Analysis and Modeling of Learning Systems and Development of a Process Model for Flexible Orchestration of Learning Environments

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Abstract. Within the fields of research and training, more and more knowledge is generated and made globally available through digital transformation. As a result of semi-structured expert interviews with the employees of an education service provider, lecturers are increasingly overstrained with the amount and the diversity of learning objects. Additionally, lecturers have insufficient knowledge about their own learning system often caused by missing formalization. This adversely affects the teaching quality.
In this paper, a concept for structuring learning systems is created. Therefore, the Learning Object Metadata (LOM) standard is extended to handle hierarchies. The approach enables lecturers to analyze and formalize their own learning system. Furthermore, a process model for the flexible orchestration of learning environments is designed. This supports the lecturer in transferring learning objects from a source to a target learning system. In a scenario-based evaluation, the applied concepts (formalization and orchestration) lead to a higher teaching quality.

Keywords: Education as a Service, Teaching as a Service, Learning System, Learning Environment

1 Introduction

Since the beginning of the 21st century, globalization and digital transformation influence not only industrial production, retail and services, but also the field of research and training [1-2]. By these "intensification border-crossing interactions" [2], broad and standardized educational areas should be formed among other things. One example is the attempted establishment of a Europe-wide higher educational area as a result of the Bologna Process [1], [3]. In contrast to standardization, the specialization in several fields of expertise increases. More and more knowledge is generated and published [4].

Through digital transformation, this wide and extensive knowledge is being made globally available and usable by means of worldwide data networks. However, nowadays, a web-based search query provides more results than usable. An additional

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problem is the missing qualitative evaluation. Thus, the retrieval of relevant content with high quality is complicated [1], [4].

These facts influence the education in general and especially the higher education. Additionally, in tertiary education, lecturers are technical well-skilled in most cases but do not encounter well-founded pedagogical concepts [3]. Another point of criticism that arised during the Bologna Process is the less practice-oriented way of teaching [3]. In this context, Kergel and Heidkamp, who investigate explorative learning, talk about the "complexity of theory-practice-transfer" [1]. The plentiful knowledge is partly not didactically prepared and Röder already mentioned that individual requirements and demand-oriented forms of knowledge transfer are often missing [4].

One possible approach to address these problems is the development of system-based curricula. Such systems might consist of learning material, an application or information system and a model organization. These systems may be provided by education service providers who are also maintaining the infrastructure and the applications for global access. This wide collection of practice-oriented learning objects is formed in the field of enterprise software. Through the years, the amount of the offered curricula increased many times over. New document types were developed, further modules or whole software solutions were added (caused by the swift progress in software technologies) and for globalization reasons new language versions were created.

Members of a special program can find this practical knowledge in terms of media and tools on a web-based platform, but the complexity problem remains. Based on the result of semi-structured expert interviews with the employees of an education service provider, lecturers are increasingly overstrained with the amount and the diversity of learning objects. A one-week train-the-trainer session is not enough to teach the lecturers in transferring learning objects to their learning environment sufficiently. As a further result of the expert interviews, the lecturers have insufficient knowledge about their own learning system often caused by the missing formalization (e.g. no formal model, many sources but partially different data, no obvious dependencies between courses) and about externally created learning content especially in new courses. This adversely affects the teaching quality, for instance because of missing course integration into higher-level context, selection of non-relevant learning objects or missing practical applications.

In order to evaluate the state of the art in this field, a well-structured and reproducible literature review following the method of Seuring and Müller [5] was conducted. The results are briefly summarized as follows. Most of the reviewed works deal with social science theories like the spatial theory, for example, in conjunction with the future campus [6] or media-virtual learning rooms [7]. Other publications do have an engineering background, but the primary focus lies either on the learner [8] or the technical learning system itself [4]. As a conclusion, the state of the art does not sufficiently support lecturers in solving the aforementioned problems.

This paper is oriented towards the Design Science Paradigm following Hevner et al. [9-10]. The problem is already identified and its relevance is investigated by means of a structured literature review. To solve the problem, different artefacts are constructed and their value is evaluated descriptively. The goal of this paper is to create a concept for the structuring respectively formalizing of learning systems and to develop a process model for the flexible orchestration of learning environments. This so-called education/teaching as a service should lead to a higher teaching quality. The scope of these concepts is limited to system-based education, as they cannot be transferred trivially to other educational fields because of their technical difference.

2 Learning System and Learning Environment

In common usage, learning system and learning environment are often used synonymously [4], whereas in the context of this work, these two essential terms were separately defined in the following.

2.1 Learning System

A learning system is conducive "to impart, practice, examine and evaluate knowledge acquirements and skills" [11]. According to Röder, it comprises a collection of media and tools [4]. In this case, media could be single- or multi-media and they encourage the learning process. As tools, he mentions for example experimental arrangements, personnel computers or institutions.

Adapted from the Systems Theory following Masak [12], a learning system is a set of learning components and their relationships to each other. It is a system whose components have learning-theoretical references and different properties. Between these single components, there could be a hierarchical structure.

Taking additional references, a learning system can be visualized [13] and it supports the lecturer choosing the main factors of an educational system (learning goals, learning contents and teaching methods) [14] and as a consequence it encourages the learning and teaching process. Furthermore, a learning system is a model to purposefully describe and optimize learning surroundings.

Learning systems can be differentiated into source learning systems and target learning systems. So-called curriculum designers create the source learning systems with the aim of an absolute standard having reference character for the usage by many lecturers. As opposed to this, the target learning system is defined by the lecturers themselves. If both learning systems have similar components with the same properties, this enables mappings from source to target systems.

Adapted from Chiticariu and Tan [15], system mappings are ambitious and describe the specifications of relations between two systems. It describes how components and their structure can be transferred from a source system to a (partly) different-structured target system.

2.2 Learning Objects

A learning system comprises several learning components. Within computer science, examples for those components are learning objects or - synonymously used - teaching materials like documents or videos and tools like (model) organizations or application or information systems. In this work, learning objects are in the main scope.

Learning objects do have an amount of properties [16]. They can be described with the help of metadata [4]. To guarantee interoperability between (learning) systems, standards have to be followed.

In terms of learning objects, the Learning Technology Standards Committee (LTSC) of IEEE recommends the usage of LOM [17]. These metadata are required for relating learning objects and structuring the learning system. Table 1 shows the extendable blueprint of the LTSC.

Table 1. Excerpt of categories within the LOM standard [4]

Category	*Generic Metadata*
General	Title, description, language
History	Status, author, version
Technical requirements	Platform, file size, media format
Pedagogical requirement	Document type, difficulty level
Rights	Originator, conditions
Relations	Type of relation, description
Classification	Source, tags, purpose

2.3 Learning Environment

According to Röder, a learning system can be structured into two different variants [4]. If the tree structure is used, a hierarchy is generated, whereas applying the main reason of using the net structure is fast navigation. In this work, trees are used because these structure leads to clearer overviews and it is especially adapted for content segmentation.

Considering a determined part of a structured learning system, this part is defined as so-called learning environment. Consequently, in the context of this work, a learning environment is a selection of learning objects (independent of the aggregation level) and their relations to each other with the help of the above-mentioned metadata categories. The complete build-up of a generic learning system is depicted in figure 1.

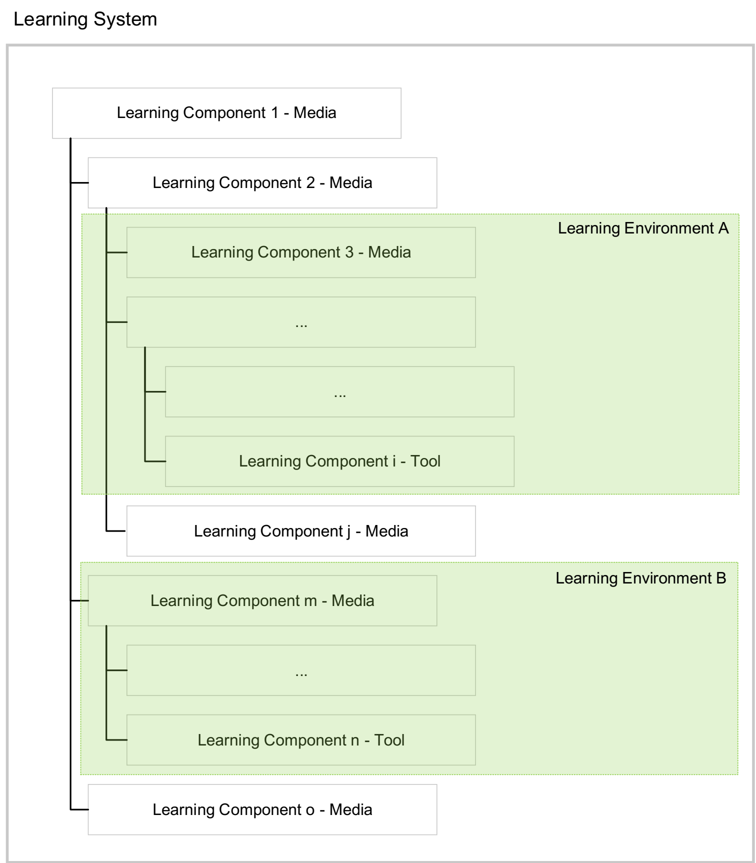

Figure 1. Build-up of a generic learning system

3 Analysis and Modeling of Learning Systems

The following section comprises the systematic derivation of learning systems. The first step is to analyze a source learning system. After that, the way of structuring a target learning system is described.

3.1 Analysis of a Source Learning System

For the mapping process, a given source learning system (e.g. of an education service provider) is assumed. To reach a satisfying mapping result, this system has to be analyzed and described. Generally, since such a system is created for several use cases, the content-related focus and thereby the pursued intentions have to be known to check the applicability for different target learning systems.

As a next step, all components of the source learning system and their relations to each other have to be examined. On this basis, it is necessary to analyze the structure of the learning system. The use of hierarchical levels enables the identification of whole learning object bundles as well as the selection of single learning objects.

As already mentioned, metadata are a requirement to relate learning components, to structure the learning system and to identify target-relevant learning objects. Those metadata can be described, analyzed and categorized with the help of the LOM standard. To handle not only single learning objects but also learning object bundles over different hierarchical levels, the LOM standard is extended in this work, for example, using one property like 'language' as bundle metadata to group together several learning objects by this property.

Moreover, it is necessary to take care of the following or content-similar metadata: 'Content-related tags', 'language' and 'difficulty level'. As a result of the first prototypical case study done within this paper (see chapter 5), these extendable set of metadata is ranked as essential for the mapping process. The more metadata exist, the more precise the selection of learning objects is.

3.2 Structuring of a Target Learning System

After analyzing the source learning system, the next step is to structure a target learning system (e.g. a course or an entire professorial chair of a university). The following guidance is a useful approach to formalize generic learning systems.

As with the source learning system, the content-related focus and its field of application have to be determined. This is a rough orientation and it enables application analysis among others.

With the help of different instruments like (module) manuals, catalogues, organizational and operating plans as well as integrated (information) systems, structuring criteria of the target learning system can be identified. For the following structuring, an unambiguous hierarchy is absolutely essential. To make this structure decision, the information content of the used instruments is crucial because potentially one of them specifies the structure (e.g. 'faculty – study path – module' or 'faculty – institute – module') implicitly.

After structuring the target learning system for the elements of all hierarchy levels, metadata have to be identified to realize the following mapping process. Again, as with the source learning system, the more relevant metadata exist and the more precise the specifications gathering these metadata are, the more precisely the need of learning objects can be defined.

Subsequently, the object under investigation has to be demarcated clearly. Examples could be single learning objects of a course, entire courses or successions of courses.

As a result of the case study done within this paper, for the demarcated object, the following or at least similar metadata are also absolutely essential for the mapping process: 'Content-related tags', 'language' and 'difficulty level'.

For the object under optimization, the following process model can be used to flexibly orchestrate learning environments.

4 Process Model for flexible Orchestration of Learning Environments

After analyzing a source learning system and structuring a target learning system, the following three-step mapping process model has to be applied. At first, both systems are adjusted to each other (adjustment) to increase the mapping result quality. Secondly, based on the selection criteria, a sample space of learning objects from the source is orchestrated (selection). This quasi-generated learning environment is adjusted within the third step (refinement). All three steps will be described in the following.

4.1 Adjustment

If both systems have similar metadata, they can be matched and afterwards mapped to each other. As already mentioned, this will increase the quality of identifying learning objects because with the help of the adjusted metadata the source learning system can be browsed effectively and efficiently. These cutbacks of the entire source learning system simplify the identification of only course-relevant learning objects for the lecturers.

To enable a productive mapping, the transformation of the three metadata 'Content-related tags', 'language' and 'difficulty level' is absolutely essential because these are the as a result of the case study identified main selection criteria. Generally, there has to be paid attention since such optimizations include some risks because of incorrectly adjusted metadata making it difficult to identify relevant learning objects.

4.2 Selection

After adjusting metadata of both systems, all necessary metadata have to be collected in the so-called metadata base. This base consisting of assembled and adjusted metadata is used to reduce the entire source learning system and filter/select relevant learning objects from all hierarchy levels step by step and transfer them into the sample space. In doing so, the following problems can occur:

1. Too many learning objects were identified.
2. Not enough or just partly relevant learning objects were identified.
3. No (relevant) learning objects were identified.

4.3 Refinement

These problems could be solved independently of each other during the refinement phase. Using content-related and structural tags, the created sample space (learning environment) could be browsed again and thus being reduced effectively and efficiently. This way, surplus learning objects can be easily removed. Additionally, a prioritization performed by the lecturer also refines the result.

Hierarchization, combination and orchestration can solve the problem of insufficient learning objects. The hierarchization uses structural attributes to identify not-selected or just (incorrectly) removed learning objects at the same hierarchy level. Because of the unambiguous reference to the original object, the selection is added to the learning environment.

Combinations make sure that necessary relations and dependencies between learning objects are included in the process of refining the learning environment. Learning objects identified this way are requirements or extensions of the present learning environment. Via orchestration, optional recommendations from the curriculum designer on the side of the source learning system can be included in the learning environment.

If there were no relevant learning objects identified, the target learning system has to be more specified in further iterations or the source learning system has to be checked for the presence of relevant learning objects.

4.4 Evaluation of the Learning Environment

As a last step, the lecturer has to apply the learning environment created for himself to evaluate the result. This includes the appraisal of the composition grade, especially with reference to usage, quality and utility of the learning objects for the purposes of the course under investigation.

As part of continuous improvements, the evaluation results can be used to enhance the source learning system with the help of the identified potentials. By way of example, a restructuring of the source learning system could lead to higher quality learning object composition grades or an addition of further metadata to existing learning objects could lead to better selections.

5 Case Study

In order to proof the concept, a scenario-based evaluation was chosen. At first, an exemplary source learning system was analyzed. Afterwards, a target learning system was restructured. Finally, the mapping process was executed to select and orchestrate course-relevant learning objects from the source and transfer them to the target learning system. The whole process model is depicted in figure 2.

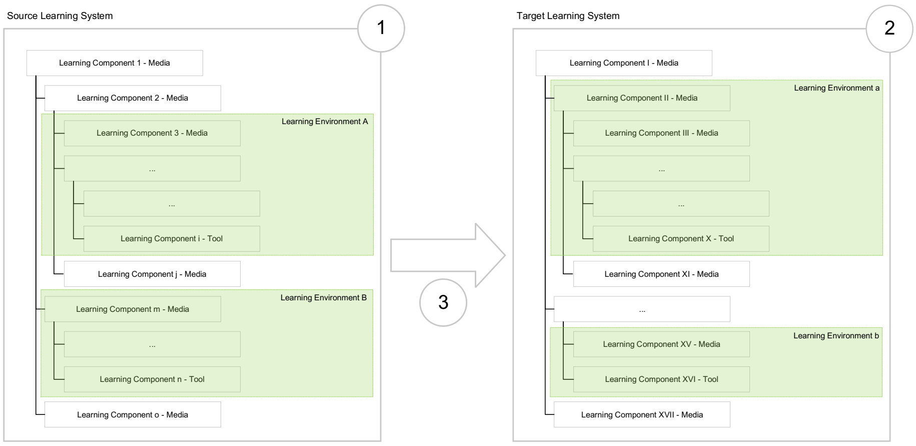

Figure 2. Generalized evaluation process model

The learning system constructed by the education service provider was taken as a source. This composition consisting of learning materials (media), a model organization and an application system (both tools) was created with the main goal of practical use. Considering media only, learning objects are on the bottom-level of the system's hierarchy. These objects were combined to so-called modules and these then were combined again to so-called curricula on the top hierarchy level. To handle those hierarchy structures, the LOM standard was extended, so that not only learning objects can have metadata, other level also could have. In figure 3 the exemplary source learning system including those metadata is depicted.

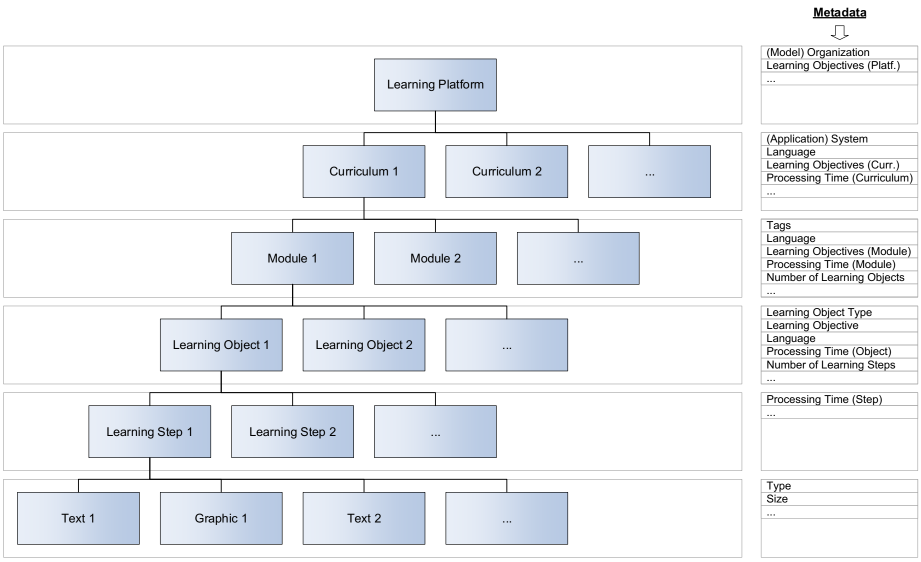

Figure 3. Structure and exemplary metadata of the source learning system

On the other side, an informatics faculty of a German university was chosen as exemplary target learning system. In a semi-structured interview with the teaching coordinator the status quo was qualitatively gathered in detail. All learning modules including some metadata were collected in a module catalogue, but there was no formal model to reveal structural dependencies between these modules. The reasons were too many artifacts trying to structure the system, redundantly data storage, uncertain responsibilities and the absence of formal rules to enter all module metadata consistently.

As main problem the numerous and diffuse structuring opportunities concomitant with missing formalization were identified. The learning system was described decentrally with different artifacts but there was no unambiguous and complete definition. With the help of these artifacts and the expert interview, the system was restructured as depicted in figure 4.

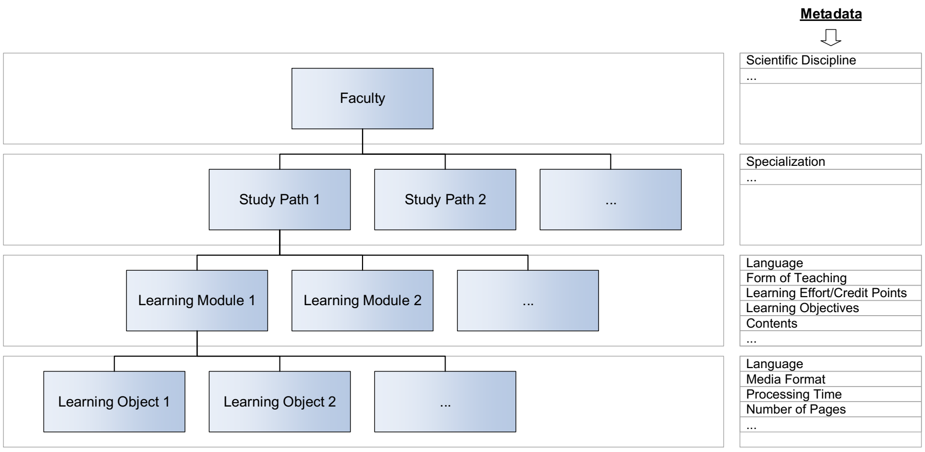

Figure 4. Structure and exemplary metadata of the target learning system

It could be seen that both systems had similar hierarchical structures. Similar metadata were identified and, if needed, adjusted to reach a higher quality mapping result. To create a learning environment for a specific course, the metadata base was determined. Based on this, learning objects were selected and the thus created learning environment was refined after a weakness analysis.

All content-related (i.e. intended learning goals, course content) and structural (i.e. language, duration, learning objectives) requirements were objectively fulfilled. For example, the temporal frame of 1,260 minutes to be available was exceeded by just 2% while using all proposed learning objects. However, the process of composition could counteract exceedance as well as shortfalls (see refinement).

A second expert interview showed that the orchestrated learning environment also subjectively fits. Despite this one specific case, important tendencies were figured out. The usage of the process model resulted in effort minimization, especially the temporal effort of the learning coordinator (approximately reduced by half), regarding learning objects selection and course creation.

By using the process model, the intricacy of the mapping process from source to target learning system is reduced and the complexity of learning systems in general is more manageable.

Of course, the mapping process, the resulting learning environments and the learning effort of the learner have to be further evaluated by means of variance analysis for at least two terms.

6 Conclusion

As stated before, the missing formalization of learning systems is a big issue. Furthermore, it was pointed out that lecturers are increasingly overstrained with the amount and the diversity of existing learning objects. As consequence, the problem is how to figure out the requirements (metadata) of a non-formalized learning system and to select and transfer relevant learning objects into a specific learning environment.

In this paper, a concept for the structuring of learning systems was created. It enables lecturers to analyze and formalize their own learning system. That is the prerequisite to fill parts of the system with high quality learning objects from a learning system with similar metadata.

Furthermore, a process model for the flexible orchestration of learning environments was designed. This supports the lecturer to transfer learning objects from a source learning system to the lecturer's target learning system (e.g. courses, research groups, trainings).

The advantages of using the learning objects from the source learning system are the large amount and variety of high quality teaching topics and their high topicality. Additionally, the lecturers have central access to the learning objects with a high availability. Finally, the lecturer can choose flexibly the learning objects and change its learning environment by means of the three-step mapping process.

All in all, if the target learning system is formalized, it enables the application of the mapping process. As a result, high quality learning environments can be transferred to the target learning system. Regarding to the introduction, this leads to a higher teaching quality as the evaluation with real lecturer staff showed in the described case study. Additionally, the lecturer has to spend less time creating learning materials. He only has to get familiar with the externally created learning objects and benefits from the external expert knowledge.

For future research, comprehensive evaluations have to be done. Therefore, the process model can be applied gradually to further test cases, for example starting from other lecturers in the same learning system up to different lecturers in further learning systems. Additionally, the transferability of the process model to other educational fields has to be investigated. Thus, the quality of the generalized process model in different domains can be examined.

Another aspect is the correlation of changes in orchestrated learning environments over at least two terms and the accompanying changes in the learner's learning success. By means of evaluations of the lecturers, conclusions about the quality of the learning systems as well as of the process model can be drawn.

For future research with engineering reference, the implementation of the selection process for the automatic orchestration of learning environments could be possible. This leads to an effort minimization for the lecturers.

References

1. Kergel, D., Heidkamp, B.: Einleitung. In: Kergel, D., Heidkamp, B. (eds.) Forschendes Lernen 2.0. Partizipatives Lernen zwischen Globalisierung und medialem Wandel, pp. 1-15. Springer VS (2016)
2. Obermaier, R.: Industrie 4.0 als unternehmerische Gestaltungsaufgabe: Strategische und operative Handlungsfelder für Industriebetriebe. In: Obermaier, R. (ed.) Industrie 4.0 als unternehmerische Gestaltungsaufgabe, pp. 3-34. Springer Gabler (2016)
3. Paetz, N.-V., Ceylan, F., Fiehn, J., Schworm, S., Harteis, C.: Kompetenz in der Hochschuldidaktik. VS Verlag (2011)
4. Röder, S.: Eine Architektur für individualisierte computergestützte Lernumgebungen. In: Ehrenberg, D., Rieger, B., Stahlknecht, P. (eds.) Schriften zur Wirtschaftsinformatik, vol. 15. Peter Lang (2003)
5. Seuring, S., Müller, M.: From a literature review to a conceptual framework for sustainable supply chain management. In: Journal of Cleaner Production, vol. 16, pp. 1699-1710. Elsevier (2008)
6. Brandt, S., Bachmann, G.: Auf dem Weg zum Campus von morgen (Keynote). In: Rummler, K. (ed.) Lernräume gestalten – Bildungskontexte vielfältig denken, pp. 15-28. Waxmann (2014)
7. Grünberger, N.: Räume zum Flanieren, Spielen und Lernen. In: Rummler, K. (ed.) Lernräume gestalten – Bildungskontexte vielfältig denken, pp. 56-67. Waxmann (2014)
8. Engelbert, B., Morisse, K., Vornberger, O.: Zwischen Nutzung und Nutzen. In: Rummler, K. (ed.) Lernräume gestalten – Bildungskontexte vielfältig denken, pp. 508-519. Waxmann (2014)
9. Hevner, A.R., Chatterjee, S.: Design Research in Information Systems. In: Sharda, R., Voß, S. (eds.) Integrated Series in Information Systems, vol. 22. Springer (2010)
10. Hevner, A.R., March, S.T., Park, J., Ram, S.: Design science in information systems research. In: MIS Quarterly, vol. 28, pp. 75-105. Springer (2004)
11. Duden: DUDEN Informatik. Ein Sachlexikon für Studium und Praxis. Dudenverlag (1993)
12. Masak, D.: SOA? Serviceorientierung in Business und Software. Springer (2007)
13. Winand, U., Pohl, W.: Forum Virtuelle Lernwelt. Ein umfassender Zugangsservice zur multimedialen Aus- und Weiterbildung. In: Winand, U., Nathusius, K. (eds.) Unternehmungsnetzwerke und virtuelle Organisationen, pp. 331-337. Schäffer-Pöschel (1998)
14. Kerres, M.: Multimediale und telemediale Lernumgebungen. Oldenbourg (1998)
15. Chiticariu, L., Tan, W.-C.: Debugging Schema Mappings with Routes. In: Proceedings of the 32nd international conference on Very large data bases, pp. 79-90. VLDB Endowment (2006)
16. Coad, P., Yourdon, E.: Object-oriented Analysis. Yourdon Press (1991)
17. Learning Technology Standards Committee: IEEE Standard for learning object metadata. In: IEEE standard 1484.12.1-2002, pp. 1-40. (2002)