Towards a Hybrid World

The Fuzzy Quality of Collaboration/Interaction (FuzzyQoC/I) Hybrid Model in the Semantic Web 3.0

Sofia B. Dias[1], Sofia J. Hadjileontiadou[2], José A. Diniz[1] and Leontios J. Hadjileontiaids[3]

[1]*Faculdade de Motricidade Humana, Universidade de Lisboa, 1499-002 Cruz Quebrada, Lisbon, Portugal*

[2]*Hellenic Open University, Praxitelous 23, GR-10562, Athens, Greece*

[2]*Department of Electrical and Computer Engineering, Aristotle University of Thessaloniki GR-54124 Thessaloniki, Greece*

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Abstract: As a decision support tool, a hybrid modelling can offer the ability to better understand the dynamics of a particular ecosystem. This paper proposes a hybrid approach that may serve as a means to synthesize/represent knowledge obtained from the data, in order to explore online learning environment (OLE) states, based on different scenarios. The potentiality of the quality of collaboration (QoC) within an Internet-based computer-supported collaborative learning environment and the quality of interaction (QoI) with a learning management system (LMS), both involving fuzzy logic-based modeling, as vehicles to improve the personalization and intelligence of an OLE is explored. In this approach, a novel framework could be established, when bridging the fields of blended- and collaborative-learning into an enhanced educational environment. The combined measures (i.e., QoC, QoI) can form the basis for a more realistic approach of OLEs within the concept of semantic Web and the associated Web 3.0 features, as they effectively capture the behaviour of the stakeholders involved in the context of Higher Education. Finally, a potential case study of the examined hybrid modelling (FuzzyQoC/I), referring to the "i-Treasures" European FP7 Programme, is discussed, to explore its functionality/applicability under pragmatic learning scenarios, serving as a proof of concept.

1 INTRODUCTION

The concept "Semantic Web" has been used inconsistently by academic researchers, holding a landscape of different fields, technologies, concepts and applications. From one point of view, Semantic Web technology could play an important role in the context of Learning Management Systems (LMSs), giving the possibility to organize information for easy retrieval, reuse, and exchange between different learning systems/tools. From another, combined with the concept of intelligent LMS (iLMS), blended (b)-learning scenarios can offer a number of learning tools, in a wide range of interaction and collaboration (Dias et al., 2014; Dias, 2014). Lukasiewicz and Straccia (2008), more pragmatically, have examined five of the most important challenges facing Semantic Web, namely: vastness, vagueness, uncertainty, inconsistency, and deceit. However, nowadays, the central challenge would be to provide adapted and personalized alternatives, where intelligent models could contribute, involving artificial intelligence and incertitude modeling, e.g., via Fuzzy Logic (FL). The latter is an efficient field that is suitable for dealing with vagueness. In addition, it is considered a form of continuous multi-valued logic allowing "computing with words" and modeling complex systems, characterized by imprecise and vague behaviours by means of a linguistic approach (Zadeh, 1965, 1971). In general, the whole point of Web 3.0 is to provide accessible information to people and computers at anytime from anywhere. Furthermore, with new technological innovations for applying intelligent agents (Web 4.0), cloud computing services has been coined as an umbrella term to describe a category of sophisticated on-demand computing services, initially offered by commercial providers (such as Amazon, Google, and Microsoft) (Voorsluys et al., 2011). By embedding the cloud computing within iLMS, access to large amount of data and different computational learning resources/environments becomes feasible.

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Based on the aforementioned perspectives, this paper examines the potentiality of the quality of collaboration (QoC), within an Internet-based computer-supported collaborative learning (CSCL) environment, and the quality of interaction (QoI) with a LMS, both involving FL-based modeling as a vehicle to improve the personalization and intelligence of an online learning environment (OLE). Furthermore, these combined measures, i.e., QoC and QoI, can form the basis for a more pragmatic approach of OLEs via Web analytics and Web controlling/monitoring, within the concept of semantic Web and the associated Web 3.0 features. A detailed description of this idea is explored and described in the succeeding section, towards a hybrid modelling approach, namely FuzzyQoC/I, where the term hybrid implies both the modelling of the interaction between the users (QoC) and between them and the system (LMS QoI).

2 THE HYBRID APPROACH IN THE SEMANTIC WEB 3.0

As underlined before, Higher Education paradigms are shifting to incorporate more online, blended, collaborative and hybrid learning. An essential factor, however, in determining the efficacy of online learning environments towards the creation and development of sustainable learning communities is the users' QoI with LMSs. From this perspective, the FuzzyQoI model (Dias and Diniz, 2013) has shown significant potential to: a) handle a multitude of variables and inference upon them, furnishing us with a quantitative approach to evaluate the QoI, both in professors' and students' case; and b) function as a means for better understanding and explaining the nature of underlying aspects and causalities, which influence the construction of users' interaction behaviour under the LMS-based b-learning approach. In addition, the collaboration/metacognition-Fuzzy Inference System (C/M-FIS) model (Hadjileontiadou et al., 2003) has contributed to the quantitative evaluation of the QoC, taking into account both the personal (metacognitive) and the social (collaborative) contexts.

A more detailed description of the FuzzyQoI and the C/M-FIS models can be found in Dias and Diniz (2013) and Hadjileontiadou et al. (2003), respectively.

The exploratory trajectory followed through the case studies and the systemic approach adopted in both models revealed noticeable aspects within the CSCL/OLE, which all are influenced by the human behaviour characteristics. OLE usability, profiles and interaction issues holistically relate with the human factor. This also holds for the collaborative interactions within a CSCL environment. Combined with the boosting of the Internet metamorphosis to an increasingly social tool, the need for online education that efficiently incorporates users' characteristics, evolving social needs and expectations becomes apparent. This, really, could transform the perception of the LMS to a more intelligent tool that functions in a more "personalized" way.

Talking about personalization, the problem becomes crucial when authors want to provide materials, which should support different users in their different phases of the learning process. The task, thus, is to find a (technological and procedural) solution in order to effectively support the learners. The knowledge society demands competencies and skills that require innovative educational practices based on open sharing and the evaluation of ideas, fostering creativity and teamwork (collaboration) among the learners.

The vast number of tools supporting collaboration on the Web is an indicator that social software tools are not only a flash in the pan, but lead to a new notion of learning and a measure for sustainable competence development. Towards such endeavour, ideas like semantic analysis of learning activities, tagging opportunities with a focus on appropriateness for learning, visualization of communities and people with similar (learning) interests, new approaches to content and network analysis, and a technical integration of different LMS, should be considered. These ideas clearly comply with the emerging concept of semantic Web 3.0 (Lukasiewicz and Straccia, 2008). Actually, the Web 3.0 is about connecting data, all data, everywhere and putting them in massive graph databases that can be read and conceptually understood by computers. Currently, most Web pages are designed to be read by people, not machines. Nevertheless, because linked, graph-based data are machine-readable, hence, computers could be able to answer increasingly sophisticated questions for the user-to interpret data, understand context, infer meaning and do reasoning. In other words, semantic databases, which sprang out of artificial intelligence, allow computers first to "think", to understand big, conceptual queries, and then find and combine exactly the information humans need to make ever-smarter decisions.

In this context, teaching-learning process should be seen as a complex and constantly dynamic reality (Peters, 2001; Garrison and Kanuka, 2004; Bates,

2005) that could be supported by Information and Communication Technologies (ICTs)-based techno-pedagogical models that include representations, visions, skills, resources, attitudes and practices of their social actors, all placed under the concept of the semantic Web 3.0. In fact, the combination of traditional Face-to-Face (F2F) and online learning, within the context of b-learning, offers different delivery methodologies/modes that have the potential to optimize the learning development, deployment costs and time (Oliver and Trigwell, 2005). In parallel, education paradigms shifted to incorporate online collaborative learning environments (Johnson et al., 2013). Actually, collaborative learning can assist students to feel more interactive and also exerts a positive influence in terms of motivation, behaviour and self-determination, as well as engagement in learning activities (Reeve and Tseng, 2011; Wijnia et al., 2011).

It is noteworthy that nowadays, digital devices and ICT, in general, intermediate the relationships between two or more users, defining a kind of "social interfacing" (de Souza e Silva, 2006). Within the latter, not only the communication relationships are reshaped, but also the space where these interactions take place. The embedded mobility in the interfacing allows the connection between physical and digital spaces, supporting interconnectivity of social/conceptual and technological interface under the ubiquity perspective. In this way, interactive activities, communicative understandings, learning theories (especially as framed through cognitive load), self-efficacy and self-regulation, become more dynamic and challenging issues to be addressed within an OLE.

Taking the aforementioned perspectives together, an enhanced LMS-based intelligent teaching/learning modeling approach could be formed, by suggesting the incorporation of the hybrid and innovative processing techniques from the fields of fuzzy modeling and fuzzy set theory. In this fashion, a novel research framework could be established, by exploring the ways effective teaching could be accomplished, when bridging the fields of b- and collaborative (c)-learning into a hybrid and enhanced teaching-learning environment. In this way, a holistic approach of the fundamental channels from which the educational process is conveyed could be adopted, combining cognitive and social information of the peers' behaviour and interactions. Consequently, the following objectives could be set:

- development of an educational and innovative framework around the online instructional environments, by exploring the potentialities of b/c-learning/teaching in the context of Higher Education and semantic Web 3.0,
- contribution to educational improvement on teaching practice supported in the LMS Moodle (or OLEs in general), providing new tools more suited to users' QoC and QoI,
- development, application and validation across a vast number of users (students/professors) of efficient hybrid modeling approaches of LMS Moodle data, based on fundamentals of Fuzzy Logic-based Inference Systems (FISs),
- introduction of extended means, new tools and pathways for shifting from the typical form of LMS to the iLMS (Dias et al., 2014), incorporating issues, such as personalization and technological adaptiveness,
- course effect analysis using the FuzzyQoI model (Dias and Diniz, 2013), to examine how the course content affects the users' QoI with LMS Moodle across the years,
- identification of possible macroscopic causal dependencies, converged or dispersed interaction trends, periodicities, specific patterns dominance in the LMS Moodle interaction/collaborative/metacognitive attitude, all reflected at the FISs, i.e., C/M-FIS and FuzzyQoI models response,
- comparative analysis across the forthcoming hybrid modeling approaches, blending the benefits of each one and identifying their pros and cons, and
- construction of new guidelines/ recommendations about the enhancement of OLE-based teaching/learning processes, contributing to the enrichment of the higher education institutions (HEIs) services and reformulation of educational policies/practices.

Adding to the above, ontologies could be used to link the quantitative metrics of QoC and QoI to information coding, so it could easier be processed by software agents, opening the door for a slew of new semantic Web 3.0-based applications. In fact, according to Gruber (1993), an ontology is a formal, explicit specification of a shared conceptualization. Pragmatically, a common ontology defines the vocabulary with which queries and assertions are exchanged among software entities. An ontology has concepts that identify the data entities of interest and these concepts are organized in a hierarchy, called a taxonomy; concepts might have attributes and relationships, whereas a data item that has been marked up with a label corresponding to a concept is called a data instance. Through this organization, ontologies could contribute to a shared and common

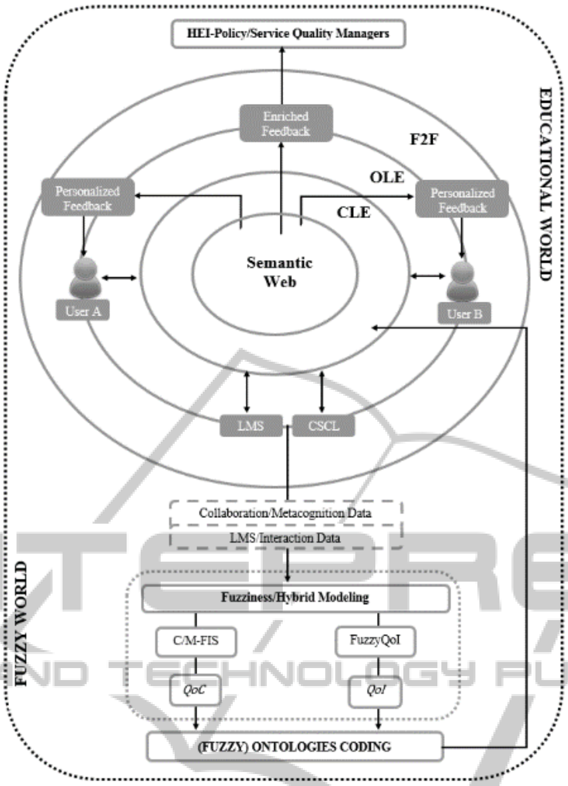

Figure 1: The architecture of the proposed FuzzyQoC/I hybrid model that connects the educational and fuzzy worlds, integrating the C/M-FIS and FuzzyQoI models. OLE: Online Learning Environment, CLE: Cloud Learning Environment, CSCL: Computer-Supported Collaborative Learning, LMS: Learning Management System, HEI: Higher Education Institution, QoC: Quality of Collaboration, QoI: Quality of Interaction.

understanding of QoC and QoI that can be communicated among the educational stakeholders and iLMSs/iOLEs. As the latter involve Web-based educational material, ontologies can be used to describe relationships between pages and other data (like QoC and QoI metrics), so to contribute to a personalized supporting system that could maximize the QoC and QoI; hence, enhance user's teaching/learning experience. They can, therefore, be used to recommend learning resources of potential interest to the learner that potentially increase his/her QoI; even to recommend a "study-buddy", with whom the learner shares common abilities and interests and can maximize his/her QoC when collaborates with him/her. From a technical point of view, this could be achieved by employing, for example, the DARPA Agent Markup Language/Ontology Inference Layer (DAML+OIL) ontology language (McGuinness et al., 2002), which describes structure of the domain, combined with the Resource Description Framework (RDF), which is used, in the same time, to describe specific instances, and Ontology Web Language and Information Retrieval (OWLIR) that handles the Event Ontologies (Connolly et al., 2001).

In one step further, using Cloud computing platforms (e.g., Microsoft Azure) and technologies in conjunction with semantic Web 3.0 technology and metadata, a shift from the traditional LMS to Cloud Learning Environments (CLEs) could be achieved, by facilitating the autonomous or collaborative study of user-chosen blends of content and courses from heterogeneous sources (Mikroyannidis, 2012). In CLE, semantic knowledge base serves as the core of the OLE, facilitating learners in finding educational services and collaborate on the Cloud, evoking collaborative ontology management techniques. In this concept, the proposed hybrid QoC/I model could combine both LMS and CLE in the learning process, placing the user at the centre and capturing his/her interaction with both contexts. This could, actually, assist HEIs to enrich their educational framework, facilitating, at the same time, the professors'/learners' interaction (both autonomous and collaborative) with the OLEs.

A schematic presentation of the proposed architectural structure of the FuzzyQoC/I hybrid model is depicted in Figure 1. Apparently, the online communication channels considered in Fig. 1 should not be seen as static; yet with fluidity, directed to provide flow opportunities of communication in human-computer interaction in an OLE. From a common perspective, learners should be behaviourally, intellectually, and emotionally involved in online learning tasks. Nevertheless, the role of educational technology is to improve academic literacies in students, to create engaging communities of practice, and to improve learner's motivation and self-empowered learners (Wankel and Blessinger, 2013).

2.1 Fuzzy Ontologies

In the hybrid model presented in Fig. 1, the role of FL is catalytic. One of the issues that could also be approached from the FL concept is the ontology one. As it was mentioned above, the Semantic Web allows relational knowledge to be embedded as metadata in Web pages, enabling machines to use ontologies and inference rules in retrieving and manipulating data. In this vein, ontologies are a key component of the Semantic Web.

As an extension of the ontologies, the fuzzy ontologies could also be defined (Widyantoro and Yen, 2001), incorporating the functionality of an ontology with the flexibility of the FL. The main definitions and characteristics of fuzzy ontologies are epitomized bellow, as a glimpse to the enhanced potentialities of the hybrid modeling of Fig. 1.

In general, the definition of a fuzzy ontology structure includes: concepts, fuzzy relations among concepts, a concept hierarchy or taxonomy, non-hierarchical associative relationships and a set of ontology axioms, expressed in an appropriate logical language. Consequently, a lexicon for a fuzzy ontology includes: lexical entries for concepts (knowledge about them can be given by fuzzy attributes, with context-dependent values), lexical entries for fuzzy relations, coupled with weights expressing the strength of associations, and reference functions linking lexical entries to concepts or relations they refer to.

Apart from the structural characteristics of the fuzzy ontology described above, the issue of fuzzy ontology mapping should also be considered. In particular, ontology mapping is the effective method to solve the problems of knowledge sharing and reusing across the heterogeneous ontologies in the Semantic Web (Doan et al., 2002). The current ontology mapping technologies are not sufficient for fuzzy ontologies (Ma et al., 2014). Therefore, with the growing number of heterogeneous fuzzy ontologies in the Semantic Web, the fuzzy ontology mapping that can handle fuzzy data becomes an important research topic. The aforementioned characteristics of the fuzzy ontologies show the potentiality of FL to handle heterogeneous data and perform more effective reasoning at the ontological level. Hence, provisional embedding within the hybrid model presented in Fig. 1 enriches its ingredients, towards the successful integration of the knowledge representation in the Semantic Web within the educational context.

Next, a provisional case study of the proposed hybrid model is discussed, with regard to the i-Treasures Programme.

3 THE I-TREASURES CASE STUDY

The i-Treasures: "Intangible Treasures - Capturing the Intangible Cultural Heritage (ICH) and Learning the Rare Know-How of Living Human Treasures" is an Integrated Project (IP) of the European Union's 7th Framework Programme ICT for Access to Cultural Resources (February 1, 2013-2017). The main aim of i-Treasure is to develop an open and extendable platform to provide access to intangible cultural heritage resources and, at the same time, to propose a novel strategic framework for the safeguarding and transmission of ICH (http://i-treasures.eu). Considering the latter, it is apparent that the issues of personalized learning, LMS interaction, ontologies coding and enriched feedback (facilitated via a sensory motor learning approach) are common elements. Based on this mutuality in the design, direct analogies could be considered as injection of the hybrid model fuzziness in the evolution of the i-Treasures Programme. In particular:

- Since the LMS is one of the main facilitator of the user's interaction with the i-Treasures platform, the simultaneous measurement of his/her QoI with the LMS via the QoC/I modeling (see Fuzziness/Hybrid Modeling in Fig. 1), could be an important enhancement in the functionality of the i-Treasures platform. This could also be used as effective feedback to the user (see Personalized Feedback in Fig. 1), and combined with the sensorimotor learning concept, could evoke reflective processes towards the intention for improvement.

Figure 2: The i-Treasures use-cases referring to traditional and contemporary singing, traditional and contemporary dance, traditional pottery, and contemporary music composition (http://i-treasures.eu).

- Similarly to the case of QoI, the QoC could serve as dynamic feedback to the i-Treasures user, reinforcing transitional changes and supporting knowledge development. As cultural knowledge is transmitted not only via changes in an individual across time, but also via the groups' behavior over time (Flynn and Siegler, 2007), the dynamic monitoring of the FL-based estimated QoC and QoI could facilitate the capturing of such changes (e.g., as transitions across the ellipses of Fig. 1, both at the individual and at the group level), exposing attitude shifts and trends, accompanied by cultural knowledge development. This approach could also be combined with the affective information of the i-Treasures acquisition modules to correlate the user's emotional engagement with the evolution of his/her QoI and QoC trends.
- The MEBNs (Laskey, 2008) used for the ontology-based knowledge representation in i-Treasures Programme could be accompanied by the concept of fuzzy ontologies, described in the previous section (see Fig. 1), in an effort to handle uncertainty in alternative to the probability way, employing the advantageous characteristics of the FL.
- Since the i-Treasures Programme is multi-layered, with a variety of acquisition modules and different use-cases, its performance evaluation and monitoring (as a whole system) is quite difficult to be approached in a mono-dimensional way. In this context, an estimation of the general performance indices (GPIs) for each use case, as well as for their sub-use cases could be achieved based on nested FISs. In addition, the GPI of the integrated platform could be estimated, reflecting its overall quality, as shown in Fig. 3.

From the above, it is clear that the FuzzyQoC/I hybrid model could be used to capture micro- (localities) and macro- (generalities) levels of the i-Treasures system use.

4 FINAL CONSIDERATIONS

The concept of a FL-based hybrid model, which combines QoC and QoI within the context of semantic Web 3.0 and CLEs in a holistic perspective of the online learning educational context, shedding light upon the requirements for offering personalized feedback to learners, supporting them throughout their learning journey, and enriched recommendation services to HEI policy/service quality managers, was the focus of this paper. The provisional hybrid model presented here combines the FL-based approaches in modelling collaborative/metacognitive and LMS user interaction data, along with the perspectives of fuzzy ontologies and fuzzy ontology mapping techniques. In this way, higher flexibility, more enhanced modeling capabilities and multidimensional inference from the fusion of information estimated at various levels of interaction/collaboration within the co-existing CSCL environments and CLE/OLEs under the b-learning concept are provided. The dynamic feedback of QoI and QoC, combined in the proposed FuzzyQoC/I hybrid approach, can account for the non-stationarities seen in students' learning process, providing more pragmatic capturing of the underlying interaction trend-shifts and/or artefacts.

Moreover, the hybrid concept adopted in this paper is in line with the European Union's perspective about

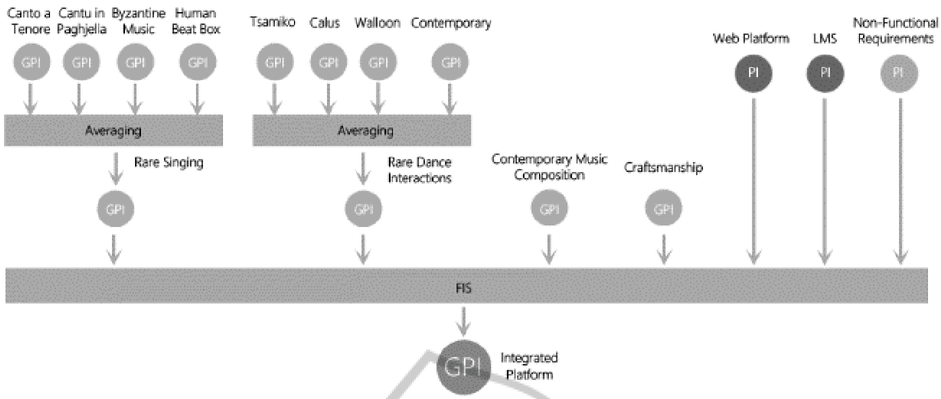

Figure 3: Fusion of the general performance indicators (GPIs) of each use-case of the i-Treasures with Web platform/LMS performance indicators (PIs) as FIS inputs to output the integrated platform GPI of the i-Treasures.

the trends and evolution of Higher Education in the next years (Johnson et al., 2015).

The metrics of QoC and QoI (combined in the hybrid model) are of great importance, as they could become key-discriminators amongst hybrid learning environments, as emerging digital tools make it easier for students to ask and respond to each other's questions and for instructors to provide feedback in real-time. In line with this, the personalized feedback based on the FL-based estimated QoC and QoI could also help instructors to leverage components of online learning and to make personalized learning scalable in large introductory classes. Compared to the traditional model of learning, in which space is needed to accommodate hundreds of students, hybrid learning can address the learning path of each individual student. From a motivational point of view, our approach resembles the efforts for hybrid modelling of instructional design (ID), such as the 4-Component/ID (4C/ID) (Van Merriënboer et al., 2003). In the 4C/ID, a hybrid-modelling framework for scaffolding practice and just-in-time information presentation, aiming to control cognitive load effectively, is presented. Taking this further, the FuzzyQoC/I model could be seen as a flexible nutshell, where such ID approaches could be encapsulated and developed in a synchronized way, towards the maximization of the learner's learning experience, both at the task (cognitive load) and collaboration/interaction (QoC/QoI) levels.

In the same view of the aforementioned, the implementation potentiality of the hybrid modeling was examined in a real case study, i.e., the i-Treasures programme, which is a currently EU FP7 running (up to 2017), aiming at the development of an open and extendable platform to provide access to ICH resources, enable project knowledge exchange between researchers, and contribute to the transmission of rare know-how from Living Human Treasures to apprentices via sensorimotor learning. Due to the nature and design of the i-Treasures, its structural characteristics are in direct connection with the ones of the FuzzyQoC/I hybrid model. In this vein, the applicability of the concept behind the hybrid approach to the real case of the i-Treasures was explored and possible interactions were identified. The outcomes of the provisional adoption of this theoretical approach in a case study will allow to further validate the proposed hybrid methodology and expand its database and implementation on case studies from diverse areas (such as the i-Treasures Programme), for its further generalization refinement. It is our hope that this effort could significantly add to the appreciation of the potentialities of the newly available technological means and networking concepts, such as semantic Web 3.0, in the field of Higher Education. Moreover, the ideas discussed in the present paper expectantly could provide an intelligent framework for possible reforms and alterations to the b- and c-learning modeling; hence, to effectively affect the educational processes within online teaching/learning environments at HEIs.

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