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Web 3.0 – Based personalisation of learning objects in virtual learning environments

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ABSTRACT

The paper aims at research on Web 3.0 – based personalisation of learning objects (LOs) while learning in virtual learning environments. Learning personalisation is analysed in terms of suitability of LOs and VLEs to particular learning styles. The novel sets portrait analysing interconnections between students' learning styles, their preferred learning activities, relevant teaching/learning methods, and LOs types is presented in more detail. The well-known standardised vocabularies of teaching/learning methods and LOs types were used to establish these interconnections. The sets portrait of these interconnections is followed by the appropriate ontology. The ontology is considered as an appropriate tool to create learners' personalised learning environments consisting of LOs, suitable teaching/learning methods and activities according to their preferred learning styles. The ontology should help the learner to find suitable LOs according to preferred learning methods/activities, and vice versa, and thus to personalise learning. The presented Web 3.0 – based approaches are the typical cases of information and communication technologies (ICT's) application for development of human capital.

1. Introduction

Educational institutions should personalise their learning process according to the main characteristics of their students. Learners have different needs and characteristics, i.e. prior knowledge, intellectual level, cognitive traits, and learning styles. In the paper, a special attention is paid to personalisation of learning according to the students' learning styles.

Personalised learning approach promotes a tailored support system, helping learner to learn. Adaptive learning is substantially connected with personalisation, recommendation-based learning, and inquire-based learning. In order to personalise learning, one needs to personalise learning objects (LOs), learning activities, learning methods, virtual learning environments (VLEs), etc.

In the paper, analysis of interconnections between students' learning styles, their preferred learning activities, relevant teaching/learning methods, and LOs types is presented in more detail. The sets portrait of these interconnections is followed by the appropriate ontology. The ontology is referred here as an appropriate tool to create learners' personalised learning environments consisting of LOs and VLEs suitable to their learning styles. Web 3.0 (or Semantic Web) approach is analysed as the suitable one to achieve this goal.

The rest of the paper is organised as follows. The related work analysis on LOs and VLEs personalisation and learning styles is presented in Section 2, (i) interconnection between learning styles, learning activities, teaching/learning methods, and LOs types, (ii) problem solving activity example to illustrate the model, and (iii) domain ontology are presented in Section 3, and conclusions are provided in Section 4.

2. Review of related work

Two research questions were established for the presented study: (1) personalisation of LOs and VLEs according to students' learning styles, and (2) Web 3.0 (or Semantic Web), since Web 3.0 is referred as suitable approach to personalise LOs and VLEs.

LO is referred here as "any digital resource that can be reused to support learning" (Wiley, 2000). The fundamental idea behind LOs is that instructional designers can build small (relative to the size of an entire course) instructional components that can be reused a number of times in different learning contexts. In addition, LOs are generally understood to be digital entities deliverable over the Internet and any number of people can access and use them simultaneously. Moreover, those who incorporate LOs can collaborate on and benefit immediately from the new versions.

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According to Kurilovas and Dagiene (2010), the concept of LOs has gained wide spread acceptance in the world of e-learning. The main purpose of LOs is to provide a modularised model, based on the standards that enhance flexibility, platform independence, and reuse of the learning content, as well as providing a higher degree of control for teachers and learners. The definition and meaning of the term ‘‘learning object’’ varies considerably between different actors and communities as well as over time. The idea of LOs is to organise the digital learning content into small, fairly context-independent chunks that can be assembled, disassembled and combined in different ways and in different learning contexts. LOs from different vendors can be combined with one another to form modules that can be used in a specific learning context. In engineering terms, the learning process can be considered as a life cycle of creation and existence of knowledge.

VLE is referred here as a single piece of software, accessed via standard Web browser, which provides an integrated online learning environment (Kurilovas & Dagiene, 2010). The main parts of each VLE are learning content (i.e. LOs) and tools. Therefore, in order to improve the (adaptation) quality of VLEs it is very important to improve semantic search for both LOs and learning tools in VLEs.

In the paper, adaptive learning is considered as recommendations of choosing and combining LOs in VLEs according to learners' preferences. Learners' preferences are referred here mainly as their learning styles that would help to choose suitable LOs. Other learner characteristics such as their intellectual level, cognitive traits, and prior knowledge, are out of the scope of the paper.

In the paper, we'll concentrate on learning personalisation in terms of semantic search of LOs while semantic search of VLE learning tools is out of scope of the paper.

2.1. Personalisation and learning styles

Learning personalisation and related issues were very popular in scientific literature in recent years (e.g., Beres, Maguar, and Turcsanyj-Szabo (2012), Dorca, Lima, Fernandes, and Lopes (2012), Lubchak, Kupenko, and Kuzikov (2012), Bodea, Dascalu, and Lytras (2012), Zhang, Ordóñez de Pablos, and Zhang (2012), Bennane (2013), Kim and Lee (2013)).

The overview of literature shows that there has not been a concrete definition of personalisation so far. The main idea is to reach an abstract common goal: to provide users with what they want or need without expecting them to ask for it explicitly (Mulvenna, Anand, & Buchner, 2000). From the educational point of view, personalisation attempts to provide for an individual tailored products, services, information, etc. A more technical standpoint to personalisation is linked with the modelling of Web objects (products and pages) and subjects (users), their categorisation, organising them to achieve the desired personalisation. According to Sampson (2002), personalisation provides training programmes that are customised to individual learners, based on an analysis of the learners' objectives, current status of skills/knowledge, learning style preferences, as well as constant monitoring of progress. Online learning material can be, then, compiled to meet personal needs, capitalising on reusable LOs. User-centric environments are learning environments where the learner takes responsibility for his/her own learning, and the instructor acts as the ‘‘guide on the side’’, rather than a ‘‘sage on the stage’’.

The concept of personalised learning becomes increasingly popular. It advocates that instruction should not be restricted by time, place or any other barriers, and should be tailored to the continuously modified individual learner's requirements, abilities, preferences, background knowledge, interests, skills, etc. The personalised learning concept signifies a radical departure in educational theory and technology, from ‘‘traditional’’ interactive learning environments to personalised learning environments. According to Sampson, Karagiannidis, and Kinshuk (2002), some of the most prominent characteristics of this shift can be summarised as follows: (i) while ‘‘traditional’’ learning environments adopt the one-to-many learning mode, personalised learning environments are based on the one-to-one or many-to-one learning concept (i.e. one, or many tutors for one learner); (ii) traditional learning environments usually pose a number of constraints in relation to the learning setting; personalised learning environments, on the other hand, facilitate learning independent of time, location, etc.; (iii) traditional learning environments are usually being designed for the ‘‘average learner’’; while, in personalised learning environments, the learning material and sequencing, learning style, learning media, etc., depend on the individual learner's characteristics, i.e. background, interests, skills, preferences, etc.; (iv) in traditional learning environments, the curriculum, learning units, etc., are determined by the tutor, while in personalised learning settings, they are based on the learner's requirements (self-directed learning).

2.1.1. The educational perspective

According to Schunk (1996), the concept of personalised learning builds mainly on the cognitive and constructivist theories of learning. Instructional principles of cognitive theories argue for active involvement by learners, emphasis on the structure and organisation of knowledge, and linking new knowledge to learner's prior cognitive structures. Constructivist instructional theory, on the other hand, implies that instructional designers determine which instructional methods and strategies will help learners to actively explore topics and advance their thinking. Learners are encouraged to develop their own understanding of knowledge.

Several research efforts have been devoted in the identification of the dimensions of individual differences. One of the most prominent research areas in this context concerns the learning styles and learning differences theory, which implies that how much individuals learn has more to do with whether the educational experience is geared towards their particular style of learning. Learning styles are strategies, or regular mental behaviours, habitually applied by an individual to learning, particularly deliberate educational learning, and built on her/his underlying potentials. Learners are different from each other, and teaching should respond by creating different instruction for different kinds of learning. Learners also differ from each other in more subject-specific aptitudes of learning, e.g. some being better at verbal than numerical things, others vice versa. Learning styles have been at the centre of controversy for several decades now, and there is still little agreement about what learning styles really are. There are numerous methodologies and tools that attempt to categorise people according to differences in learning and cognitive styles. The most well-known of these efforts include the Myers-Briggs Type Indicator (Keirsey, 1998); Multiple Intelligences (Gardner, 1999); Auditory, Visual, Tactile/Kinaesthetic Learning Styles (Sarasin, 1998); Grasha-Riechmann student Learning Style Scales – GRLSS (Grasha, 1996); Kolb Learning Styles Theory (Kolb, 1985); Felder and Silberman Index of Learning Styles (Felder, 1996); and Honey and Mumford Learning Styles (Honey & Mumford, 1992).

In the paper, we'll analyse the last one because of its popularity in scientific community. Honey and Mumford (1992) identified four distinct learning styles or preferences: Activist, Theorist; Pragmatist and Reflector.

According to Sampson et al. (2002), in order for these methodologies and tools to be effectively applied, we need to be able to (i) accurately classify each learner according to a selected taxonomy of individual differences, and (ii) determine which are the characteristics of the learning environment that are appropriate for this category of learners.

2.1.2. The technological perspective

Several notions are used to define personalised VLE. They are as follows:

According to Sampson et al. (2002), intelligent learning environments (ILEs) are capable of automatically adapting to the individual learner, and therefore constitute the most promising technological approach towards the realisation of the personalised learning concept. An ILE is capable of automatically, dynamically, and continuously adapting to the learning context, which is defined by the learner characteristics, the type of educational material being exchanged, etc.

According to Brusilovsky, Eklund, and Schwarz (1998), Adaptive Educational Hypermedia (AEH) is a relatively new direction of research within the area of adaptive and user model-based educational applications AEH systems build a model of the individual user/learner, and apply it for adaptation to that user. AEH can be categorised with respect to several dimensions.

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

Another important question concerning AEH systems is: what can be adapted by the system? Which features of the system can differ for different students? What is the space of possible adaptations? The adaptations in AEH systems may include the content of the hypermedia pages (adaptive presentation), as well as the links included in each page (adaptive navigation support). The former case can be further decomposed into adaptive multimedia presentation, and adaptive text presentation, which is most commonly used. The latter case includes direct guidance (providing the "next" node to follow), adaptive sorting of links, adaptive hiding of links, adaptive annotation of links, and/or map adaptation. The last broad categorisation of AEH systems concerns how adaptation can help, i.e. the methods and techniques of adaptation, for content adaptation and adaptive navigation support. Concerning the methods for content adaptation, the most popular one is to hide from the student some parts of the information about a particular subject which are not relevant to the student's level of knowledge about this concept. Following another approach, which has been termed prerequisite explanation, before presenting an explanation of a concept, the system may insert explanations of all its prerequisite concepts which are not sufficiently known to the student. Alternatively, following the explanation variants method, the system may store several variants for some part of the page content, and the student gets the variant that corresponds to his/her student model; or the system may sort the fragments of information about a concept, and present the information that is most relevant to the student's knowledge.

Concerning the techniques for content adaptation, one can distinguish between the conditional text technique, where all possible information about a particular concept is divided into several chunks of text, each one associated with a condition concerning the student's knowledge of the domain, and only the chunks for which the condition is true are presented to the student; or the stretch-text technique, where particular "hot-words" are associated with some text, which is "collapsed", or "un-collapsed" according to the student's knowledge. The most powerful adaptation technique for content adaptation is frame-based adaptation, where all the information about a particular concept is represented in form of a frame, and special presentation rules are used to select which information within a frame will be presented, according to the student's knowledge. Finally, concerning the methods for adaptive navigation support, we can distinguish between global guidance, local guidance, local orientation support, global orientation support and management of personalised views.

According to Becta (2007), there are four key areas of learning platforms (i.e., VLEs) functionality, all of which will contribute to a personalised learning experience:

- Communication tools: email, messaging or discussion boards, to enable dialogue between peers and mentors.
- Individual working space, to enable the creation and sharing of learning resources which can be accessed online, outside lesson time and from any location.
- Management tools so teachers can manage e-learning resources and assess, monitor and track individual and group progress.
- Access that is safe and secure, at any time and from any internet-enabled device.

Learning platforms will bring about a wide range of benefits, and will:

- help meet individual learning needs and encourage collaboration,
- provide all learners and teachers with access to rich, subject-related, interactive content, appropriate to their needs,
- enable more engaging models of learning for disaffected learners, and alternative models for those not in school,
- create an open and accessible system available to learners and families beyond school and out of normal school hours,
- enable assessment for learning,
- promote communication and collaboration within and beyond the institution,
- enable schools to gain best value, with a reduced technical burden.

The main future research trends should involve improvement of both personalisation aspects and automatic adaptivity features of VLEs matching particular learners' styles.

Several works in the area are already performed in Europe, e.g. research on Intelligent Adaptive Learning Environment presented in Pedrazzoli and Dall'Acqua (2009), Adaptive Learning Environments (ALE) presented in Oneto, Abel, Herder, and Smits (2009), research on adaptivity features to a regular LMS to support creation of advanced eLessons presented in Komlenov, Budimac, and Ivanovic (2010), and research on diagnosing students' learning style in an educational hypermedia system presented in Popescu (2009).

2.1.3. Intelligent pedagogical agents

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

Because pedagogical agents are autonomous agents, they inherit many of the same concerns that autonomous agents in general must address. It has been argued that practical autonomous agents must in general manage complexity. According to Sampson et al. (2002), they must exhibit robust behaviour in rich, unpredictable environments; they must co-ordinate their behaviour with that of other agents, and must manage their own behaviour in a coherent fashion, arbitrating between alternative actions and responding to a multitude of environmental stimuli. In the case of pedagogical agents, their environment includes both the students and the learning context in which the agents are situated. Student behaviour is by nature unpredictable, since students may exhibit a variety of aptitudes, levels of proficiency, and learning styles.

2.2. Learning objects

2.2.1. The ecological approach

The ecological approach was first proposed by McCalla (2004) in the context of providing a more flexible and powerful way to mark up and use LOs to achieve various pedagogical goals. In the ecological approach the e-learning system keeps a learner model for each learner, tracking characteristics of the learner and information about the learner's interactions with the LOs they encounter. After a learner has finished with a LO, the LO is associated with an instance of the learner model that records the learner's state(s) and activities while interacting with the LO. According to Brooks and McCalla (2006), the information in such a learner model instance can include:

- information about the learner, including cognitive, affective and social characteristics and the learner's goal(s) in accessing the LO,
- information about the learner's perspectives on the LO itself, including the learner's feedback on the content, or the learner's knowledge of the content (as determined, for example, by a test administered during the learner's interactions with the LO),
- information about how the learner interacted with the LO, including observed metrics such as dwell time, the number of learner keystrokes, and patterns of access,
- information about the technical context of use, including characteristics of the learner's software and hardware environment,
- information about the social context of use, including links to the learner model instances attached to LOs previously encountered by the learner.

2.2.2. The standardisation perspective

During the past few years, a number of international efforts have been initiated for defining specifications and standards which can facilitate reusability in learning technologies. The main initiatives in the area are the IEEE LTSC (Learning Technologies Standards Committee, http://ltsc.ieee.org), the IMS (Instructional Management Systems) Global Learning Consortium Inc (http://www.imsproject.org), the European CEN/ISSS Learning Technologies Workshop (http://www.cenorm.be/isss/Workshop/lt), and the US ADLnet (Advanced Distributed Learning Network, http://www.adlnet.org). These efforts have already resulted in a number of specifications for e-Learning applications and services. However, the current versions of these specifications do not support personalised learning.

In particular, today we can describe in a common way LOs, e.g. through the IEEE Learning Objects Metadata (LOM) specification. Further in the paper, we'll refer to the popular European application profile of LOM, i.e. LRE APv4.7 (2011). We can also describe learner characteristics in a common format, e.g. through the IMS Learner Information Profile (LIP) specification. Moreover, we can describe learning packages (i.e. collections of LOs) in a common format, though the IMS Content Packaging (CP) specification. However, the current version of this specification facilitates only the definition of simple, table of contents-like structures. As a result, an e-learning system importing a content package can only present the same information to all learners, thus personalised, on-demand learning cannot be supported.

In this context, a number of international efforts have been initiated for the extension of the current versions of these specifications, to allow the definition of rules which determine which (different) parts of learning packages should be selected for different learner categories. One such approach is carried out in the context of the European KOD "Knowledge on Demand" project (http://kod.iti.gr/). The KOD project works on an extension of the CP specification (the knowledge packaging format), so that it can enable the definition of adaptation rules, which specify which parts a learning package should be selected for different learner categories. As a result, the KOD e-learning system (or any e-learning system which is compliant with the KOD knowledge packaging format) can import knowledge packages, disaggregate them, interpret the rules included in them, and present different "knowledge routes" to different learners, according to their individual profiles. Moreover, since the "adaptation logic" (adaptation rules) behind adaptive educational content are represented in a common format, adaptive educational content can be easily interchanged and reused, thus reusability for personalised, on-demand access can be supported.

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

Further in the paper, another approach to personalise learning is presented. It is based on semantic search of LOs according to students' learning styles, preferred learning activities, and teaching/learning methods.

2.3. Web 3.0

There is a lack of the research on using so-called Semantic Web (or Web 3.0) for intelligent semantic search of the LOs suitable for the particular learning styles. If there should exist the qualitative technologies for semantic intelligent search of the relevant learning content on the Web, the learners should get the additional possibility to use this suitable content in their VLEs.

According to Berners-Lee, Hendler, and Lassila (2001), the Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation.

Two important technologies for developing the Semantic Web are XML and RDF. XML allows users to add arbitrary structure to documents without saying what these structures mean. RDF allows meaning to be specified between objects on the Web and was intentionally designed as a metadata modelling language.

A third important aspect of the Semantic Web is a set of ontologies. According to Gruber (1993), an ontology is a specification of a conceptualisation. It describes the concepts and relationships of some phenomenon in the world. According to Mohan and Brooks (2003), by using well-defined ontologies on the Web, it is possible for computers to meaningfully process data since there is a common understanding of terms used and the relationships between these terms.

The Semantic Web is concerned about the meaning of all kinds of information (such as LOs) on the Web.

3. Interconnection and ontologies

Literature review has shown that from standardisation perspective the current versions of LOs specifications do not support personalised learning. On the other hand, Web 3.0 approach based on RDF, XML and ontologies is suitable to personalise LOs. Therefore, further on we'll concentrate on creating the ontologies to semantic search of LOs suitable to particular learners.

3.1. Interconnections between learning styles, learning activities, teaching methods, and LOs types

Let us analyse personalisation of LOs in terms of providing the learners of particular learning style with LOs suitable for teaching/learning methods that could be part of their preferred learning activities. To achieve this goal, one should interconnect learning styles, learning activities, teaching/learning methods, and LOs types (see Table 1).

As it was mentioned before, we'll use Honey and Mumford (1992) research on learning styles and preferred learning activities.

From standardisations perspective, one of the last and very popular initiatives in the area are standardisation of LOs types according to European LRE APv4.7 (2011) (i.e., a popular European LOM standard application profile), and vocabulary of teaching/learning methods suggested by iCOPER D3.1 (2009).

We'll explain some of these interconnections further on using the example of problem solving activity.

3.2. Example of problem solving learning activity

Let us analyse the case study of "Problem Solving" activity (A1) on how to create an online course (i.e., sequence of works/methods) broadly used by the lead author in E-Learning Systems course in Vilnius Gediminas Technical University (Lithuania).

First of all, we should interconnect A1 with suitable iCOPER teaching/learning methods and LRE AP LO types.

According to iCOPER D3.1 (2009) teaching/learning methods vocabulary, A1 suitable methods are as follows:

M2: Active Learning: Learners propose, plan, execute, and evaluate a project that requires the application of knowledge from educational science. The setting of the project is the learners' actual work environment. Guidance is provided both at the working place and at the distance university;

M3: Blogging: Students download and set-up a Wordpress blog. They create custom categories, change themes, and install plug-ins. Practical work with the blog is to identify, describe and reflect upon how blogs can be used in educational contexts. Students use the blog to document the personal learning experience while working with the assignment;

M4: Brainstorming and Reflection: Brainstorming and Reflection is used to introduce new concepts and definitions that "seem familiar" to students but are not (yet) exactly and accurately defined, by brainstorming, raising ideas by shouting, and discussing the issues in the whole group;

M14: Presenting Homework: For each lesson a student prepares the homework for presentation in front of the class (e.g. via Power point and beamer, overhead transparency, etc.). The presentation should include both the description of the process and the final product of the homework. During the presentation students and teacher can ask questions and discuss or contribute alternative solutions and strategies;

M17: In-class Online Discussion: A synchronous online discussion to be held in regular workshops to discuss a predetermined question reflecting the course readings and lectures;

M21: Modelling: The main goal of the modelling teaching method is to train learners to solve problems autonomously;

M22: Online Reaction Sheets: Reaction sheets are used to collect students' feedback and to share it between all participants. The reaction sheets are likely to have an influence on the follow-up units;

M25: Peer Assessment: Peer assessment is based on the idea that students assess their peers' work in order to enhance students' interpretation and reflection;

M29: Resource-based Analysis: Divided in groups, students work and compete to analyse a design problem, managing their available resources;

M31: Student Wiki Collaboration: Students work in small groups on a particular problem. All details of the work and the procedure are organised by themselves. Their results shall be published in a Wiki. Finally, short presentations face-to-face are given. Participation is voluntary.

According to LRE APv4.7 (2011) learning object types vocabulary, A1 suitable LOs types are as follows:

T1. Application – computer software designed to enable end users to perform a specific task or group of tasks;

T12. Glossary – a resource that is a collection of specialised terms and their meanings usually arranged in a specified order;

T16. Presentation – information organised and delivered (often by using specific presentation software) by an instructor in order to inform a group about a topic;

T18. Reference – a resource such as a database, dictionary, encyclopedia, and glossary. That is a general source of information or which provides specific information on a topic or activity;

T21. Textbook – resource providing comprehensive materials for specific topics (use for: chapters or other typical book components);

T22. Tool – editors and other kinds of programs for producing something. Editors can process e.g. text or pictures and they can be used for creating and editing other LOs. Tools can also perform calculations or conversions;

Table 1
Interconnection between learning styles, learning activities, teaching methods, and LO types.

Learning styles (Honey & Mumford, 1992)	Preferred learning activities (Honey & Mumford, 1992)	Suitable teaching/learning methods (iCOPER D3.1 (2009))	Suitable learning object types (LRE APv4.7 (20,011))
Activists are those people who learn by doing. Have an open-minded approach to learning, involving themselves fully and without bias in new experiences	Brainstorming, problem solving, group discussion, puzzles, competitions, and role-play	3 Times 3 things learnt, active learning, blogging, brainstorming and reflection, competitive simulation, constellation, creative workshops, creation of personalised learning environments, cultura, cultural awareness, E-portfolio, exercise unit, games genre, presenting homework, image sharing, in-class online discussion, mini conference, modeling, online reaction sheets, online training, peer assessment, process-based assessment, process documentation, project-based learning, resource-based analysis, role play, student wiki collaboration, world café, webquest	Application, assessment, broadcast, case study, drill and practice, educational game, enquiry-oriented activity, experiment, exploration, glossary, open activity, presentation, project, reference, role play, simulation, tool, website
Reflectors learn by observing and thinking about what happened. They prefer to stand back and view experiences from a number of different perspectives, collecting data and taking the time to work towards an appropriate conclusion	Paired discussions, self-analysis questionnaires, personality questionnaires, time out, observing activities, feedback from others, coaching, and interviews	3 Times 3 things learnt, blogging, brainstorming and reflection, constellation, creative workshops, creation of personalised learning environments, cultura, cultural awareness, E-portfolio, exercise unit, presenting homework, image sharing, in-class online discussion, listen–do–reflect, ten-plus-two variation, mini conference, modeling, online reaction sheets, online training, peer-to-peer teaching, peer assessment, process-based assessment, process documentation, resource-based analysis, student wiki collaboration, world café, webquest	Application, assessment, broadcast, case study, demonstration, glossary, guide, presentation, reference, textbook, website
Pragmatists need to be able to see how to put the learning into practice in the real world. Abstract concepts and games are of limited use unless they can see a way to put the ideas into action in their lives. They are experimenters, trying out new ideas, theories and techniques to see if they work	Time to think about how to apply learning in reality, case studies, problem solving, and discussion	3 Times 3 things learnt, active learning, blogging, brainstorming and reflection, competitive simulation, constellation, creative workshops, creation of personalised learning environments, creation of personalised learning environments, cultura, cultural awareness, E-portfolio, exercise unit, games genre, presenting homework, image sharing, in-class online discussion, listen–do–reflect, ten-plus-two variation, mini conference, modeling, online reaction sheets, online training, peer-to-peer teaching, peer assessment, process-based assessment, process documentation, project-based learning, resource-based analysis, role play, student wiki collaboration, world café, webquest	Application, assessment, broadcast, case study, course, drill and practice, educational game, enquiry-oriented activity, experiment, exploration, glossary, guide, open activity, presentation, project, reference, role play, simulation, tool, website
Theorist learners like to understand the theory behind the actions. They need models, concepts and facts in order to engage in the learning process. Prefer to analyse and synthesise, drawing new information into a systematic and logical 'theory'	Models, statistics, stories, quotes, background information, and applying theories	3 Times 3 things learnt, blogging, constellation, creative workshops, creation of personalised learning environments, cultura, cultural awareness, e-portfolio, exercise unit, presenting homework, image sharing, in-class online discussion, listen–do–reflect, ten-plus-two variation, mini conference, modeling, online reaction sheets, online training, peer-to-peer teaching, peer assessment, process-based assessment, process documentation, resource-based analysis, student wiki collaboration, world café, webquest	Application, assessment, broadcast, course, demonstration, glossary, guide, presentation, reference, textbook, website

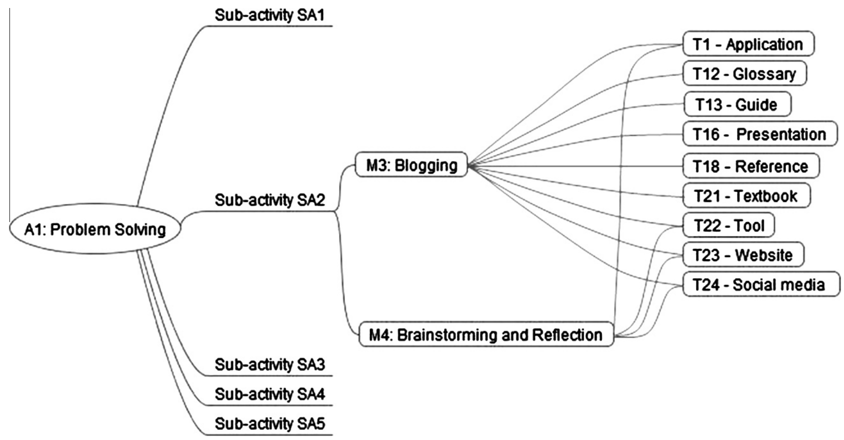

Fig. 1. Interconnection between teaching/learning methods (M) and LOs types (T) for SA2 sub-activity.

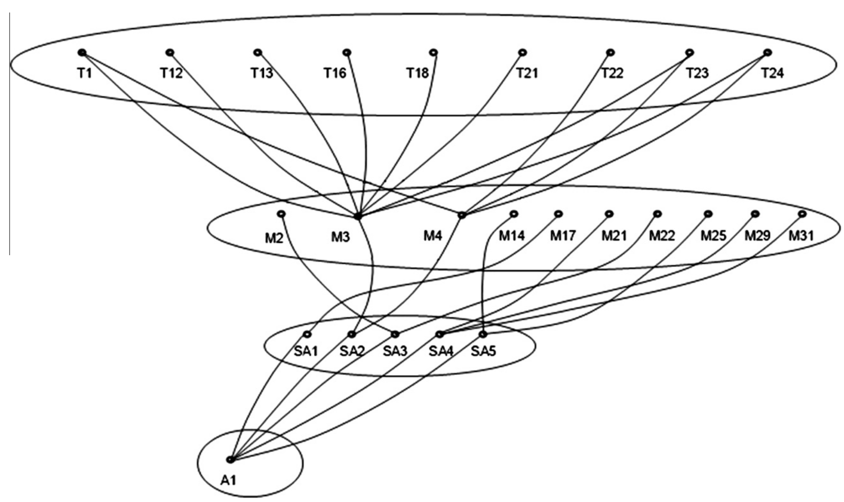

Fig. 2. Sets portrait between the sets of learning methods (M) and LOs types (T) for Problem Solving activity A1.

T23. Website – a collection of web pages (containing a collection of hyperlinked documents and files) typically identified by a common IP address on the World Wide Web on the Internet;
T24. Social media.

There are several sub-activities used in the problem solving activity A1. They are:

- SA1: Discuss the problem-scenario in the group, which promotes communication skills and cooperative learning;
- SA2: Brainstorm ideas to cross the learning boundaries, which promotes creative learning, and knowledge integration;

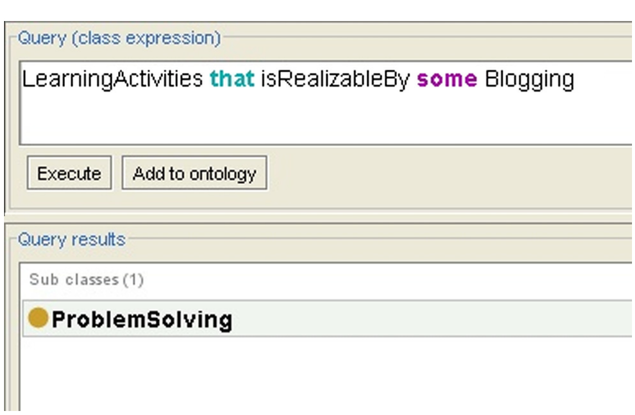

Fig. 3. Ontology example 1: Query for finding suitable learning activities by methods.

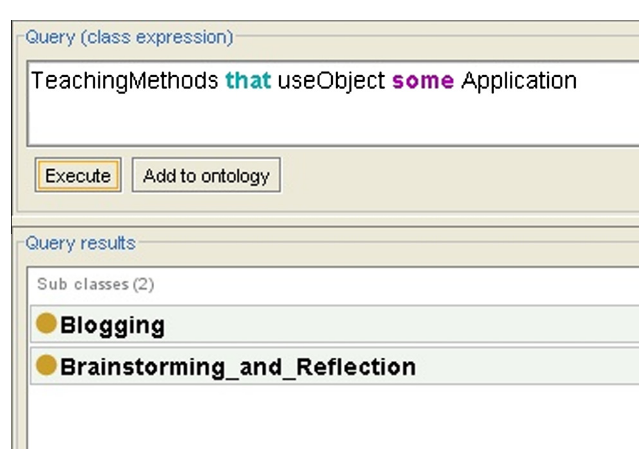

Fig. 4. Ontology example 2: Query for finding suitable teaching/learning methods by LOs types.

- SA3: Identify the learning issues for research, which promotes active learning and critical thinking;
- SA4: Research to construct the action plans, which promote new knowledge development;
- SA5: Report the research findings to the group, which promotes peer-to-peer learning complete the final products: such as, project, research report or presentation, which promotes independent study and self-directed working skills in the teamwork.

Interconnections between these sub-activities (SA) and teaching/learning methods (M) are as follows:

- SA1 <=> M17;
- SA2 <=> M3 and M4;
- SA3 <=> M2 and M22;
- SA4 <=> M21, M29 and M31, and
- SA5 <=> M14 and M25.

Fig. 1 shows interconnection between teaching/learning methods (M) and LOs types (T) for the case of Problem Solving activity's A1 sub-activity SA2:

Indeed, sub-activity A2 "Brainstorm ideas to cross the learning boundaries, which promotes creative learning, and knowledge integration" can be realised by M3 "Blogging" and M4 "Brainstorming and Reflection" teaching/learning methods, while the other iCOPER methods are not directly applicable to implement A2. In its turn, suitable LOs to implement the M3 "Blogging" method are T1 "Application", T12 "Glossary", T13 "Guide", T16 "Presentation", T18 "Reference", T21 "Textbook", T22 "Tool", T23 "Website", and T24 "Social media". In its turn, M4 "Brainstorming and Reflection" method could be implemented using different means to enhance brainstorming of ideas and its further reflection are applications (T1), tools (T21), websites (T23), and social media (T24).

Fig. 2 presents sets portrait between the sets of (1) learning activities, i.e. Problem Solving (A1), (2) sub-activities SA1...SA5, (3) teaching–learning methods M2...M31, and (4) suitable LO types T1...T24.

3.3. Ontologies

The sets portrait of the presented interconnections should be followed by the appropriate ontology. The ontology is the main tool to create learners' personalised learning environments consisting of LOs, suitable teaching/learning methods, and activities according to their preferred learning styles. The ontology should help the learner to find suitable LOs according to preferred learning methods/activities, and vice versa, and thus to personalise learning.

The sets portraits between the sets of learning activities (A), learning methods (M), and LOs types (T) presented in Table 1 and Figs. 1 and 2 are suitable to apply in the ontologies and, accordingly, in creating search engines to find LOs suitable to particular learners (i.e. learning styles) by implementing semantic search using presented activities/sub-activities and methods, and vice versa.

Let us provide some examples to illustrate this.

Ontology example 1: Query for finding suitable learning activities (i.e. "Problem Solving" activity could be found using "Blogging" teaching/learning method) (see Fig. 3).

Ontology example 2: Query for finding suitable teaching/learning methods (i.e. "Blogging" and "Brainstorming and Reflection" teaching/learning methods could be found using suitable Application LO type) (see Fig. 4).

4. Conclusion

Literature review has shown that from standardisation perspective the current versions of LOs specifications do not support personalised learning, and Web 3.0 approach based on RDF, XML and ontologies is suitable to personalise LOs.

In the paper, learning personalisation is analysed in terms of suitability of LOs, teaching/learning methods, and learning activities to particular learning styles.

The novel sets portrait analysing the interconnections between students' learning styles, their preferred learning activities, relevant teaching/learning methods, and LOs types is presented in the paper. The well-known European standardised vocabularies of teaching/learning methods and LOs types were used to establish these interconnections. Problem solving activity example is provided to illustrate the model. The sets portrait of these interconnections is followed by the appropriate ontology to create learners' personalised learning environments consisting of LOs, suitable teaching/learning methods and activities according to their preferred learning styles. The ontology presented should help the learners to find suitable LOs according to their preferred learning methods/activities, and vice versa, and thus to personalise learning.

Further research should include the evidence how to implement and evaluate the proposed model, show how the personalisation is really applied in this context of study, and how the ontology should be integrated in the learning management system. The proposed ontology based approach should be validated, and further research should provide the results achieved during the validation phase.

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