ISBN: 978-989-8533-23-4 © 2014 IADIS

ICT COMPETENCE-BASED LEARNING OBJECT RECOMMENDATIONS FOR TEACHERS

Stylianos Sergis[1,2], Panagiotis Zervas[1,2] and Demetrios G. Sampson[1,2]
[1]*Department of Digital Systems, University of Piraeus, 150, Androutsou Str, Piraeus, Greece*
[2]*Information Technologies Institute, Centre for Research and Technology Hellas, 6th km Charilaou-Thermi Rd, Thessaloniki, Greece*

ABSTRACT

Recommender Systems (RS) have been applied in the Technology enhanced Learning (TeL) field for facilitating, among others, Learning Object (LO) selection and retrieval. Most of the existing approaches, however, aim at accommodating the needs of learners and teacher-oriented RS are still an under-investigated field. Moreover, the systems that focus on teachers, do not explicitly exploit their ICT competence profiles when providing LO recommendations. This is a significant drawback, since it can result in LO recommendations that are beyond the teachers' competence to use. Towards tackling this issue, this paper extends previous work and proposes a teacher ICT Competence-based RS that considers teachers' ICT Competence Profiles when recommending Learning Objects. Moreover, the results of its accuracy evaluation are presented. The results indicate that the proposed approach provides high predictive accuracy and outperforms commonly used, existing RS approaches.

KEYWORDS

Recommender Systems, Teacher ICT Competence, Learning Object Recommendation

1. INTRODUCTION

Recommender Systems (RS) are adaptive software applications aimed at providing suggestions for potentially useful items to the users (Bobadilla et al., 2013). They are widely used in many contexts, such as Movie Industry (Bobadilla et al. 2011) and Technology Enhanced Learning (TeL) (Manouselis et al. 2013a). RS are mainly divided in three categories in terms of the method applied for providing these recommendations (Ricci et al. 2011). These are (a) content-based recommenders, which build user models based on the items that users have already interacted with, (b) collaborative filtering recommenders, which produce recommendations for users based on the rating patterns of the users' neighbors (like-minded users), and (c) hybrid recommenders, which combine techniques from both previous approaches in order to reap the benefits of both, while tackling their individual drawbacks.

In the context of TeL, one of the key applications of RS is the location and selection of Learning Objects (LO) (Manouselis et al. 2013b). The majority of existing TeL RS, however, is focused on the target group of learners and aims to accommodate their specific characteristics in the recommendation process, such as their learning styles or their learning preferences (Ferreira-Satler et al. 2012; Chrysafiadi & Virvou 2013). From the standpoint of teachers, however, less research has been performed and few approaches actually consider teacher characteristics towards providing more personalized recommendations for their course design and delivery (Sergis et al., 2014). Due to the diversity in these characteristics, the "appropriateness" and usefulness of each LO to-be-recommended is different for each teacher based on her unique profile and needs. A significant type of such characteristics are the teachers' ICT Competences, since the latter are an important factor affecting their everyday practice (Sang et al. 2010; Goktas et al. 2013). Therefore, accommodating for these teacher attributes has the potential to provide significant added value in the teacher-oriented RS.

Under this light, previous work was performed towards tackling the identified research problem of facilitating LO recommendation for teachers based on their ICT Competence profiles (ICT-CP). This work included the design and evaluation of a set of mapping rules linking teachers' ICT Competences to LO

metadata elements for identifying appropriate LOs for each teacher, competence-wise (Sergis et al., 2014). The contribution of the present paper is to extend this work by designing and developing an ICT Competence-based RS, which utilizes the proposed mapping rules and delivers informed LO recommendations to teachers based on their ICT-CP. Moreover, the predictive accuracy of the proposed approach is benchmarked against commonly used user- and item-based collaborative filtering approaches.

The remainder of this paper is structured as follows. In Section 2 the current state of the TeL teacher-oriented RS landscape is presented. Moreover, the research problem and the contribution of the present paper is clearly identified. Section 3 presents the proposed approach for providing ICT Competence-based Learning Object recommendations to teachers. Section 4 comprises the evaluation method and results for validating the proposed approach's predictive accuracy. Finally, Section 5 contains the conclusions drawn and the future work in this research agenda.

2. PREVIOUS WORK: TEACHER-ORIENTED TEL RECOMMENDER SYSTEMS

In previous work (Sergis et al., 2014), a literature review was performed in the landscape of TeL Recommender Systems in order to highlight approaches that were addressed to teachers. The results of this process identified a set of 22 teacher-oriented RS. Moreover, an additional refinement of this list highlighted those approaches that created profiles with personal characteristics of the teachers (in addition to simple social data profiles) and utilized these data in order to drive more informed recommendations. This list comprises 7 RS and is presented in Table 1. Additional information depicted in Table 1 include the type of profile data that these RS capture.

Table 1. Existing teacher-oriented TeL Recommender Systems

#	Paper	Profile data
1	Bozo et al. (2010)	Demographic data
2	Schoefegger et al. (2010)	User work-related knowledge levels - *not restricted to teachers*
3	Sielis et al. (2012)	*Not clearly stated*
4	Schirru et al. (2010)	User interest on items based on social data and item descriptions
5	Aehnelt et al. (2008)	Users experiences of resource use - *not restricted to teachers*
6	Cobos et al. (2013)	*Not clearly stated*
7	Zapata et al. (2013)	Demographic data, Information Technology experience - *Low metric granularity*

As Table 1 depicts, each of the seven identified RS utilized a different type of user data in order to create their profile, while some did not include explicit information on the manner in which the reported profiles were created. However, a commonly identified issue in all approaches was the universal lack of consideration for exploiting the teachers' ICT competences. Bearing in mind the significance of these characteristics to the level of the level of ICT uptake of teachers (Vanderlinde et al. 2014), their integration in the LO recommendation process was proposed as a significant research problem.

More specifically, a research problem was formulated, namely how can the process of LO recommendations to teachers based on their ICT-CP be facilitated. This is reinforced by the reported need for more informed user modeling processes towards better recommendations (Adomavicius & Tuzhilin 2005). A first step towards tackling this issue was performed by constructing and evaluating a set of mapping rules linking (a) specific ICT Competences as they are depicted in the UNESCO ICT Competency Framework for Teachers (http://tinyurl.com/ocaxgqk) (ICT-CFT) to (b) specific Learning Object Metadata attributes, as they were depicted in the OpenDiscoverySpace (ODS) Project (http://www.opendiscoveryspace.eu) LOM Application Profile (Sergis et al., 2014). This work showed that the proposed mapping rules provided high accuracy and could, therefore, effectively classify LOs as appropriate in terms of each teacher's ICT-CP.

The next step in this research agenda is the investigation of the potential added value that this approach could deliver in the teacher-oriented RS. Therefore, the aim and contribution of the present paper is to progress this research agenda by reporting on the process of designing, implementing and evaluating a RS that utilizes these mapping rules in order to deliver ICT Competence-based LO recommendations to teachers. More specifically, the RS overview is presented and its recommendation methodology is described in detail. Finally, the predictive accuracy evaluation of the system is presented and the added value of this approach is discussed.

3. ICT COMPETENCE-BASED LEARNING OBJECT RECOMMENDER SYSTEM FOR TEACHERS

The overview of the proposed ICT Competence-based approach to recommending LOs to teachers is presented in Figure 1.

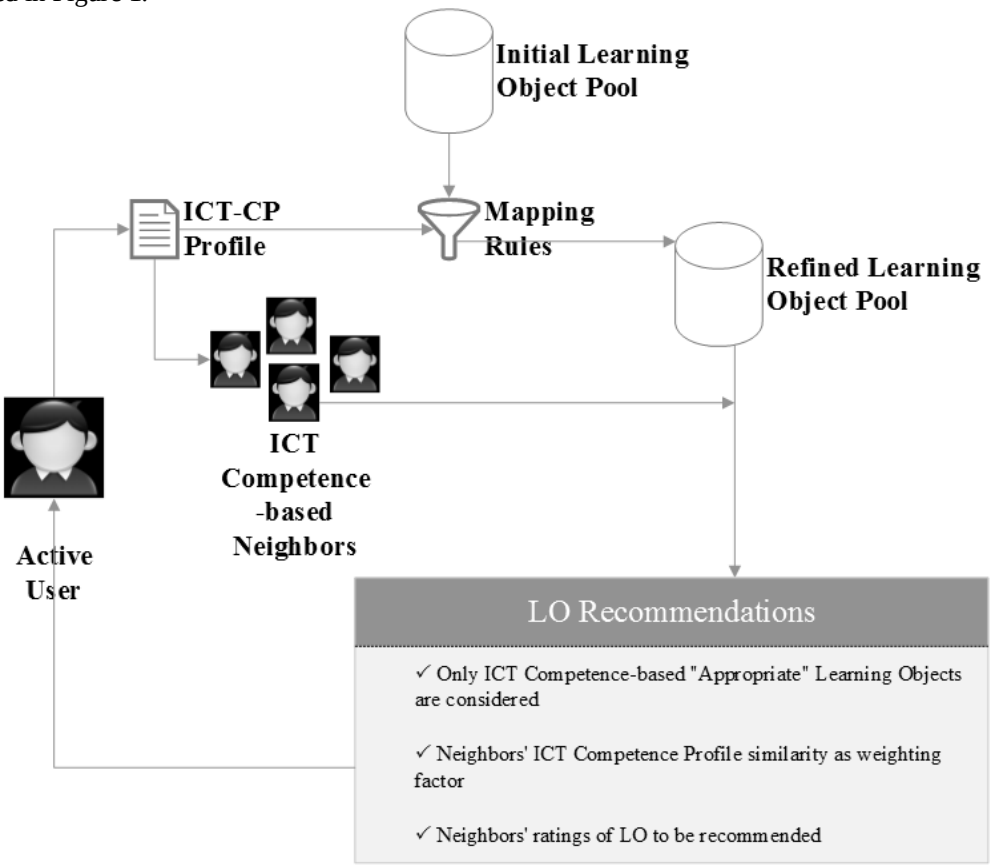

Figure 1. Overview of proposed teacher ICT Competence-based Learning Object Recommendation System

The methodology for creating LO recommendations includes an initial pre-filtering of the full set of LOs, in order to keep only those that correspond to the teacher's ICT-CP. This step is realized by utilizing the mapping rules designed and evaluated in previous work (Sergis et al., 2014). At the end of this process (which is performed offline), a refined pool of LOs has been created that contains the "appropriate" LOs for the active teacher. Following this step, this refined pool of LOs is used for delivering the recommendations based on the ICT Competence-based neighbors of the active user. Therefore, the proposed approach utilizes the teachers' ICT-CP in a twofold manner, namely (a) as a pre-filtering mechanism for identifying LOs that are beyond the active teachers' competence to use, and (b) as an alternative neighborhood creation method, focusing on ICT competence profile similarities instead of common rating patterns.

As the Figure 1 describes, the proposed approach comprises a set of distinct steps, each of which are presented in the following sections.

3.1 Teacher ICT Competence Profile Depiction

As aforementioned, the teacher ICT-CP was depicted using the UNESCO ICT Competency Framework for Teachers (CFT). The reasons for selecting the CFT over alternative frameworks have been discussed in Zervas et al. (2014).This framework addresses all aspects of a teacher's practice within their work context and aims to provide comprehensive teacher ICT competency standards for assisting them in successfully addressing all relevant dimensions. It comprises 6 categories of ICT Competences spanning 3 proficiency levels. Each competence category is further divided in sub-competences that are differentiated according to the proficiency levels. The total number of sub-competences described in the CFT is 61. Therefore, a teacher ICT Competence Profile submitted to the system would include each of these sub-competences, evaluated in terms of whether the active teacher possesses it or not.

3.2 ICT Competence-based Neighborhood Creation

The neighborhood creation process in the proposed approach is performed in a novel manner. More specifically, the method employed in the proposed approach utilizes the teachers' ICT-CP in order to create these neighborhoods. This alternative has the potential to provide more informed recommendations, since users (in our case, teachers) would receive LO recommendations based on the opinions of colleagues that have the same competence background with them.

In the context of this paper, the ICT Competence-based neighborhoods were constructed using the Jaccard co-efficient (JC) (Verbert et al. 2011). This coefficient measures the similarity between two sets (in our case ICT Competences) by dividing the number of common items with the number of different items from both sets of rated items. It is calculated using the formula:

$$JC = \frac{|I_U \cap I_V|}{|I_U| + |I_V| - |I_U \cap I_V|}$$

where I_U and $I_V$are the Competences of users *U* and *V* respectively.

Within the context of the proposed RS, the output of this formula served as an indicator of the "closeness" between two users, i.e., how similar are their ICT Competence profiles. This indicator was utilized in the recommendation process of the proposed approach (section 3.4) as a weighting factor for predicting the rating of the active user based on the ratings of her neighbors.

3.3 Pre-filtering Learning Objects

The second step in the proposed ICT Competence-based recommendation system relates to the pre-filtering of the available LOs in order to consider only those that are "appropriate" for the active teacher, in terms of her ICT-CP. This process was performed by utilizing the set of mapping rules linking specific ICT Competences described in the CFT and specific LO metadata elements. Therefore, for each LO the corresponding mapping rule was fired and the system would flag the LO appropriately in terms of the active teacher's ICT-CP. At the end of this process (which was performed offline to reduce the systems' response time), each teacher would have their own unique set of "appropriate" LOs, based on their ICT-CP. Finally, utilizing this refined pool, the system would deliver the LO recommendations.

3.4 ICT Competence-based Learning Object Recommendations

The process of delivering the LO recommendations is similar to the existing collaborative filtering approaches. More specifically, a weighted average of the neighbors' ratings was utilized in order to predict the rating that each user would assign to a LO that was to-be-recommended. The difference with existing

collaborative filtering approaches, apart from the fact that the candidate LOs would come from the refined pool of "appropriate" LOs instead of the full pool of all available LOs of the repository, is the nature of the weights assigned to the weighted average metric. More specifically, as aforementioned in a previous section, these weights were the output values of the Jaccard coefficient used for creating the competence-based teacher neighborhoods. Therefore, "closer" neighbors, i.e., neighbors with more similar ICT-CPs to the active user and higher Jaccard coefficient, had a greater impact in the recommendation process.

The predicted rating r_{ui} for each LO *i* by the active user u was calculated based on the formula:

$$r_{ui} = \frac{\sum_1^N w_j * r_{ji}}{\sum_1^N w_j}$$

where r_{ji} is the rating provided by neighbor *j* on the LO *i*, *j* is the j_{th} neighbor of the active user and *N* is the neighborhood size utilized. Based on the generated predicted rating, the system could infer not only if each LO would be appropriate for the active user, but, moreover, whether it would be of interest to her.

The proposed system was evaluated in terms of its predictive accuracy. The evaluation methodology followed is described in the following section.

4. EVALUATION

4.1 Dataset

An experiment was performed towards the evaluation of the proposed recommendation method based on teachers' ICT Competence profiles. The dataset which was utilized came from the OpenDiscoverySpace (ODS) Project (http://www.opendiscoveryspace.eu). The reason for selecting this dataset was that it contained existing ICT Competence profiles provided by 115 real teachers. The overview of the retrieved dataset is presented in Table 2. Aggregation Level 1 LOs refer to standalone Educational Resources (e.g., flash simulations), while Aggregation Level 2 LOs refer to Lesson Plans.

Table 2. ODS Dataset Overview

Category	Sample Size (N)	Rating Data
User ICT-CP	115	-
AL 1 Learning Objects	523	1375
AL 2 Learning Objects	475	986

4.2 Evaluation Method

The evaluation was based on the predictive accuracy of the proposed approach. It involved the standard "Leave-N-out" technique, where 70% of the data are used as a "training" set for the recommender system and the remaining 30% of the data are used as a "test" set for evaluating the performance of the system; in our case, its predictive accuracy. The Root Mean Squared Error (RMSE) metric was selected for measuring the predictive accuracy of the system (Shani & Gunawardana 2011). This metric is calculated based on the formula:

$$RMSE = \sqrt{\frac{1}{T}\sum_{u,i \in T}(\bar{r}_{ui} - r_{ui})^2}$$

where $\bar{r}_{ui}$ is the set of generated predicted ratings, r_{ui} is the set of known ratings and T is the set of users and items for which the ratings are known.

Moreover, the proposed approach was benchmarked against two "control" recommendation methods, namely a user-based collaborative filtering approach and an item-based collaborative filtering approach. Both

these approaches utilized the Pearson correlation coefficient (PCC) for creating the user/item neighborhoods (Verbert et al. 2011). The Pearson correlation coefficient is calculated based on the formula:

$$PCC = \frac{\sum_{i \in I}(r_{ui} - \bar{r_u})(r_{wi} - \bar{r_w})}{\sqrt{\sum_{i \in I}(r_{ui} - r_u)^2 \sum_{i \in I}(r_{wi} - r_w)^2}}$$

where I is the set of items that both users u and w have rated, r_{ui} and r_{wi} denote the ratings of the users u and w on the item i, while $\bar{r_u}$ and $\bar{r_w}$ denote the average ratings of the two users respectively. Following this step, both "control" approaches utilized the PCC as a weighting factor for creating the predictions of the active user for the LOs that they had not yet rated.

Finally, the evaluation experiment was run for an increasing number of neighborhood size in order to monitor the behavior of each approach in each occasion. The results of the evaluation experiment are presented in the following section.

4.3 Evaluation Results

The results of the evaluation experiment are presented in Figure 2 and Figure 3. The former presents the results concerning Aggregation Level 1 LOs, while the latter presents the results for Aggregation Level 2 LOs. The reason for examining both these LO Levels is that in the "Pre-filtering" step of the proposed approach, different mapping rules are utilized for these LO Levels, and therefore, both had to be evaluated compared to the existing approaches.

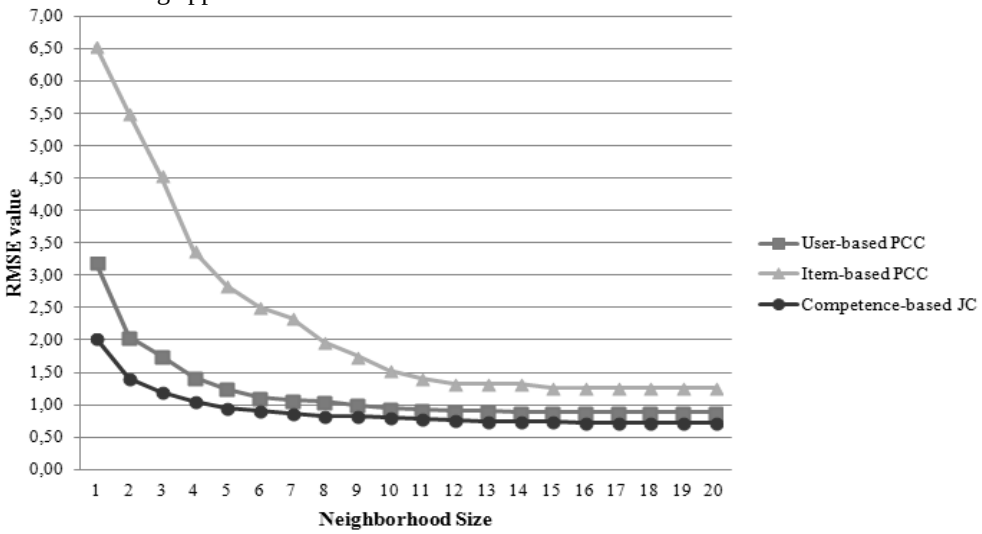

Figure 2. RMSE results for Aggregation Level 1 Learning Objects

As the Figures 2 and 3 depict, the results of the evaluation experiment are very promising. More specifically, the proposed approach achieved high levels of predictive accuracy (in the form of low RMSE value) for both Aggregation Level LOs. This means that it can effectively identify LOs as appropriate or not in terms of the teachers' ICT Competences, as well as to select those that are interesting to her.

Moreover, compared to the user- and item-based approaches, a significant improvement was detected. This means that incorporating the teachers' ICT-CP in the LO recommendation process (and the manner in which this was performed) can provide added value in existing RS systems and offer teachers with more useful services.

Another important finding is that ICT Competence-based recommendations out-perform existing commonly used collaborative filtering approaches for all neighborhood sizes, signifying that they could prove beneficial in tackling some common collaborative filtering problems, such as the new user problem (Bobadilla et al. 2012).

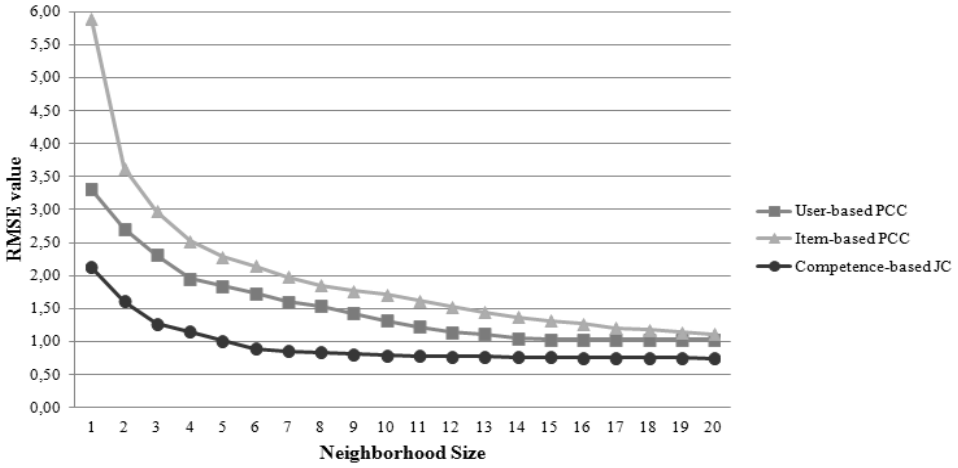

Figure 3. RMSE Results for Aggregation Level 2 Learning Objects

The new user problem occurs within RS when it is not possible to make reliable personalized recommendations due to an initial lack of ratings by the active user. This is more evident in educational datasets, which are usually very sparse. The results of this paper show that the inclusion of the teacher profile information as a means for creating neighborhoods could assist in remedying for this issue in a significant degree, since the active user could be linked to a set of appropriate neighbors without the need for their own ratings.

The above overall findings provide with strong evidence that the inclusion of teachers' ICT-CP in the learning object recommendation process within Learning Object Repositories (LORs) can provide enhanced personalized services in a number of ways and can accommodate each teachers' individual profile and competence-related needs.

5. CONCLUSIONS AND FUTURE WORK

This paper, building on previous work, proposed a system that integrated the teachers' ICT-CP in the LO recommendation process within LORs. This work was focused at tackling a research gap in the RS landscape, related to the lack of consideration of the teachers' ICT-CP when recommending LOs. This was considered as a significant drawback, bearing in mind the apparent importance of these personal characteristics in the everyday level of ICT uptake of teachers.

Towards measuring the level of the added value of the proposed approach, an evaluation experiment was performed, which focused on benchmarking the predictive accuracy of the approach against two commonly used collaborative filtering approaches. The results provided with evidence that the proposed approach can deliver better recommendations (in terms of low system RMSE) for all LO Aggregation Levels and can also perform adequately in small neighborhood sizes.

Bearing in mind the added value that the proposed approach showed to deliver in the LO recommendation process for teachers, future work should be focused on identifying a robust framework for eliciting these teacher characteristic from their usage patterns within LORs. The need for this springs from the fact that teachers (and users in general) are usually either unwilling to provide personal information or when they do, the validity of the provided data cannot be ensured (Belk et al. 2013). Therefore, in order to overcome the above issue, and reap the reported benefits of ICT Competence-based LO recommendations, mechanisms should exist for inferring the teachers' profile from their usage patterns (Marin et al. 2014).

ACKNOWLEDGMENT

The work presented in this paper has been partly supported by the Open Discovery Space Project that is funded by the European Commission's CIP-ICT Policy Support Programme (Project Number: 297229).

REFERENCES

Adomavicius, G. and Tuzhilin, A. 2005. Toward the next generation of recommender systems: A survey of the state-of-the-art and possible extensions. *IEEE Transactions on Knowledge and Data Engineering* 17(6), pp. 734-749.

Aehnelt, M. et al. 2008. A socio-technical approach towards supporting intra-organizational collaboration. In Dillenbourg, P. and Specht, M. Eds. *Times of Convergence. Technologies Across Learning Contexts*. Berlin Heidelberg: Springer, pp. 33-38.

Belk, M. et al. 2013. Modeling users on the World Wide Web based on cognitive factors, navigation behavior and clustering techniques. *Journal of Systems and Software* 86(12), 2995-3012.

Bobadilla, J. et al. 2011. Improving collaborative filtering recommender system results and performance using genetic algorithms. *Knowledge-based systems* 24(8), 1310-1316.

Bobadilla, J. et al. 2012. A collaborative filtering approach to mitigate the new user cold start problem. *Knowledge-Based Systems* 26, 225-238.

Bobadilla, J. et al. 2013. Recommender systems survey. *Knowledge-Based Systems* 46, 109-132.

Bozo, J. et al. 2010. Recommending Learning Objects According to a Teachers' Contex Model. In Wolpers, M., Kirschner, P.A., Scheffel, M., Lindstaedt, S., Dimitrova, V. Eds. *Sustaining TEL: From Innovation to Learning and Practice*. Berlin Heidelberg: Springer, pp. 470-475.

Chrysafiadi, K. and Virvou, M. 2013. Student modeling approaches: A literature review for the last decade. *Expert Systems with Applications* 40(11), 4715-4729.

Cobos, C. et al. 2013. A hybrid system of pedagogical pattern recommendations based on singular value decomposition and variable data attributes. *Information Processing & Management* 49(3), 607-625.

Ferreira-Satler, M. et al. 2012. Fuzzy ontologies-based user profiles applied to enhance e-learning activities. *Soft Computing* 16(7), 1129-1141.

Goktas, Y. et al. 2013. Enablers and barriers to the use of ICT in primary schools in Turkey: A comparative study of 2005–2011. *Computers & Education* 68, 211-222.

Manouselis, N. et al. 2013a. Introduction and Background. In Manouselis, N., Drachsler, H., Verbert, K. and Duval, E. Eds. *Recommender Systems for Learning.* New York: Springer, pp. 1-20.

Manouselis, N. et al. 2013b. TEL as a Recommendation Context. In Manouselis, N., Drachsler, H., Verbert, K. and Duval, E. Eds. *Recommender Systems for Learning.* New York: Springer, pp. 21-36.

Marin, L. et al. 2014. Automatic preference learning on numeric and multi-valued categorical attributes. *Knowledge-Based Systems* 56, 201-215.

Ricci, F. et al. 2011. *Recommender systems handbook*. New York: Springer.

Sang, G. et al. 2010. Student teachers' thinking processes and ICT integration: Predictors of prospective teaching behaviors with educational technology. *Computers & Education* 54(1), 103-112.

Schirru, R. et al. 2010. Extraction of Contextualized User Interest Profiles in Social Sharing Platforms. *Journal of Universal Computer Science* 16(16), 2196-2213.

Schoefegger, K. et al. 2010. Towards a user model for personalized recommendations in work-integrated learning: A report on an experimental study with a collaborative tagging system. *Procedia Computer Science* 1(2), 2829-2838.

Sergis, S. et al. 2014. Towards learning object recommendations based on teachers' ICT Competence Profiles. *Proceedings of the 14th IEEE International Conference on Advanced Learning Technologies*, Athens, Greece, In Press.

Shani, G. and Gunawardana, A. 2011. Evaluating recommendation systems. In Ricci, F., Rokach, L., Shapira, B. and Kantor, P. Eds. *Recommender systems handbook*. New York: Springer, pp. 257-297.

Sielis, G.A. et al. 2011. Context-Aware Recommendations using Topic Maps Technology for the Enhancement of the Creativity Process. *Educational Recommender Systems and Technologies*. IGI Global.

Vanderlinde, R. et al. 2014. Institutionalised ICT use in primary education: A multilevel analysis. *Computers & Education* 72, 1-10.

Verbert, K. et al. 2011. Dataset-driven research for improving recommender systems for learning. *Proceedings of the 1st International Conference on Learning Analytics and Knowledge*, Alberta, Canada, pp. 44-53.

Zapata, A. et al. 2013. A framework for recommendation in learning object repositories: An example of application in civil engineering. *Advances in Engineering Software* 56, 1-14.

Zervas, P. et al. 2014. Modelling ICT Teachers' Competences Profile. In Huang, R., Kinshuk, & Price, J.K. Eds. *ICT in Education in Global Context: Emerging Trends 2013-2014*, New York: Springer, In Press.