus in a worst case, thoughts about how the sex of a person affect the ability to understand an issue can cause strong limitations for learning as well as decrease in self-confidence. Effects of breaking down these limitations can have a great influence on a person's life [22].

The problem of talented students does not concern only the recognition of the talent but also the support for the student. Talent is a challenge for all: how to deal with it and how to accept this difference from others.

Supporting talented students is not inequality or unfair for other students as it is often said. While supporting talents we, in fact, allow each and everyone to develop themselves and their abilities based on their own capabilities and interests [15, 21]. This is more equal than trying to keep everyone in same level – when has equality meant similarity?

3 World of Technology

Before we continue our journey into the pedagogy of technology, we should discuss something about technology, what it is and what it is not. Until now we have been discussing issues such as ability to understand technology. Now we consider science itself.

As mentioned earlier, technology is something and everything around us. Our clothes do exist because of technology (fabrics), and we are able to eat because of technology (spoons, forks, cooking abilities). On the basis of this, technology should be interesting for all of us and it should be easy. At the same time it is based on basic human characteristics: humans are interested in things, issues, how they work and what can or cannot be done with them or without.

3.1 Determination of Technology

Technology education and technique are closely associated with mathematics. In fact the relation between technology and mathematics is companionship more than anything else: technology offers a great deal of equipment to ease the work of mathematics, for example, computers and simulators, while the technique of mathematics is a tool itself. With mathematics it is possible to calculate, simulate and model things, systems and theoretical laws. But the science called technique or technology is more than just mathematics just as education science is more than the equipment of teaching.

The term technology can be defined widely as any skill or ability [5], or it can be defined more tightly as planning, doing, using and studying artefacts as products of knowledge and skills of human beings. Thus the common swimming trip via a small lake can be technology because of the skill of swimming or technology is viewed only in the swimming suit.

Similar interpretations can also be found in other publications [1, 8].

Determination of terms is an important issue in the discussion – in Finnish the discussion considers the terms technology (*teknologia*) and technique (*tekniikka*) [4, 5, 9]. The problem is that in the profession of technology the normal term to use from the science is technique or even engineering. Thus the term technology means systems that are applied from the science. On the point of view of educational science the determination of the term technology is opposite which causes confusion in both sides of discussion: at least in Finland, technology education in school for example means teaching of using of mobile phones while technique or engineering education means teaching of technical thinking. This idea is illustrated in Fig. 1.

Ability to use products of technology and ability in technical thinking is two different issues. From the point of view of science, both are important but ability of thinking is more valuable – it allows us to continue the development of tools.

Even though there is some confusion on terms, both views have the same concern for the development of technology and human's ability to understand, use and develop it further [4, 5, 9, 15].

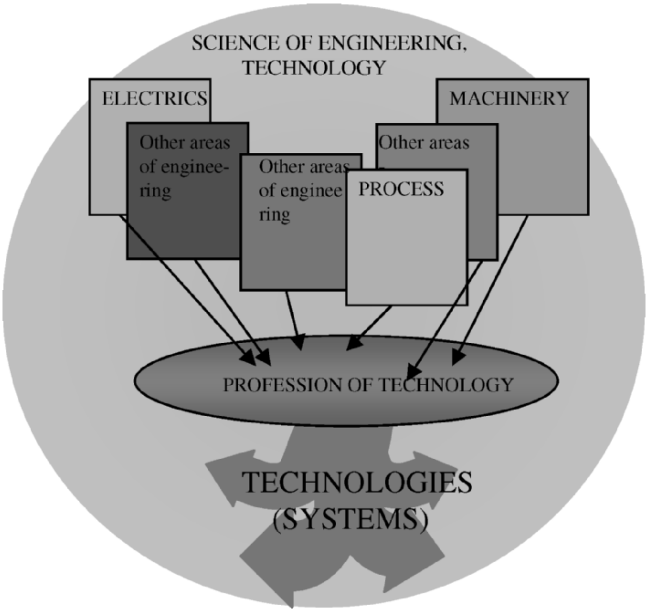

Fig. 1. Relation of terms technology (or engineering) as a science and applications of science as technologies (systems)

3.2 Science Called Technology

The aim of technology as a science is to help humans, to produce equipment, tools and assistance for living. From a historical point of view this can be seen in the education of handicrafts, which truly developed pupil skills that were useful later in adult life [8]. Education of these skills has been understood as an education of working culture, which is based on equipment as well as theoretical and practical technology [8].

Thus practice, as a basis of determination is very useful: the value of scientific technological research depends on the ability of applying results into real life problems [5]. The aim of technical research is to produce better artefacts and understanding of the phenomena connected to them [8]. This thinking can be seen in scientific research hypothesis, which is often in the form of a problem to be solved [5, 8]. This aspect makes it sometimes a bit difficult to divide the technical research into basic scientific research and to R&D-activities [5, 8].

Technology science is interested in artefacts in their own environment – it is interested in phenomena *in* somewhere, not only phenomena themselves

[8]. This is the basic distinction between technology and science as mathematics, physics and chemistry. Technology is not an application or continuation of other sciences', but differs from them in terms of the subject of interest, working procedure and purpose [5, 6]. It is said that nature's existence is not dependent on human actions, while technical issues are the result of human thinking [8].

Technology can be divided into three categories [5]:

(1) *Technology as a scientific activity*: The interesting subject is *research of bases of actions* as studies of planning and R&D-processes and methods, *planning, developing, inventing and creating artefacts.*
(2) *Technology as an activity*: Technical activities include *planning*. Activities are *application design, physical construction, use, maintenance and configuration* of artefacts.
(3) *Technology as an artefact*:Technology produces artefacts and can be an artefact itself at the same time. For example phone and television are a part of technology and products of technology, artefacts.

Technology is quite open-minded science. It uses different kinds of tools to produce and develop new tools. It also includes itself into the set of available tools as well as results of other sciences [5, 8]. This means that any tool, which solves the problem, can be used. There are no limitations for using tools. Thus, on the behalf of technology, its results are available for other areas of science too.

Will and ability to solve problems are basic to technological thinking. This can be seen for example from targets of technological studies in Finnish universities: already in candidate thesis the ability to solve the problems must be seen [27].

In modern society, highly educated expertise is more than theoretical knowledge. It is also the ability to solve problems based on this theoretical and practical knowledge, including real world limitations and deep understanding of them. Educated expertise also involves communication skills, co-operation, and team working abilities together with holistic view, understanding of large processes, courage and skill [24]. In technical education these skills are included into studies as a solid part of science itself.

The technical profession is built on three issues discussed above: holistic and practical way of thinking, theoretical knowledge of technology and other sciences, and connection to reality. This last issue makes technology special [5, 6, 8]. This structure is illustrated in Fig. 2.

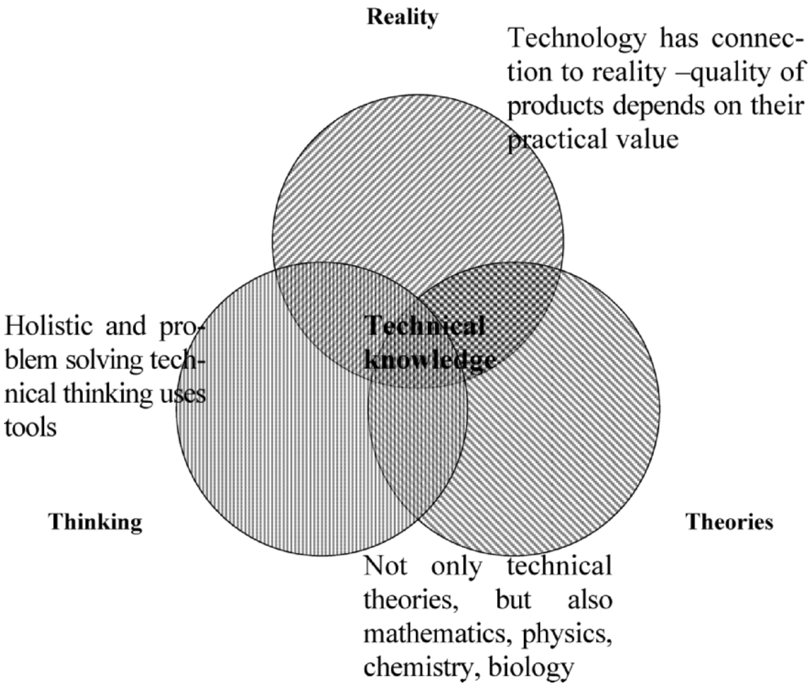

Fig. 2. Technical knowledge is based on good knowledge of theories, certain way of thinking and on connection to practise

This base – way of thinking, theory bases and connection to reality – is the challenge to education of technology. How to keep all of them at the same time in education? How to support thinking and learning to use these tools?

4 Basics of Pedagogy

In this chapter we discuss basics of pedagogy in language technicians understand. Issues for discussion include: What is learning and teaching? Why and how to plan processes of learning and teaching? Who is responsible for results, students or teachers? Is it possible to make learning and teaching more efficient? How to support both students and teachers?

Usually technology is taught by a person with good skills of technology but less knowledge of education. Different kinds of attitudes might prevent using solutions pedagogy offers for support of learning.

Pedagogy is not something opposite to technology. It is a set of theories relating to learning and teaching. Its aim is to support these functions as well as to help us to develop better methods, equipment and environment for learning and teaching. Thus pedagogy offers technicians tools to improve education of technology.

This chapter considers some basics of pedagogy while in the next chapter these theories are applied in practice into planning of education. Some questions for helping planning are included in the Chap. 5.

4.1 Process Planning of Education

As usual in technology, actions should be planned correctly beforehand. The same goes with education in all branches. Good education is always carefully planned before it is done. This plan or curriculum is also delivered in suitable form to teachers, students and other persons. A good plan acts like a base of work for both teachers and students. With it, it is possible for them to plan their own actions in the future [7].

The process of planning education, creating and updating curricula, progresses through several phases: evaluation of need for education, determination of students and targets, description of subjects, methods and evaluation.

Evaluation of need for education answers basic questions of planning: Why this education exists? Is there a real need for this education? On which decision, law etc. is this education based? Through these questions the basic function of education is determined.

Determination of students means background evaluation of students, determination of possibilities and learning limitations. The purpose of this phase is to ensure that teachers are aware of the number of students, their earlier studies, their skills, learning problems and aims.

Determination of purpose of education helps teachers and students to plan their actions in teaching and learning. Purpose of education is related to the society around the school, future work and laws.

Detailed subjects of education inside the title of studies are chosen so that they guarantee results of education.

Implementation of plan, methods and evaluation of results impact on different parts of learning: methods, learning environment and atmosphere can support or hinder learning.

4.2 Process of Learning

Learning and teaching is understood more widely today than in past years. Learning happens not only in lectures in school, but also at home, with friends and at work. Also teaching has changed. A modern teacher is more like a guide on the beginning of path to knowledge than the professor who knows everything on the subject.

Learning is understood as an active action [30]: learning is seeking, receiving, understanding and handling of information. Learning is cumulative while its base is earlier learned issues. Old knowledge is modified with and by new information and skills. Learning is self-controlled: the student has ability to plan, control and evaluate her or his own learning process and its results. Learning always has a purpose, which the student understands and develops, creating their own purposes. Learning is always connected to the situation and environment where it happens. Even the most theoretical issues should always have some kind of connection to reality. Interaction is a solid part of learning, while learning has social aspect [12, 19, 30].

Learning is a complex process, which can be studied from different points of view. Modelling of learning can consider, for example, environmental and mental aspects or it can see learning only as a change in pupil's behaviour. All of these models are correct and can be found in teaching: teacher's actions tell us which models she or he uses. Depending on teacher's and pupil's personality, the subject to be studied, environment where to study, and time, the most suitable model differs – as in normal technical processes: one model does not fit into each case.

Increasingly, researchers of pedagogy agree that learning is a process of change. The change can happen in inner processes (mental) or in behaviour of a pupil (which can easily be seen). In this process, the experience a pupil gets in a learning situation turns into knowledge, skills, attitudes and values. Learning is affected by a pupil's earlier experiences, knowledge, information, skills and motivation, as well as a teacher's actions, teaching methods and evaluation of learning results. The following descriptions of the three most widely used models are based on [2, 14, 19, 20, 24–26, 30].

The behaviouristic model has been widely used in all education in 1910–1970s. It can be seen even today in certain schools. This model is based on the idea of science where learning is understood to be similar for humans and for animals.

The approach to learning in the behaviouristic model is a kind of black box model, where teacher's inputs affect student's actions causing noticeable change in behaviour as shown in Fig. 3. It is not interested in mental processes of learning. Change of behaviour is controlled by a teacher's actions. Learning has happened only if changes of behaviour can be seen.

In behaviourism, the role of teacher is active while the student is a passive receiver. The teacher controls the learning through carefully planning all the small details. Usually, results of learning are controlled with a test, where it is more important to remember small details than show understanding of the whole issue.

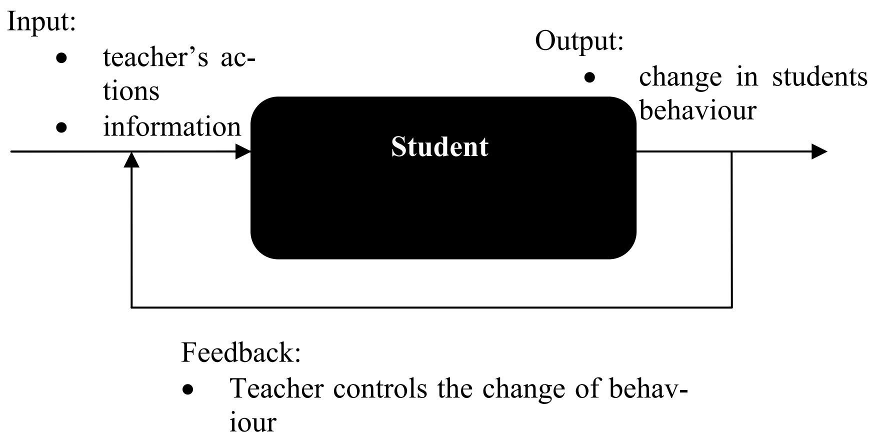

Fig. 3. Behaviouristic model sees learning as a change in behaviour

Other theories of learning are more interested in the inner processes of a student as in Fig. 4. *Experiential learning* is based on humanistic approach where the human is active, motivated, self-controlling and free. Learning is a cyclic, growing process, which includes experiences. The key element of the process is the student's personal information processing.

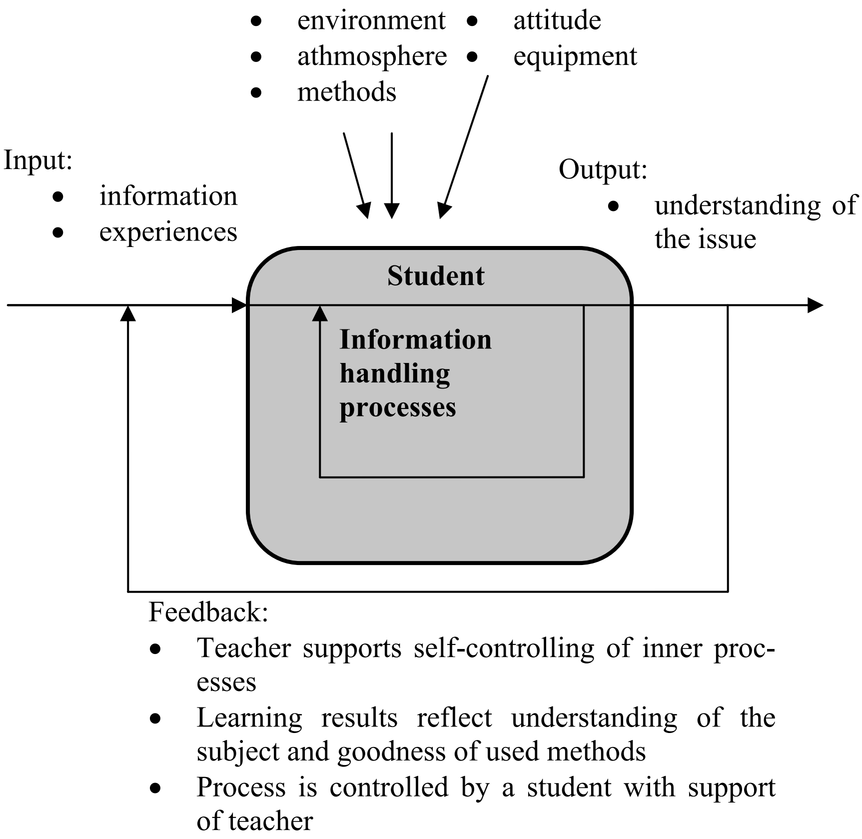

Fig. 4. Learning as information handling processes is affected by different kinds of inputs and environmental issues

A cyclic model of experiential learning is illustrated in Fig. 5, where the understanding of new information as well as applying it into new situations are the base of the model [12].

Each and every student brings her or his experiences into the learning situation. The teacher can use these experiences as a tool and support the learning. Feelings, self-reflection and practical exercises are important in this model.

The teacher's task is to support and guide student's information processing. She or he acts in a role of a tutor, mentor and guide. Teaching is flexible and actions depend on the learning situation.

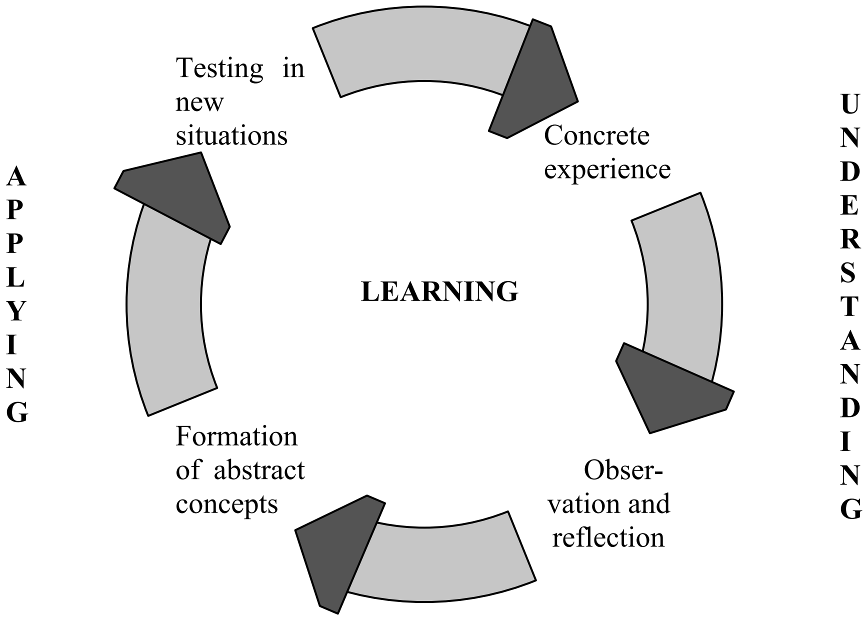

Fig. 5. Experiential learning has cyclic structure

The student is responsible for her or his learning, through interaction with others using different kinds of team working methods. In this model, a pleasant learning environment is considered to be very important. This does not mean that everything is allowed, nor that there is no discipline or that everything must be fun. This means that a useful, practical environment where atmosphere allows learning, mistakes and successes. The learning situation is safe and supporting.

The teacher does not do detailed planning of learning, but writes down the main principles, methods and subjects. The plan can be changed during teaching if necessary. The timetable is flexible and without details.

The constructive model of learning is based on the cognitive processes of a student. It includes a set of different approaches which all illustrate certain details of learning. All the models agree with the idea of learning as an active information construction process, which is personal or social.

Key elements of learning in this model are understanding, thinking and meta-cognition skills. With these skills a student can control her or his learning. The purpose is that the student is finally independent and responsible of her or his actions.

Learning is connected always to the situation and culture where it happens. Thus environmental aspects are important in the process. The teacher's task is to guide the process, motivate students and lead them into the subject. This means that the teacher must beforehand plan and arrange the learning situation, collect suitable materials etc. On the other hand the plan is quite short: it includes basic ideas and purposes of teaching. Evaluation is incorporated throughout the learning process.

4.3 Adult as a Student

The age of a learner affects the learning process. Thus an adult as a student differs somewhat from a child. Adults have a larger set of experiences, both negative and positive. Otherwise the same processes do exist with adults as with children. The same targets of self-control, independency and motivation apply.

An adult student is often thought to be more independent, active, motivated and self-controlled than a child. This, though, is quite an optimistic point of view. Rather we understand that the learning of adults is also described with words like conservatism and selfishness. Also it is noticed that meta-cognitive skills do not always improve by age – their development depends on student's personality.

One certain fact about adults is the existence of experiences with tacit knowledge of them. A student is in the learning situation with her or his history, skills, knowledge and attitude. This brings new challenges to the teacher: learning is always an experiential, constructive processing of information.

5 Planning of Education

Planning of education is the best way to guarantee the quality of studies. Carefully, planned and written curricula provide a good tool for both teachers and students. Thus it is necessary to understand for whom the plan is designed.

The quality of the curricula is checked by referring the written plan to the education given and to the learning results. Based on this, it is developed further. The development process is in fact similar whether creating a new plan or updating an old one. The development process is illustrated in Fig. 6.

Planning of education is based on the demands and laws of the surrounding society. Real world experiences also have an effect on how the

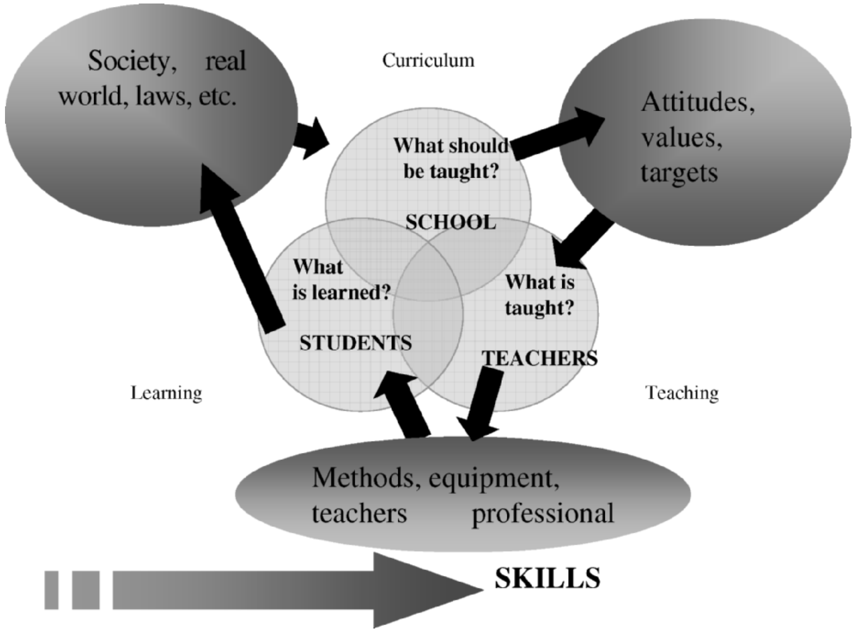

Fig. 6. Relationship of teaching, learning and planning is complex

plan is finally realised, and how subjects are taught. All the attitudes and values can be seen in for example the finance of resources for education. What really was learned is a sum of these and actions of the teacher.

A curriculum is not only a list of subject requirements to be taught and how much time there is for each subject. It considers discussions of function, competences, values, methods and structure of this education. Results of these conversations are written down into the plan.

After all, planning of education is similar to any other process planning. Now the object process is learning with some limitations of resources and time. Methods to control and improve the process depend on targets and used models of learning. The teacher is a kind of a process controller, while the process is inside a learner. It is possible to handle the process from outside as a black box model, or learn to understand it more deeply.

5.1 Phases of Planning

With planning of education it is possible to define limits to the teacher for her or his actions. Thus, detailed planning is not necessary or useful.

Freedom for working in a suitable way for the teacher is an important motivating issue.

Planning of education can be divided into five phases as shown in Fig. 7 [10]. All these phases are included into the planning process with both new and old plans.

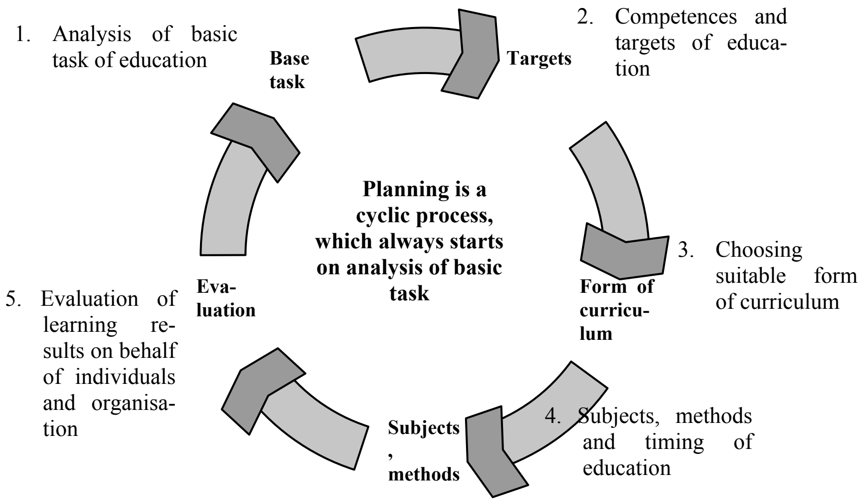

Fig. 7. Planning is a cyclic process

A curriculum is always created, updated and developed with wide co-operation of schools, personnel and students. The co-operation is a simple way to bind them to the curriculum through providing an opportunity for all parties to influence the curriculum. Because the process of curriculum development needs time and work, there must be enough resources for it. Different kinds of team working methods do improve the efficiency of the process. As processes, creating a new curriculum or updating the old one, there is not too much difference.

The following Sects. 5.2–5.6 discusses more detailed phases of the process. At the end of each section there are a set of questions to help in the practical work of curriculum development.

5.2 Analysis of Basic Task of Education

The basic task of education is always preparing for the future. It is based on a vision and tries to meet emerging demands of the professions. The basic task can be based on both scientific and professional aspects. There can be philosophical or practical views in it. The starting point of analysis is the demands of today's and tomorrow's societies and circumstances.

The underlying principles of the curriculum must always be clear whenever developing a curriculum. Even when similar education has been given for decades, it is very useful to check now and then the demands of the world around it. The technical development itself has impacts on the demands of education: some years ago, reading and writing capacity was enough, but now one must also understand and know how to use computers, programs and internet. With new skills it is possible to not only meet demands but also to modify them.

Following questions will help in planning:

What kind of education is really needed in the future?
What are the purposes of this education?
Whose purposes are these?
Who needs this education?

5.3 Competences and Targets of Education

Education always produces certain skills. In other words, education must give some kinds of competences to students. Usually in universities, at least in Finland, determination of competences is part of the job of a professor, but also other components of society can be part of it.

Again co-operation is the key element of good determination of competences and targets. Together with experts of schools and society it is possible to produce curricula with good quality.

The basic idea in determination of competences is to determine what skills a student acquires during education. Targets of this education are then drawn from these competences. It is always necessary to remember the reality of existing resources in this work: experts cannot be educated in short time, with lack of teachers and equipment.

Following questions will help in planning:

Who determines basic competences?
What kind of information, knowledge and skills should education produce?
Which are the most important outcomes and how are they achieved?
What kind of education is possible with existing resources and time?

5.4 Form of Curriculum

The existing curriculum itself is a useful tool for teachers and students, especially if it has been done carefully beforehand. Still, the form or structure of the curriculum – how subjects of education are described in the document – affects the outcomes and the possible methods of education.

One of the most effective characteristics of curriculum structure is diversification of subject offerings. A large choice gives a student more freedom and responsibility for her or his studies, but at the same time it makes it easy for the student to study less important issues for this education. The big picture of the purpose of education disappears and the student might have some motivation problems – it is easy to give up and quit studies. On the point of view of teacher and school many small entities makes it harder to plan studies when the number of students of each entity is not known beforehand [10, 11] .

Small entities lead to learning, where understanding is not important but remembering small details is. With larger entities education could concentrate on understanding and deep learning [10, 11].

To avoid small entities it is necessary to combine subjects together as larger combinations, where the idea of these studies can be seen as a clear line.

Curricula can be produced with different form and structure [10]. These models of curriculum can be modified, combined and developed further. Based on the structure curricula can be divided into four categories:

Course based model is a traditional model, which gives more freedom and responsibility to students. It allows free choice of studies, which is not an efficient way to get through education. To avoid the model's negative aspects it is possible to try to co-ordinate studies with individual guidance of students. This model limits the use of some methods of education such as problem-based learning. The model is illustrated in Fig. 8 [10].

Fig. 8. Course based model of studies [10]

For students, this model is traditional and represented by large freedom of choice. It is easy for the student to prepare timetables, but the disadvantage is the "big picture" objectives of the curriculum might disappear. Studies tend to take longer time, and courses might have similar subjects.

For a teacher, this model means easy working, while instead of planning larger education outcomes, planning consider small entities. This allows teacher to be a perfect expert in a small area. Evaluation of learning results is also easy when the entity is small enough. Teaching and learning is concentrated on the teacher's activities.

Block model, as shown in Fig. 9, is used when studies of a semester do form one solid larger entity, block, in time and on subject. During one block it is not possible study anything from other blocks. This structure supports timing of education so that studies are finished on time [10].

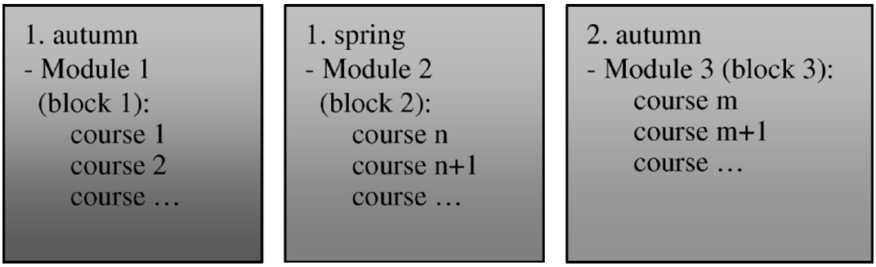

Fig. 9. The block model of the studies [10]

To the student, this model is very safe, because there is not much freedom or alternatives. The model supports learning with its logical and cumulative structure. It makes group phenomena stronger. Usually most of the students graduate at the same time.

To the teacher, this model is logical and it eases the work because of its cumulative nature. The teacher is aware of students' earlier studies and what they are going to study after this block. The model is not flexible and all the bigger changes are slow. This model tends to increase number of students in a course, which weakens learning results.

In *the module model*, courses are collected together to form large entities, modules. The order of modules as well as the order of courses inside a module can be determined or free. Each module is a solid entity, which is studied as it is. This structure allows teachers and students to see and understand the big picture and it encourages understanding learning. The model is illustrated in Fig. 10 [10].

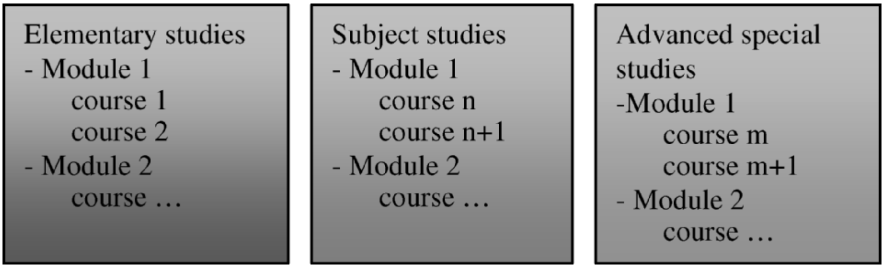

Fig. 10. The module model of the studies [10]

To students, the model is easy with strict and logical order of modules and courses. This makes both the curriculum and studying clear. The model supports constructive learning but it does not have many alternatives in studies.

To the teacher, this model means that all the students have the same starting point. They have similar education history. The model demands good co-operation among teachers. The main principle of planning of education using this structure is binding theories to practice. Thus applying knowledge and information transfer is taken into account in planning.

In *the case model*, as shown in Fig. 11, entities of education are determined as multi-scientific cases through all the studies. Entities can be described as problems to be solved or tasks to be done during studies with help of different science areas together. A case might last through all education or just a part of it [10].

	course 1 (Case 1)	course 2 (Case 2)	course 3 (Case 3)	
Project 1	x		x	
Project 2		x	x	
Project 3		x	x	
…				

Fig. 11. The case model of the studies [10]

To the student and teacher, this model is interesting. It offers big picture understanding of studies and supports stronger understanding learning. It allows expertise of small entities and forces co-operation among teachers and students.

Following questions will help in planning:

Which plan guarantees the required results?
What are the reasons for the choice?
Is there need to develop the chosen form or combine forms?
How are students taken into account in the choice of form?

5.5 Subjects, Methods and Timing of Education

Subjects of education must be determined by classifying them into categories of *must know*, *should know* and *nice to know* knowledge and skills. Realism must be included into this determination: it is not possible to teach everything, but it is possible to teach how to find missing information and gain missing skills [10, 11].

Based on determination and classification of subjects it is quite simple to do the timing of studies. Important, must know subjects get more time than less important ones. At the same time it is possible to decide which methods are the most useful. Usually thus a set of suitable methods is introduced to teachers. She or he can then choose the best method or methods for her or him [10, 11].

Through determination and classification of education it is easy to add new subjects or drop off old ones. This makes it possible to keep subjects up to date.

There are common guidelines for calculating work demands of education. Of course, some students need more or less time for learning. Also there is a huge difference between the works needed for deep understanding learning and for learning, which is enough just for finishing the course. Underlying this calculation is the idea that one academic year consists of 1,600 h of student work. In Europe, member states of the European higher education area are thus jointly developed the ECTS credit system. According to this system 60 ECTS credits correspond to 1,600 hours of student work [10, 11].

It is also important to notice that how demanding education is and how much time and work it takes to get it done are not the same. Even an easy subject can need a lot of work and a lot of time if organisation, methods and materials of studies are not correct.

For example in Finnish university studies the following guidelines are used [11]:

1 ECTS means = 26.7 h of work.

While *studying literature* working hours are determined uniquely for each book, but commonly a book written in mother tongue means work as 40 h/200–250 pages (about five pages per hour) while in foreign language it means 40 h/125–150 pages (about 3.5 pages per hour). If this includes writing an essay more time is needed.

Working hours of *writing* depends on the required quality of the result as well as the skills of a writer. The basic guideline in writing is 8–12 pages/40 h (about 0.25 pages per hour).

Preparing for an *exam* entails work of about 5 h per 1 ECTS for the student. This time is independent of form of the exam.

Deep learning of subjects discussed in *lessons* means about double the time commitment: A 1-hour lesson needs 1 hour of home work. Of course, some lessons are such that they do not need extra work – in that case it can be asked why have such lessons, which make students passive ("physical existence needed but no brains")?

While the teacher is updating her or his knowledge, the same process of learning is going on. Thus these guidelines can be used also in approximations of teacher's work.

The following questions will help in planning:

What are the important subjects in education (must know, should know, nice to know)?
Which issues and subjects are offered to every one?
What is taught? In which order are they taught?
How are age and experiences of students taken into account?
What are the connections between theory and practice?
How is it guaranteed that learning subjects are based on reliable, modern and diverse material?
How are learning subjects described in curriculum?
What methods are possible in this education?
How is the student guided?
How do the methods support actions and development of both teacher and students?
What possibilities are gained from the learning environment?
What demands do the teaching methods bring to the learning environment?
Is the timing correct?
Is there enough time to learn?
What happens if there is not enough time?
What is left out if there is not enough time?
How does the plan allow personal choices of studies?
What if the student has problems in learning?

5.6 Evaluation

Evaluation of learning results is done for the student, the teacher and for the sake of development of the process. Based on the evaluation the plan of education, the curriculum is updated. Also, the professional development needs of the teacher can be seen from evaluations.

Evaluation does not only mean statistics of exam results of students, but also answers to questions such as: How good was the curriculum in practice? Did teachers use the methods mentioned in the curriculum? Why did the teachers use these methods? Were the results expected? Based on this it is possible to determine targets of further development: organisation, teacher's professional skills, subjects and methods of education.

Learning itself can be evaluated from different points of view: evaluation can concentrate only on the exam or to the whole process of learning. The results of evaluation can be understood in many ways: good numbers can mean good learning as well as easy subjects or inappropriate evaluation. Numbers do not necessarily inform the quality of education.

The following questions will help in planning:

Who evaluates?
What is evaluated?
How is the evaluation done?
Is the evaluation based on quality methods?
How are the data collected for the evaluation?
Where is the data stored?
How are results of the evaluation published?
When is the evaluation done?
Why is it done?
What will happen to the results of evaluation?
How does the evaluation affect teaching and planning?
How are students taken into account in evaluation?

6 Effective Learning

The effective learning process varies a lot. It includes different kinds of methods of learning and teaching. It includes a set of tasks to be done. Learning based on variations of methods guarantees best learning results: each human learns differently [13, 16, 28].

Technology is practical in its nature [5]. It is active and based on doing, testing and trying. This can be seen in teaching and learning of technology: there have always been plenty of demonstration and practical exercises [5, 6, 8, 9]. So, in basic structure, technology is very modern and allows modern, good teaching practices.

A wide variation of educational methods offers more than just effective learning: it is also possible to optimise the use of resources with certain methods. For example, distance education needs fewer room resources than traditional lecturing.

Instead of traditional education it is possible to use, for example, different kinds of projects and essays as educational tools. Combinations of these tools add variety to the educational experience, and students learn also meta-cognitive skills along with the original subject content.

For the teacher, this kind of teaching is refreshing. It does not free her or him from responsibility, but the results of learning depend on the student instead of the teacher. In this kind of education the teacher must be available for students whenever they need support. The teacher's role is more like a guide than anything else.

Distance education is a way to vary the methods of teaching. Usually, in distance education, teaching and learning utilises telecommunication. This kind of education requires students to be more active, motivated and self-disciplined. It also means more independence, which of course is not suitable for all. On the other hand it gives to the student and the teacher freedom of time and place. It also demands the ability to organise learning tasks as well as knowledge of own learning skills [3, 29].

Because of the fewer traditional contacts between teacher and student, the distance education must be planned even more carefully than other forms of education. The structure of studies must support active distance education. Also this plan must be delivered to teachers and students as early as possible.

After all, learning and teaching is an interesting area, which can be seen via technology science as a tool for better technology and professionals of technology. Pedagogy is not an enemy of technology, but an assistant to the science. At the same time, technology offers a lot to pedagogy: it is not only a tool but also the traditional education of technology does incorporate the usefulness of constructive and experiential learning.

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Authoring and Management Tools for Adaptive Educational Hypermedia Systems: The AHA! Case Study

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Summary. Creating and maintaining adaptive educational applications is hard work for teachers and developers. In order to help the author perform these tasks the e-learning systems must provide authoring and management tools. In this chapter we describe several useful tools for working with adaptive educational hypermedia systems, using the Adaptive Hypermedia Architecture (AHA!) system. AHA! is a well-known open source general-purpose adaptive hypermedia system. In the current AHA! distribution versions there are some general adaptive author tools as Concept Editor, Graph Editor, and Form Editor, all accessible through the overall Application Management Tool. There is also a specific educational tool: the Test Editor (and the associated Test Engine) and we are now developing some others such as a Course Editor and Mining tool. In this chapter we describe the AHA! system and the functionality of each of these authoring and management tools intended to help teachers and application developers.

1 Introduction

In recent years, we have seen an explosive growth in the use of web-based technology in distance learning systems. At the same time, more and more artificial intelligence techniques have been integrated into these systems to improve students' learning, turning them into Intelligent Tutoring Systems.

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The union of web-based hypermedia with Intelligent Tutors has led to the current Web-based Adaptive Educational Hypermedia Systems that allow adapting the teaching to each individual student [6]. Adaptive Educational Hypermedia (AEH) is an alternative to the traditional one-size-fits-all approach in web-based education. It combines the concepts of hypertext/hypermedia with user modeling and user adaptive systems to adapt the hypertext to the needs of each particular student. Adaptive Hypermedia Systems (AHS) [4] started to appear around 1990, when researchers combined the concepts of hypertext/hypermedia with user modeling and user adaptation. The first and foremost application of adaptive hypermedia was in education, where the navigational freedom of hypermedia was introduced into the area of intelligent tutoring systems. But since then applications in information systems, information retrieval and filtering, electronic shopping, recommender systems, etc. have been realized. The advent of the Web has made the use of (basic) hypermedia facilities easier, through the use of HTML. However, creating adaptive hypermedia on the Web requires server-side functionality for user modeling and for the adaptive generation of (HTML) pages. Until recently, almost every adaptive hypermedia application was based on a special-purpose (server-side) system. The development of adaptive hypermedia applications and systems has had a one-to-one relationship. This has seriously hindered the development of interesting new adaptive applications by researchers with insufficient skills or financial means to develop their own adaptive hypermedia system. Despite the potential benefits of adaptive educational hypermedia for educational applications, the use of adaptive hypermedia has not been as widely accepted as might be expected. One of the reasons might be in relation to difficulties in authoring. So, it is necessary to provide authoring and management tools in order to help the teacher or application developer in performing a multitude of authoring tasks.

There are several modern authoring systems to develop adaptive educational hypermedia [12] such as InterBook, Web DCG, DCG+GTE, AHA!, ACE, ALE, NetCoach/ART-WEB, ECSAIWeb, MetaLinks, SIGUE, etc., all oriented to educational practitioners. There are two major approaches used by authoring tools: the markup approach and GUI (Graphic User Interface) approach. The markup language uses a regular word processor with the help of special markup language. The GUI uses special authoring user interfaces. In general, it could be a command-based, form-based or a direct manipulation interface, but all existing AHS authoring tools use form-based GUI. This kind of interface provides very good support for the non-professional. The main task of these tools is to help the developer to author the content objects and to specify the links between them. However, in order to maintain an AEH application it is necessary to perform many additional tasks such as to develop assessments and activities to evaluate students, to visualize and analyze the students' usage information, to modify and improve the course content and structure, to do back-up and to reuse educational material of other systems, etc. Hence, it is necessary to provide authoring and management tools for each of these tasks.

A well-known AHS system is AHA! [7–10], or *Adaptive Hypermedia Architecture*. It was designed and implemented at the Eindhoven University of Technology, and sponsored by the NLnet Foundation through the Adaptive *Hypermedia for All* (AHA!) project. AHA! is an open source general-purpose adaptive hypermedia system, through which very different adaptive applications can be created. AHA! offers low-level facilities for creating exactly the desired look-and-feel for each application and for fine-tuning the adaptation, and it offers high-level facilities for creating the conceptual structure of an application, using concepts and concept relationships. Since AHA! is essentially an adaptive client and server at the same time it can be used as a component in the content delivery pipeline and thus integrated into other server environments. AHA! was originally developed to support an online course with some user guidance through conditional (extra) explanations and conditional link hiding. But now AHA! has many extensions and tools that have turned it into a versatile adaptive hypermedia platform and it has a complete set of authoring tools (Concept Editor, Graph Author, Form Editor, Test Editor, etc.) to allow authors to easily create or change applications or courses, concepts, concept relationships, computerized tests, etc.

In this chapter, we describe the overall AHA! architecture and then discuss the main authoring tools that it provides to the author. First we describe the tools that are included in the current distribution version, available from the Eindhoven University of Technology, at http://aha.win.tue.nl/. Next we describe some new tools that we are developing at Córdoba University, and finally we present some conclusions.

2 AHA! Architecture

AHA! [7–10] is a Java-servlet-based software environment that works with the Tomcat web server, on Linux (or UNIX) as well as on Microsoft Windows. It is available from http://aha.win.tue.nl/. Figure 1 shows the overall architecture of the AHA! system. The core is formed by the AHA! engine which is implemented using Java Servlets running on (and communicating with) the Web server. The information on the server consists of three parts that are described in detail below: a combined domain and adaptation model (DM/AM), corresponding to these models in AHAM, a user model (UM) which keeps track of the user's knowledge about the domain concepts, and the local pages which contain the content of the application or course. It is possible to include external pages (retrieved from other Web servers), which are (potentially) adapted in the same way as local pages. AHA! also contains authoring and management tools, explained in a later section.

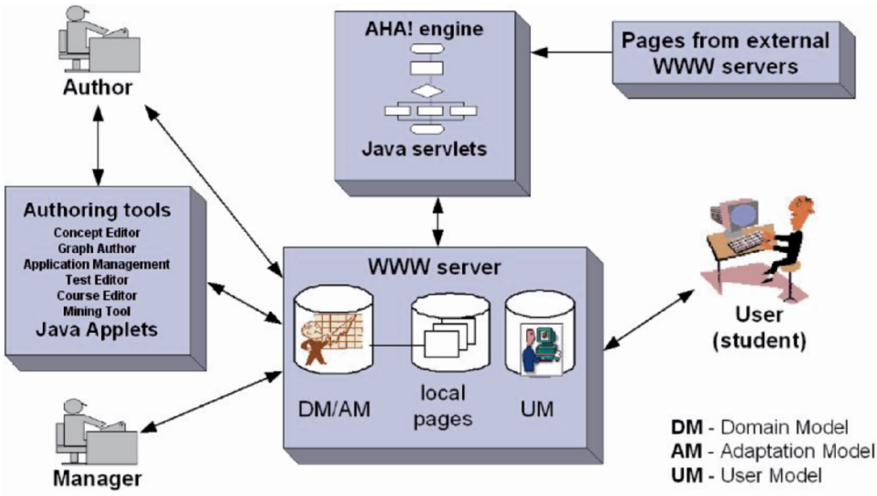

Fig. 1. Overall AHA! architecture

AHA! is an Open Source Web server extension to add adaptation to applications such as online courses. Users request pages by clicking on links in a browser, and AHA! delivers the pages that correspond to these links. However, in order to generate these pages AHA! uses three models of information.

The first, or domain model (DM), contains a conceptual representation of the application's content. It consists of concepts and concept relationships. In AHA! every page that can be presented to the end-user must have a corresponding concept. It is also possible to have conditionally included fragments in pages. For each place where a decision needs to be made as to what to include, a concept must be defined. (Such a concept can be shared between different pages on which the same information is conditionally included.) Pages are normally grouped into sections or chapters or other high-level structures. AHA! makes use of a concept hierarchy through which knowledge can be easily propagated from pages to sections and chapters, and through which AHA! can automatically generate and present a hierarchical table of contents. Concepts can be connected to each other through concept relationships. In AHA! there can be arbitrarily many types of concept relationships. A number of types are predefined to ensure quick access as an author. A typical example of a (predefined) relationship type is prerequisite. When concept A is a prerequisite for concept B the end-user should be advised (or forced) to study or read about concept A before continuing with concept B. This relationship is translated into adaptation rules that will adapt the colors of anchors for links to concept B. The translation from concept relationships to the actual adaptation using colors and/or icons is very flexible but defined through templates the average author may not wish to change. The flexible scheme is explained by De Bra, Smits, and Stash [10]. By default the link anchors will have the normal Web colors (blue or purple) when the link leads to a concept (or page) for which all the prerequisites are met, and will have the color black when some prerequisites are not met. Creating a domain model, using existing templates, is easiest using the Graph Author tool.

The second or user model (UM) in AHA! consists of a set of concepts with attributes (and attribute values). This model contains an overlay model, which means that for every concept in DM there is a concept in UM. UM can contain additional concepts (that have no meaning in DM) and it always contains a special pseudo-concept named personal. This concept has attributes to describe the user and includes such items as login and password. When a user accesses an AHA! application the login form may contain arbitrary (usually hidden) fields that contain values for attributes of the personal concept. It is thus possible to initialize preferences through the login form. To get you going quickly as an author the AHA! authoring tools provide a number of UM concept templates, resulting in concepts with predefined attributes. Typical attributes are *knowledge* and *interest*, to indicate the user's knowledge of or interest in a certain concept. AHA! will automatically propagate an increase in knowledge of a concept to higher-level concepts (higher in the concept hierarchy of DM). It will also record a lower knowledge increase when studying concepts for which the prerequisites are not yet known.

The final model, called the adaptation model (AM), is what drives the adaptation engine. It defines how user actions are translated into user model updates and into the generation of an adapted presentation of a requested page. This model consists of adaptation rules that are actually event-condition-action rules. Most authors will never have to learn about AM because the rules are generated automatically by the Graph Author. For very specific adaptation needs (not possible with the existing templates) it is desirable to either learn to create individualized templates or study the Concept Editor that allows the creation of arbitrary adaptation rules. The following explanation describes what happens exactly when the end-user clicks on a link in a page served by AHA!:

1. In AHA! there are two types of links: links to a page and links to a concept. Since in DM pages are linked to concepts AHA! can find out which concept corresponds to a page and which page corresponds to a concept.
2. The adaptation engine starts by executing the rules associated with the attribute access of the requested concept (or the concept that corresponds to the requested page). Access is a system-defined attribute that is used specifically for the purpose of starting the rule execution.
3. Each rule may update the value of some attribute(s) of some concept(s). Each such update triggers the rules associated with the attributes of these concepts.
4. When the rules have been executed, AHA! determines which page was requested. (It is possible to associate several pages with a concept and have rules decide to which page to present, just like with conditional fragments inside a page. Details are described by De Bra, Smits, and Stash [10].).
5. A frame is generated with components that define the look and feel of the application. The presentation may include a hierarchical menu with chapters and sections for instance. One frame (typically the largest one) is used to present the requested frame.
6. The requested page is adapted. This adaptation includes changing the link colors and conditionally including fragments (also called objects). The insertion of objects actually has some complex side effects that are not discussed further in this chapter.

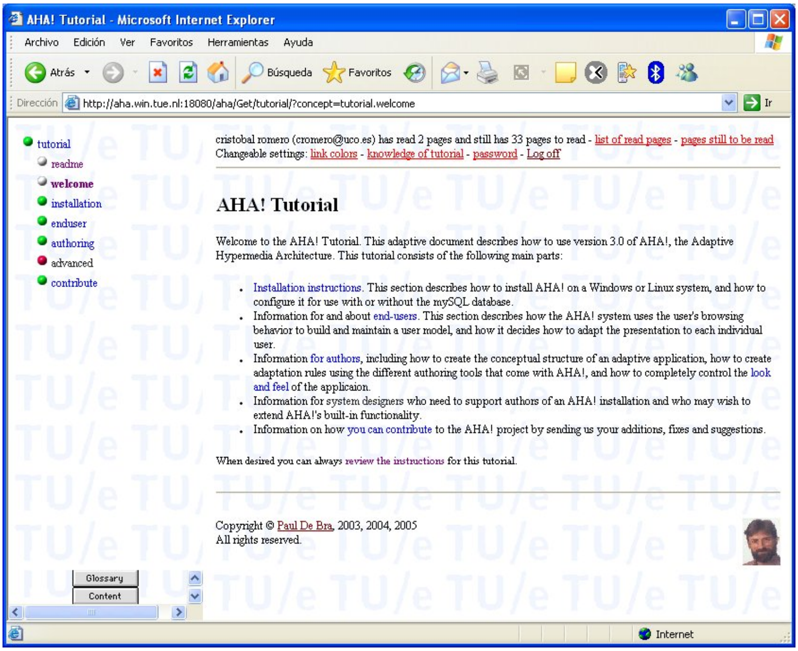

Fig. 2. AHA! Tutorial

In AHA! the presentation of a course can be influenced in many more ways that are beyond the scope of this chapter. AHA! uses a layout model to define how concepts (of different types) are presented. A layout is basically an HTML frames structure, and apart from a frame that shows a page there can be frames that show parts of a table of contents, concepts of which the knowledge is increased by reading the current page, prerequisite concepts (and their knowledge level), etc. Through the powerful layout model AHA! applications can be made to look very similar to applications in other adaptive educational hypermedia platforms. Figure 2 shows the AHA! tutorial as an AHA! application, using just one of many ways in which the presentation is possible.

3 Authoring and Management Tools in AHA!

Authors in AHA! are special users, created by the manager (who installs AHA!). An author can access the different authoring tools and account information through the main starting page of the AHA! distribution. From this page (see Fig. 3) the author can go to the following subparts:

– The Configuration is an interface for manipulating the different AHA! data structures. It allows a choice between the use of XML files or a mySQL database for the concept structures and the user models, and allows conversion of authoring formats to internal formats. It also allows authors to be defined and assigns applications to authors.
– The Application Management Tool is the "parent" authoring tool. It allows files to be transferred from your local machine to the server and back, and allows most other authoring tools to be activated by simply clicking on the names of the authoring files.
– The Author Workplace permits changes to authors, and access for all the authoring tools (Concept Editor, Graph Author, Form Editor, Test Editor, etc.). Authorization is required to change author settings. Authoring tools can also be accessed directly from the authoring page. (The tools ask for authorization when they are initiated.) .
– The starting page may provide links that lead to hyperdocuments or applications that are served from this instance of the AHA! system. The standard AHA! 3.0 start page offers access to one application: the AHA! 3.0 tutorial. The tutorial is adaptive. By studying the source files for the tutorial it is possible to also learn more about how to create adaptive documents with/for AHA!

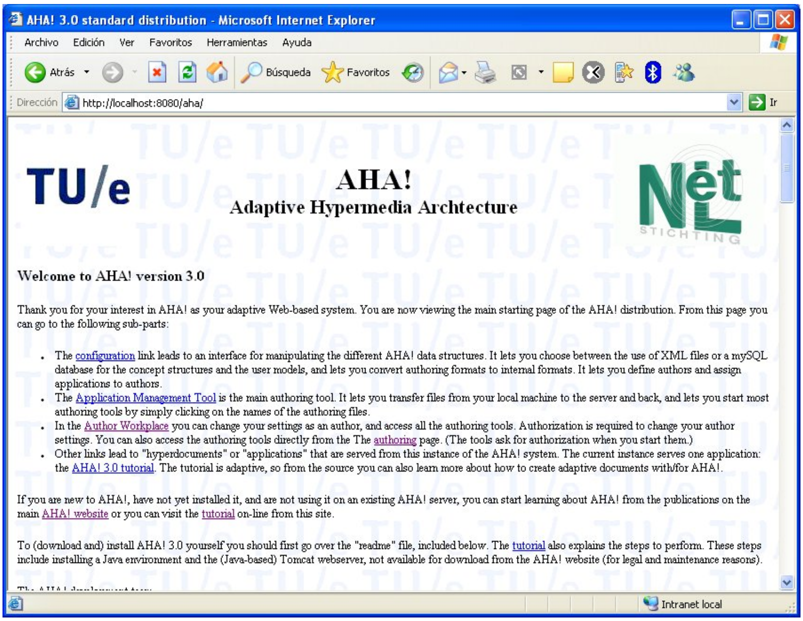

Fig. 3. Main starting page of the AHA! distribution

3.1 Application Management Tool

The Application Management Tool [9] gives easy access to the authoring tools as well, and provides a file transfer tool that allows files to be copied back and forth between the authoring workstation and the AHA! server. In order to manage an application as an author the application management tool, or AMT for short, offers a user-friendly interface to copy files between the local PC and the AHA! server. AMT works as a signed Java applet, in order to be able to access the local file system. Figure 4 shows the AMT interface. The left half of the window gives an explorer-like view of the local file system. The right half can either show the application files which are all the files that are created by the author and that the server uses when the application is running. The alternative view shows the author files which are the files that are created using the special AHA! authoring tools for the domain model. A double-click on one of these files automatically allows the appropriate authoring tool to be started. The files created by the authoring tools (Graph Author and Concept Editor) are not stored on the PC, only on the server.

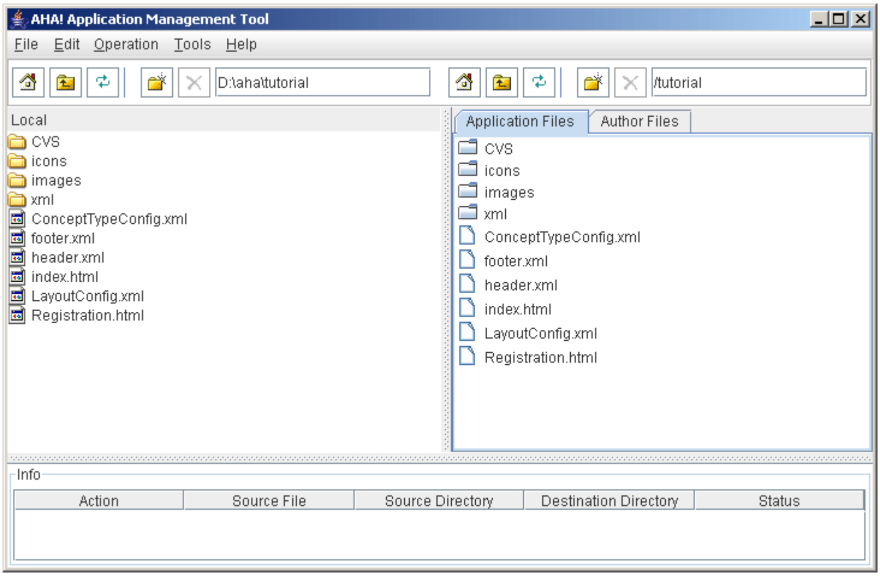

Fig. 4. Application Management Tool main window

The Application Management Tool (AMT) shows an interface that is similar to that of a popular secure shell (ssh) interface. On the left is the local file system, and on the right is either the server's file system (in the Application Files tab) or the server-side authoring files for the Graph Author and Concept Editor. A double-click on the .gaf files automatically starts the Graph Author and a double-click on the .aha files starts the Concept Editor. It is thus possible to perform all the application creation and maintenance using AMT. The one part that is not supported by special tools in AHA! is the creation of the application's files like pages and images. Although AHA! contains some limited backward compatibility support for plain HTML, it works best with XHTML, with or without some AHA! extensions.

3.2 Graph Author Tool

The Graph Author Tool [9] is the main authoring tool for the concept structure. It permits the creation of a concept hierarchy and concept relationships of different types. The Graph Author is also a graphical, Java applet based tool, but it uses high-level concept relationships. Again, when concepts are created a set of attributes and adaptation rules is generated. But this tool also has templates for different types of concept relationships (also defined by the author). Creating knowledge propagation, prerequisite relationships, or any other relationship is just a matter of drawing a graph structure using this graphical tool. The translation from high-level constructs to the low-level adaptation rules is done automatically, based on the templates. Figure 5 shows a screenshot of the Graph Author.

Concepts and concept relationships are created using the Graph Author. The Graph Author window is split into two parts (see Fig. 5), showing the concepts (as a hierarchy) on the left and showing the concept relationships (as a graph) on the right. The graph represents the structure of prerequisite relationships in a tutorial application. The concepts are structured as a hierarchy which in fact also is a structure of concept relationships (and always present in an AHA! application). Every type of relationship has a different meaning related to the adaptation an application provides (explained later) and is represented using different colors and styles of arrows.

The concept relationship graph is created by dragging concepts from the hierarchy shown on the left to the drawing pane, and by then drawing arrows between the concepts. First, the appropriate concept relationship type is selected from the drop-down list (top right in Fig. 5) and then a click on the source concept allows it to be dragged to the destination concept. Some concept relationships may have an optional parameter. By clicking on the arrow a textfield appears in which the parameter value can be entered. For a prerequisite for instance the amount of knowledge that must be exceeded in order for AHA! to consider the prerequisite to be fulfilled is a parameter. (Its default value is 50 in this case.) Also, the rules are executed (conditionally) when a page (associated with the concept) is accessed. In an application like the tutorial one we have three types of concept relationships that play a role:

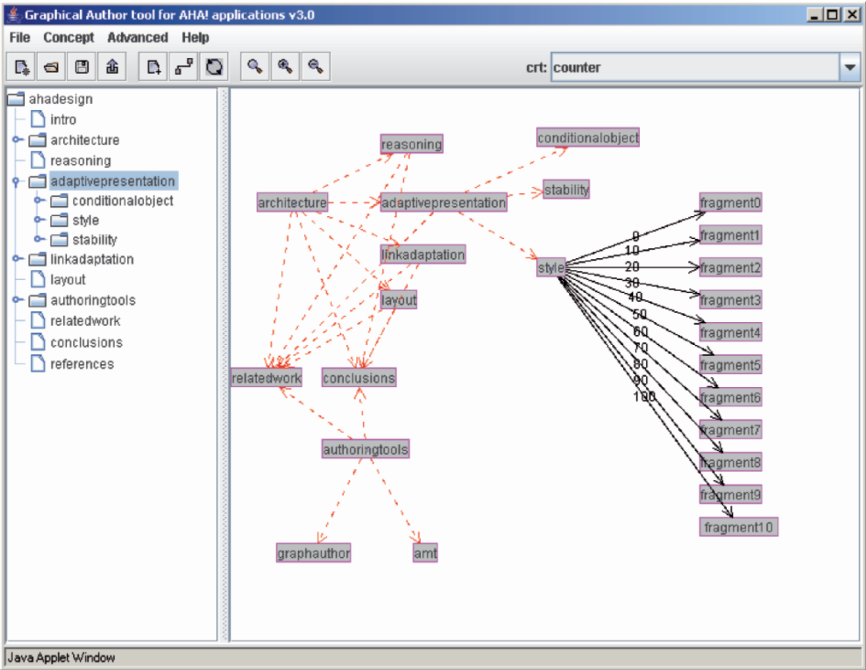

Fig. 5. Graph Author tool main window

For every page there is a unary relationship (a relationship from the page to itself), called knowledge update. When a page is read the action that is performed depends on the suitability of the page. If the suitability attribute is true then the knowledge of the page is set to 100. If it is false then the knowledge of the page is increased to 35. (By this we mean the value is set to 35 if it is lower, but left at its previous value if that was already over 35.).

– The concept hierarchy shown in the Graph Author is used for knowledge propagation. When the knowledge of a concept changes that change is propagated to the concepts that are higher in the concept hierarchy. How much knowledge is propagated depends on the number of siblings the concept has. The idea is that when all siblings reach a knowledge level of 100 the parent should have 100 as well. (But due to integer arithmetic and truncation that value may end up being slightly lower.)

– The prerequisite relationships determine the suitability of a concept. If A is a prerequisite for B, expressed by drawing a prerequisite arc from A to B in the graph, the suitability of B depends on the knowledge of A. The standard rule requires the knowledge of A to be higher than 50 in order for B to be considered suitable.

3.3 Concept Editor

The Concept Editor [9] is an authoring tool for defining concepts and adaptation rules. This tool is a graphical, Java applet based tool to define concepts and adaptation rules. It uses an (author-defined) template to associate a predefined set of attributes and adaptation rules with each newly created concept. It is a low-level tool in the sense that all adaptation rules between concepts must be defined by the author. Many applications have a number of constructs that appear frequently, e.g., the knowledge propagation from page to section to chapter, or the existence of prerequisite relationships. This leads to a lot of repetitive work for the author. Note that whereas the Graph Author can generate files in the Concept Editor's authoring format it cannot import them. Some user interface differences between the Graph Author and the Concept Editor exist for historical reasons only. Figure 6 shows the Concept Editor with the same tutorial example used earlier.

The concept hierarchy is represented inside the concepts, but the Concept Editor (unfortunately) does not show that hierarchy in its left frame. Also, the Concept Editor is sometimes referred to as Generatelist Editor for historical reasons. The authoring format with concepts and adaptation rules is called the generatelist format. The editor lists all the concepts (of a single application) on the left, and shows details of a selected concept on the right.

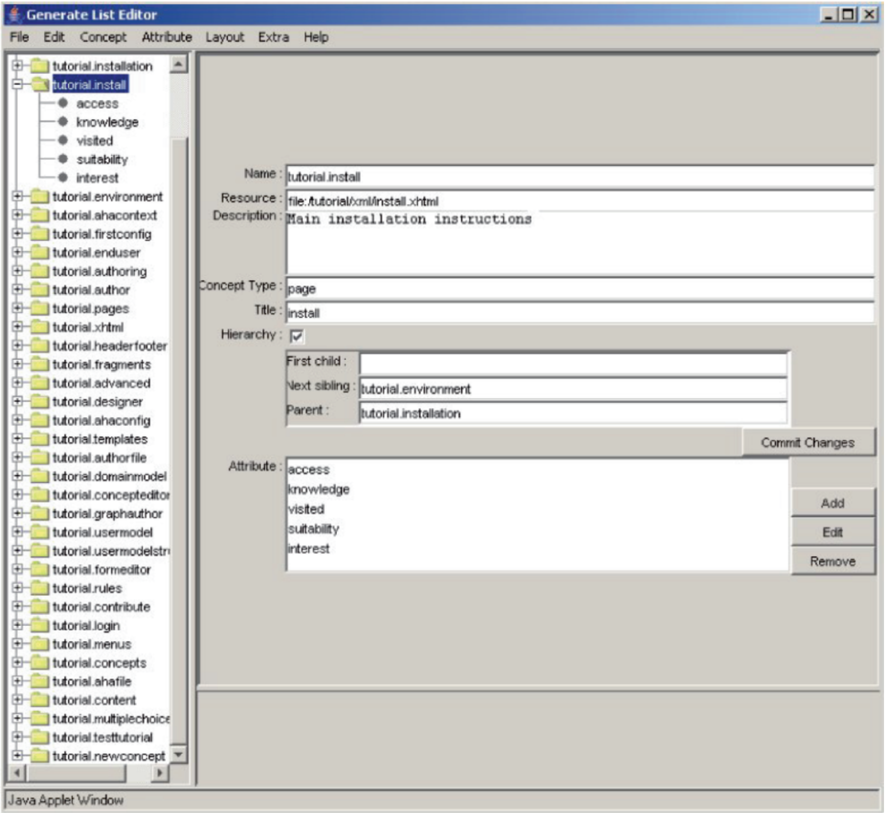

Fig. 6. Concept Editor main window

3.4 Form Editor

The Form Editor [9] enables the creation of custom forms to let end-users change values of attributes of concepts in their user model. Attributes of concepts defined as changeable can be included in a custom-made form. The Form Editor also allows the creation of an (X)HTML form in which elements for the attributes of concepts are inserted automatically, and in which the remainder of the presentation is created by means of plain HTML code. A form is bound to an application, so when creating a new form it is necessary to load the conceptual structure of that application. (File, Load AHA! application). The form editor creates a skeleton representing an empty form. A HTML code can be used for the presentation and access to the buttons Input, Select, Option, and Button to add form elements. A form can be viewed as HTML source and can be previewed. The Form Editor uses a standard Java HTML editor class to do this (see Fig. 7). At the time of writing this tutorial this standard class is not yet fully XHTML compliant, a somewhat simplified HTML is used, which is normally enough for a simple form. Forms created with the Form Editor are saved in the authoring directory. These are copied to whichever location on the server is used to refer to them from within the content pages that have a link to them. (A tool that allows forms to be created inside the application's document tree right away is being developed at present.)

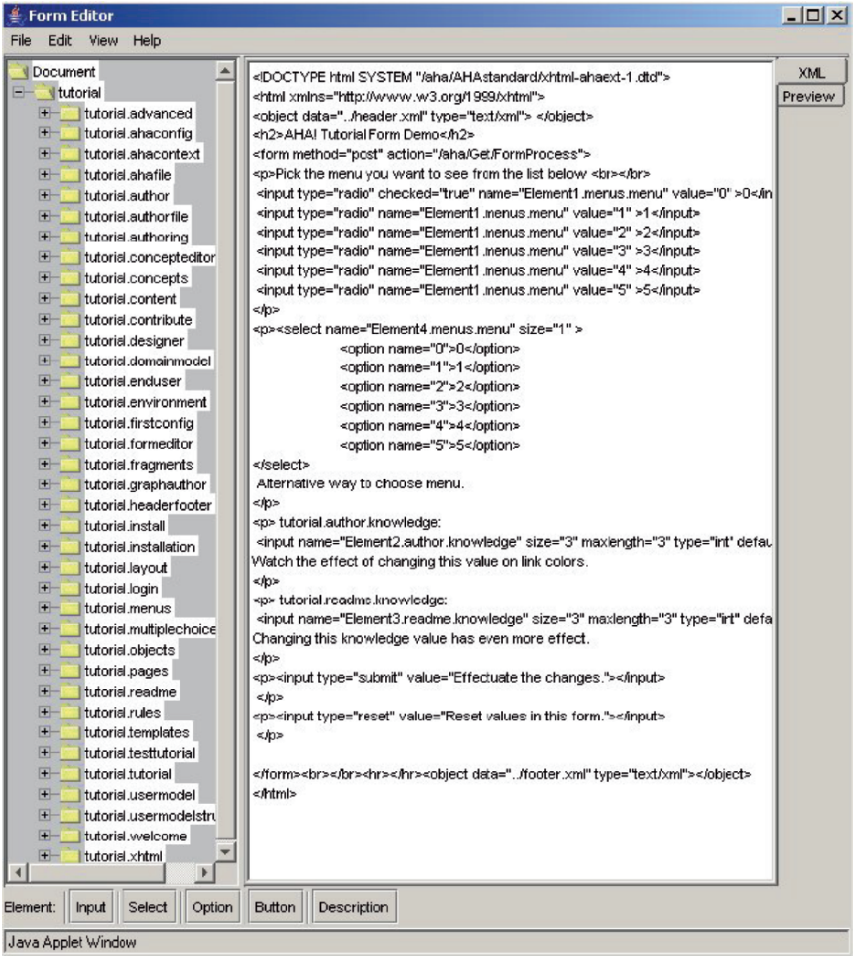

Fig. 7. Form Editor with an example form

3.5 Test Editor

AHA! 3.0 comes with a (new) authoring tool (Test Editor) for developing multiple-choice tests that can be used in web-based systems and wireless devices [14, 17]. Computerized tests or quizzes are among the most widely used and well-developed tools in web-based education [5]. There are different types of computerized tests, depending on the type of items or questions (yes/no questions, multiple-choice/single-answer questions, fill-in questions, etc.) and there are two main types of control algorithms: classic or linear tests and adaptive tests [19]. Test Editor is an authoring tool for building adaptive (and randomized) and classic (nonrandomized) multiple-choice tests. The specific life cycle of tests we have used is:

– As the first step for developing a test with Test Editor, the examiner has to create one or several (XML) *items* files. An *item* consists of a single question about a single concept (from an AHA! application or course), the answers (right or wrong) and explanations for the wrong answers. Several items/questions about the same concept can be grouped together into one items file. Figure 8 shows how to add questions to the items file, one by one. The examiner must also specify some required parameters (the enunciate flag, and for each answer a flag to indicate whether the answer is correct) and can add some optional parameters (an illustrative image, explanations and Item Response Theory (IRT) parameters [19]: item

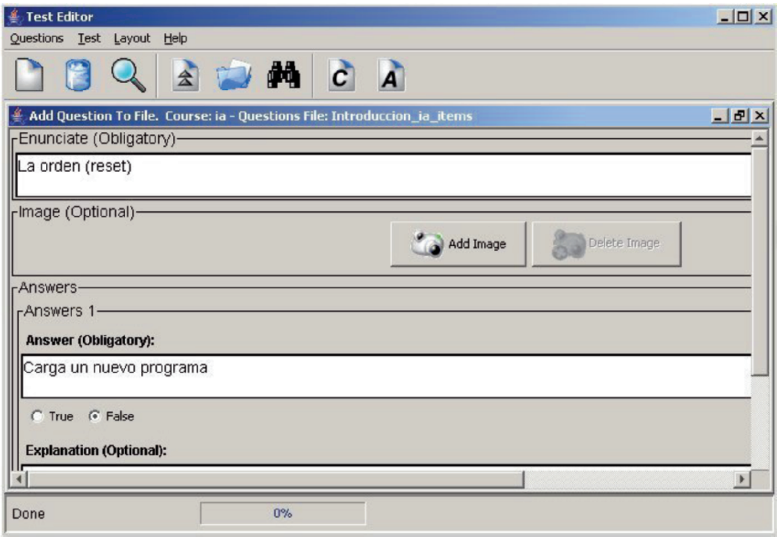

Fig. 8. Test Editor: Windows to introduce the obligatory parameters of an item

difficulty, discrimination, and guessing). Using the Test Editor items can be added, modified, or deleted. They can be imported/exported to/from other tests systems (IMS QTI [3], QuestionMark [13], SIETTE [2], Moodle [11] etc.). Questions can thus be reused from other test environments without needing to enter them again.

– The second step is to build tests out of items. The examiner decides on the test type (classic test or adaptive test) desired and whether to use just one or several items files. If the test evaluates only one concept, it is considered to be an activity. If the test evaluates several concepts, it will be an exam, about a chapter or perhaps a whole course. Next, the examiner can use different methods to select what specific items from these items files will be used in the test (the selection can be done manually, randomly, or randomly with some restrictions). Then presentation parameters (see Fig. 9) about how questions are shown to examinees are set: the order in which questions and answers are shown, whether to show or hide explanations of the answers (through the verbose flag), the maximum time to respond, whether to show the correct answer or just a

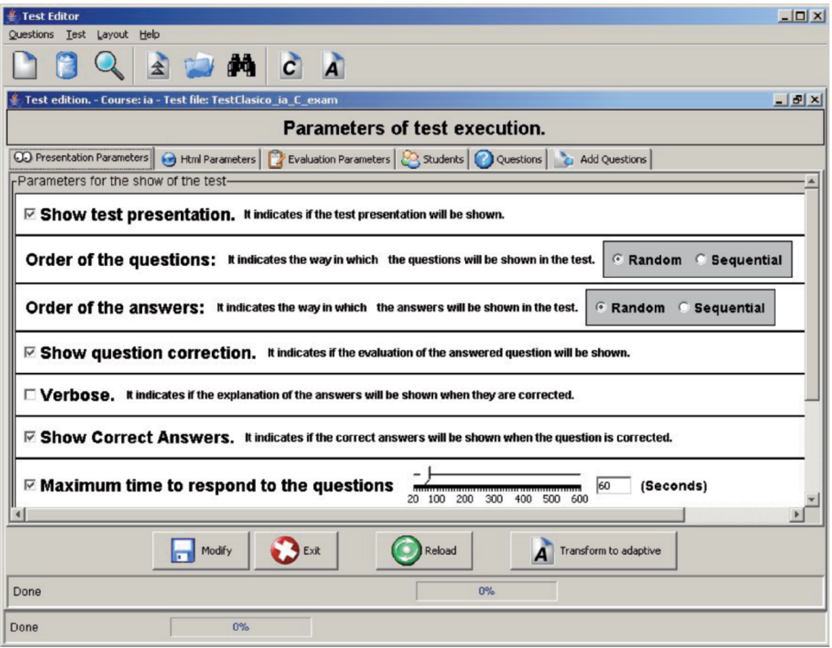

Fig. 9. Test Editor: Windows to select the questions presentation parameters

score, etc. In addition to these there are also parameters about evaluation: to penalize incorrect answers, to penalize unanswered questions and what percentage of knowledge the final score represents in the associated concept/concepts. If the test is adaptive, the examiner also has to set the adaptive algorithm parameters (questions, selection procedure and termination criterion). Each test is stored in an XML file and that is exactly the same for both versions (PC and mobile). But for the mobile devices it also is necessary to create a *.jar* and *.jad* file that includes both the multiple-choice test code (a Java Midlet test engine) as well as the questions and parameters (XML file).

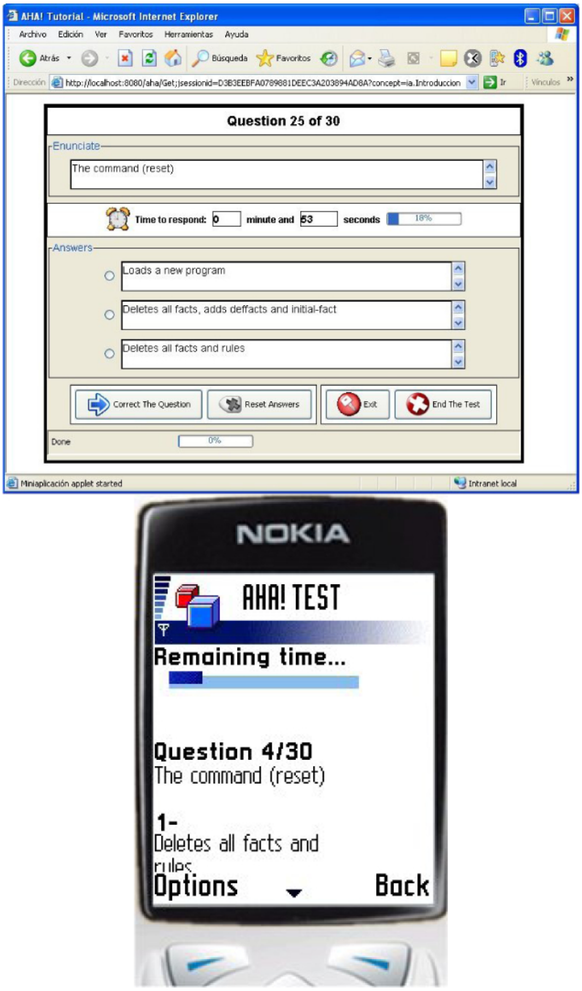

Fig. 10. Interface of a question in an AHA! course and in a mobile phone

– The generated test can be downloaded (the *.jar* file) into a mobile phone and/or can be used directly (through a browser) in an AHA! course. When used with AHA! a test is presented in an Java Applet, with a look and feel that is similar to the Java Midlet version (see Fig. 10). The results of tests are logged on the server. After a large number of examinees have performed some tests, examiners can examine statistical information in the Test Editor (success rate per question, mean times to answer the questions, questions usage percentage, etc.) and use that information for maintenance and improvements of the tests. The examiner may decide to modify or delete bad items, add new items, but can also modify the test configuration. Test Editor can also do items calibration, in order to transform a classic test into an adaptive one, or to optimize the IRT parameter of an adaptive test.

3.6 Mining Tool

Currently, we are developing a new mining tool in order to help authors in discovering interesting information from students' usage information that can be used to improve the courses. Currently, we have developed a "links recommendation" facility based on sequential pattern mining. The recommendation of links (to content pages, activities, etc.) is very important in e-learning systems in order to personalize (or adapt) the learning for each student and to guide them to the best learning path. One way to automate this process is the application of data mining techniques into the students' usage information. In most e-learning systems, all the pages accessed by students are saved in log files (either one log file for each student or just one big log file for everyone) that contain all the information about the interaction of the students with the system. Therefore, after preprocessing this information, it is possible to discover sequential patterns from these log files by using some data mining algorithms. Sequential pattern mining can be defined as the process of discovering all subsequences that appear frequently on a given sequence database and have minimum support threshold. Our objective is to use the discovered sequential patterns to create interesting recommendation links to show to the students while they use the e-learning system. To do that, all the sequential patterns are split in sequences of only two components. These obtained sequences can be considered as a rule with only one antecedent and one consequent, so that the antecedent represents the page in which the recommendation is shown and the consequent is the link recommended to the student.

We have developed a mining tool (see Fig. 11) in order to help the teacher to carry out all this process. This application is a Java Applet, just like other AHA! authoring tools. In order to use it, the author has to first choose the appropriate courses and students. Then, the application creates a file with the preprocessed data in Weka format [20]. Next, the author has to select a data mining algorithm for extracting sequential patterns from the available ones [1]: AprioriAll, GSP, and PrefixSpan. When the algorithm finishes its execution, the discovered sequences are shown and they can be automatically translated into recommendations links to be inserted in the corresponding course web page.

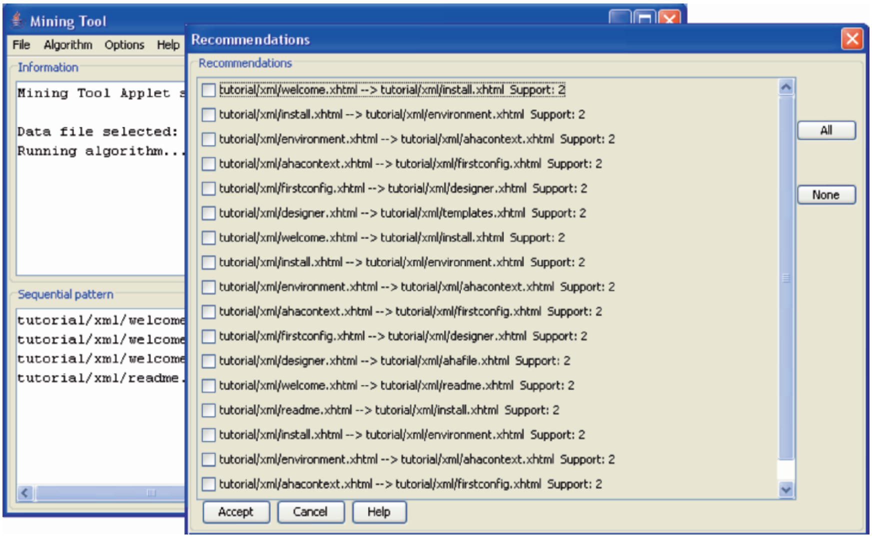

Fig. 11. Recommendation links window and application main window

3.7 Course Editor

At the University of Córdoba we are also working on a new high-level tool, named Course Editor (see Fig. 12). Using this tool, (of which the completion date is currently still undetermined), authors can easily create and maintain AHA! courses. This tool can create a new course or import and export AHA! courses to/from SCORM courses [18], can edit the XHTML course pages, can visually configure the layout of the course, can add collaborative services like a chat, an announcement board, an upload tool, etc. to a course.

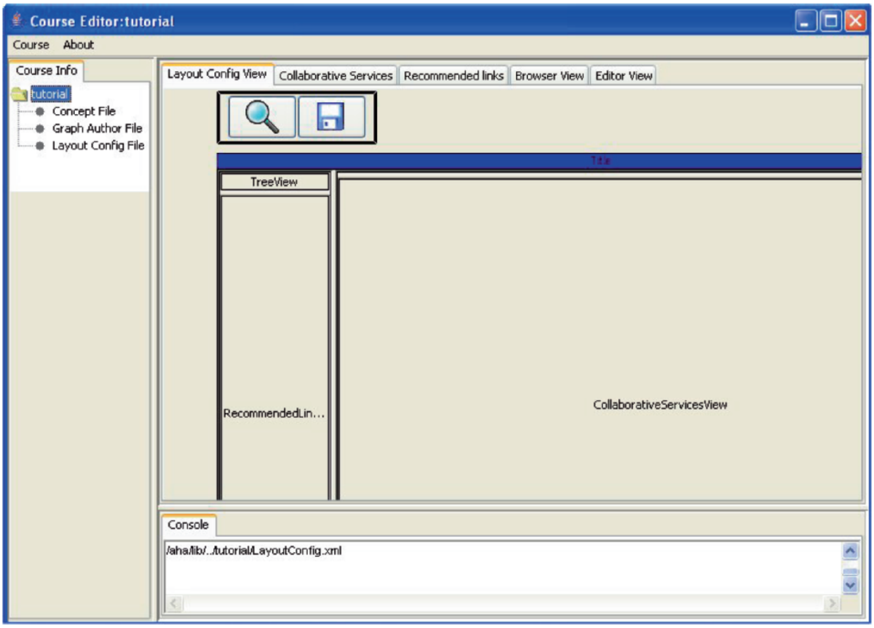

Fig. 12. Course editor main window

The main functions that the Course Editor tool provides to the author are:

– *Creating New Courses*. Course Editor can create a new complete AHA! course. It creates not only the configuration files (.aha and .gaf) but also all the directories and pages (.xml, .html, etc.) with the content of the course. It can also open a previously created AHA! course in order to edit and add new characteristics.
– *SCORM Export and Import*. Course Editor provides a way to create a new AHA! course from a SCORM 2004 package course [18]. So, it's very easy to create a course or a base-plan for a new course. It also provides a way to export AHA! courses to SCORM courses in order to reuse courses previously created in other e-learning environments.
– *Layout View Configuration*. With Course Editor, an author is able to change the layout of the course, change sizes of frames in a WYSIWYG way or add/remove views (corresponding to HTML frames) to the main window.

- *Collaborative Services*. Course Editor allows authors to include a new layout in the main window (or in a secondary one), giving access to collaboration tools. Adding collaborative services such as Chat, Announcement Board, Upload, and Download, enables students to interact with the teacher and with other students using the same platform, or even the same course.
- *Recommended Links*. With these recommended links, authors can include direct links to other pages. These recommendations are a type of relationship between concepts. The teacher can use his personal experience, history of students' results, a data mining study, etc. to establish them. These direct relationships are shown in the student's browser window, as direct links between concepts related to each other, external links or links to a test where AHA! may evaluate the student's progress and understanding of the concept.
- *Navigation Panel*. With this panel, authors are able to see all the pages and concepts that a course has, as well as the relationships between these concepts.
- *Complete XHTML Editor*. Even if authors have no knowledge of XHTML, sometimes it is needed to edit these files, for example, to create or modify a course Web page to include special AHA! tags, for a conditionally included fragment or for AHA!-specific anchors. Editing will be performed by using a WYSIWYG tool, which will include AHA! options as additional option to standard XHTML editing.
- *Browser View*. Course Editor provides a way to view a page of the course as it may appear when students will see it. (We say "may" because the actual presentation depends on the student's user model.) This view will be shown in an embedded browser in the Course Editor, Internet Explorer or whatever browser is the default on the author's machine.

Figure 13 shows the interface of a course edited with Course Editor in which we have added some Collaborative Services and Recommended Links; in this case, the student is recommended to go to the "graph author" concept if he is currently reading the "pages" concept.

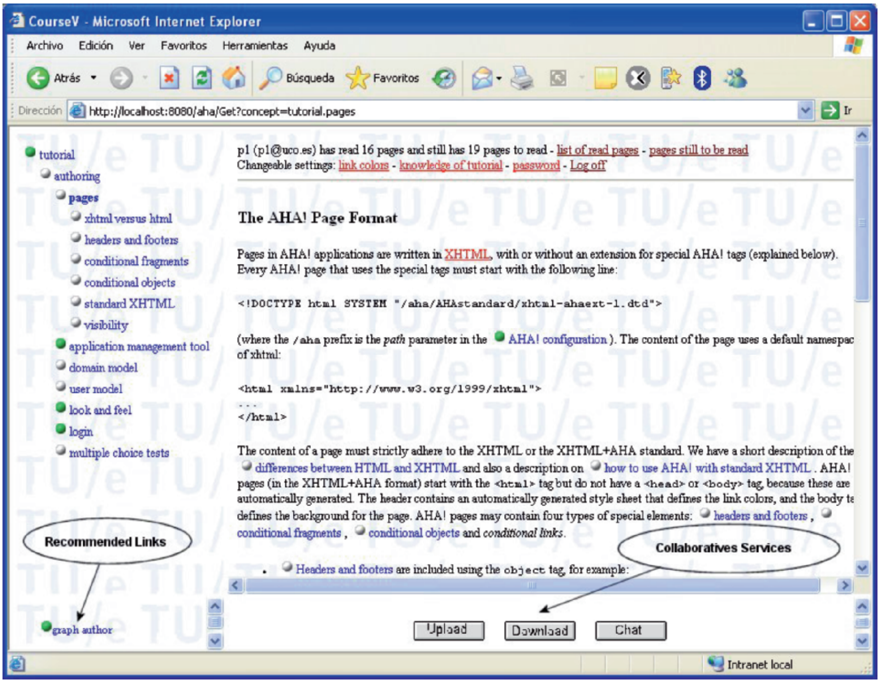

Fig. 13. AHA! Tutorial with Collaborative Services and Recommended Links

4 Conclusion

In this chapter, we have described some authoring and management tools of the AHA! system. AHA! is one of the first and most extended adaptive systems in the world. The AHA! project, which stands for Adaptive Hypermedia for All builds on the Open Source AHA! system (the Adaptive Hypermedia Architecture), being developed by the Eindhoven University of Technology, in the Database and Hypermedia group. We have described the general architecture and the specific functionality of the AHA! system. We have described some of the main tools provided by the currently distributed AHA! version such as: Concept Editor, Graph Author, Application Management, Form Editor, and Test Editor. We described some new tools that we are developing such as: Course Editor and Mining Tools. Using all these tools the development and maintenance of AHA! applications is made easier for nontechnical authors. Some of these tools are oriented to adaptive hypermedia applications in general (Concept

Editor, Graph Editor, Application Management) and others are more oriented to educational applications (Test Editor, Course Editor, Mining Editor).

Currently we are developing the Course Editor and we want to improve the Mining tool in order to add to it more data mining methods as classification, clustering, association, prediction, etc. in order to enable the discovery of much more interesting information to teachers. We are also working on a tool for visualizing the student's usage data. Using this tool the teacher can see graphically all the usage information of a whole class or of specific students (visited pages, access or reading times, obtained scores, etc.).

Finally, AHA! is continuously being further developed and improved. We welcome contributions from other groups and will do our best to include the contributions in future releases.

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