Supporting the Creation and Sharing of Domain Taxonomies in STEM Learning

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Abstract: Aiming at facilitating STEM learning through video-making, the JuxtaLearn project supports teachers in defining their own domain taxonomies as semantic building blocks for various learning activities. This paper reports on an evaluation with 17 teachers using a semantic recommender system for taxonomy building and lesson planning. Our results indicate that the system is perceived as supportive, but it also reveals problems caused by teachers' individual preferences.

Keywords: collaborative knowledge building, recommender systems, lesson planning

1. Introduction

The EU project JuxtaLearn aims at supporting students' learning of STEM subjects through the creation, exchange and discussion of learner-created videos. The JuxtaLearn approach can be seen as a kind of "second order inquiry learning" in which the creative process follows an initial phase in which the learners appropriate the basic concepts of the domain. No specific assumptions are made about the prior knowledge building process. The ensuing JuxtaLearn-specific process (cf. Figure 1) comprises eight steps: (1) Identification of Tricky Topics, (2) demonstration of subject matter, (3) interpretation of the subject matter by the students, (4) video enactment, (5) composition of a video, (6) sharing the video with others, (7) discussion of the video and (8) review of the results. Tricky Topics and their particular Stumbling Blocks feed through the whole process.

From an educational design perspective, the JuxtaLearn approach is based on the notion of "threshold concepts" (Meyer & Land, 2003) to characterize knowledge elements that enable important shifts of understanding. In the JuxtaLearn approach these are represented as so-called "Tricky Topics" with subordinate "Stumbling Blocks". Initially, the selection of Tricky Topics and Stumbling Blocks depends on the teachers' choices and are not prescribed through a normative reference list e.g. represented in an ontology. Whilst applying a top down ontological construction of threshold concepts would quickly support the system development it would not provide the level of school based validity and engagement required for the levels of impact envisioned in the project.

To support the Tricky Topic definition teachers are provided with a tool to create, manage and explore Tricky Topics easily. The possibility to reuse and share them with other teachers is particularly useful for novice teachers as they profit from previously identified student problems by other teachers.

Teachers begin by identifying the main Tricky Topic and the related Stumbling Blocks. When teachers have problems doing this, they are guided to reflecting on the student problems by proposing Stumbling Blocks that are considered matching to the current set of Stumbling Blocks.

Technically, Tricky Topics and Stumbling Blocks serve as "semantic glue" in the learning environment, as they are attached to all types of learning objects: student problems, quizzes, teaching materials and all subsequent work that students perform.

2. Recommendation of Stumbling Blocks

The recommendation algorithm relies on given pre-knowledge about relations between science topics. The initial knowledge base contains an excerpt from Wikipedia's pages and their underlying taxonomic structure. Thus, a mapping is required between the entered labels and the concepts in the knowledge base. For that reason the user's stemmed input is matched with stemmed labels of the ontology concepts. If no matching concept can be found a new concept with the given label is created for further use.

After the initial matching, the recommendation algorithm works with the concept instead of the label as this allows for language-independent matchings within the knowledge base. A list of candidates for recommendations is generated by considering the following sub-ratings:

1. The current set of Stumbling Blocks is compared to the sets of other Tricky Topics stored in the knowledge base. An adapted version of the Edit-Distance is used to compare these sorted sets. Each stumbling block is considered a symbol, i.e. the more Stumbling Blocks are shared the higher a set is rated. Non-shared Stumbling Blocks are considered for recommendation.
2. All Stumbling Blocks that occur in a minimum number of Tricky Topics are considered as candidates as well. A higher frequency leads to a higher rating.
3. Siblings of the already entered Stumbling Blocks. If a candidate is a sibling of more than one Stumbling block in the set of selected Stumbling Blocks it is rated higher.

At most 15 candidates are chosen from the complete list depending on the weighted sum of ratings from the ratings above. Thus, we implemented a hybrid recommender system (cf. Burke, 2002). Similarity of Tricky Topics is currently weighted higher than the relatedness of Stumbling Blocks. The frequency has a medium weight, because it supports the identification of common Stumbling Blocks for evenly distributed Tricky Topics, but it may have to be revised if the Tricky Topic set becomes unbalanced with respect to topic variety. Stumbling Blocks that are already part of the current Tricky Topic are dropped.

Recommended Stumbling Blocks are shown in the sidebar of the Tricky Topic Authoring Tool (see Figure 1). Users may click on a proposed Stumbling Block to transfer it to the current set of tags. After teachers have entered the first Stumbling Block recommendations are calculated depending on the current set of selected/entered Stumbling Blocks. Newly added Stumbling Block are highlighted.

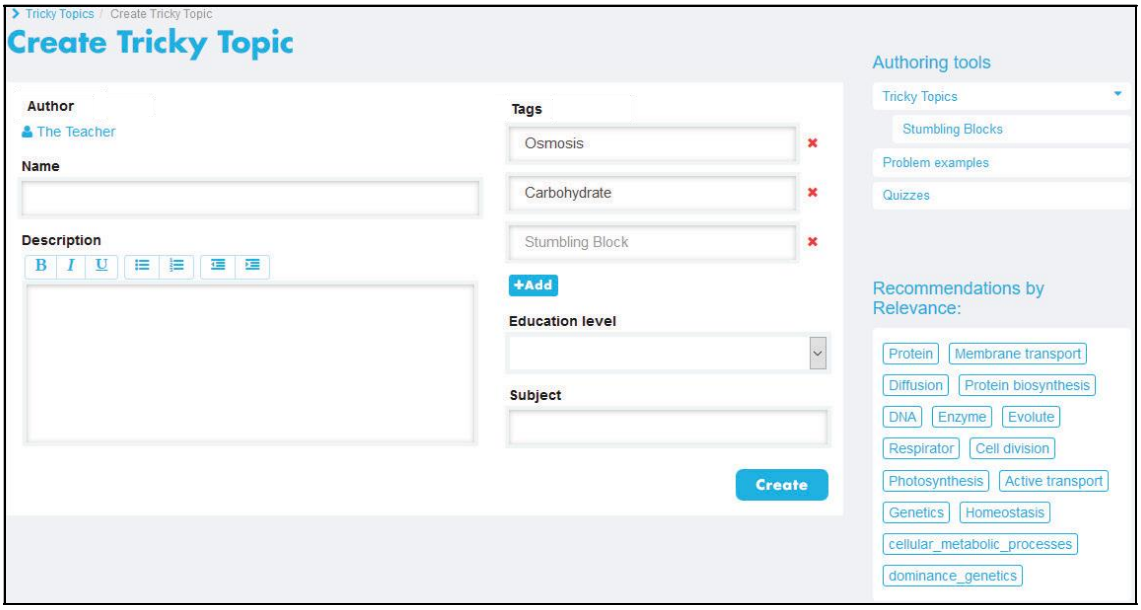

Figure 1. Tricky Topic Authoring. Recommendations are shown in the lower right corner.

3. Evaluation

To evaluate the usefulness and functionality of the recommendation system for Stumbling Blocks, we conducted an experiment. It was conducted with 17 German teachers (14 with more than 5 years of teaching experience) from four different schools (secondary level) teaching math, biology, computer science and physics. They were asked to generate Stumbling Blocks for a given Tricky Topic from their subject using the recommender. Afterwards, the teachers are asked to fill in a questionnaire on their experience with the system (along the ResQue framework presented by Pu et al. (2011)), their affinity for computers and e-Learning (using the 3TUM questionnaire by (Liaw, Huang, & Chen, 2007), and basic demographic data including age and gender. In addition, the Stumbling Blocks taken from the system-generated recommendations were counted and set in relation to the Stumbling Blocks teachers entered individually. The teachers created 16 Math, 16 Biology, 8 Physics and 8 Computer Science topics. The following observations have been derived:

1. Teachers make use of the recommendations and add them to the given Tricky Topic: 29 were created using at least 1 recommended item as a stumbling block. On average 26,69% of the Stumbling Blocks added to a Tricky Topic were added using the Recommendations. ´
2. Teachers perceive the recommendations as a support to build a Tricky Topic: The recommender system was perceived as helpful to discover new items (M = 2.33, SD = .900).
3. The embedding of the Recommendation Tool proves to be smooth and well integrated into the process of creating a Tricky Topic. Most of the users found the embedment of the recommendations results adequate (M = 3.29, SD = .985) and be-came quickly familiar with the system (M = 3.71, SD = .588). Thus, the recommendations are sufficiently embedded.
4. Recommendations contain both novel and diverse items (variety). The Stumbling Blocks were perceived as mostly up-to-date and relevant (M = 2.50, SD = .730). Regarding the variability of the recommended Stumbling Blocks, teachers assessed this desirable feature as moderately expressed (M = 2.29, SD = 1.160).

4. Conclusion

Using the Wikipedia concept hierarchy as a starting point for the underlying system taxonomy provides a rich and solid basis, but it does not always match the teachers' needs in a given curricular context. This is especially true for lower grades in which the systematic scientific structure of the domain may be too detailed for the curricular needs. Accordingly, the system highly benefits from an increasing number of teacher generated Tricky Topics.

We have also observed that the idea of Tricky Topics and Stumbling Blocks was not understood by all teachers (although they said otherwise), as they used whole sentences and very broad concepts (like "problem solving" or "using a calculator") as Stumbling Blocks. While this cannot be solved solely by a recommender system, it once again shows that Tricky Topic editing is a worthwhile exercise that stimulates teachers in anticipating essential problems of understanding on the part of their students.

To enhance the variety of labels that are mapped to the same concept it is planned to include dbpedia's redirection information for similar/equivalent terms. Additionally, a distinction with respect to the educational level may be helpful. It is clear from our findings that teachers want "autonomy of choice" (of vocabulary to describe their curricular concepts) and do not accept to be forced to use only a pre-defined, standardized terminology. On the other hand, they are willing to make use of recommendations as long as these are well contextualized and remain under their control.

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