Information System for Mapping the Coverage of Reference Curriculum Guidelines in the Teaching Curricula of a Higher-Education Institution

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***Abstract*—This paper presents the results of a project of the introduction of a specialized Information System for mapping the coverage of knowledge topics as given in reference curriculum guidelines established by renowned world organizations (such as ACM and IEEE in the area of computing), as a step to enable the establishment of a qualitative, and not just quantitative process to reforming the existing curricula and introduction of new knowledge areas or topics in order to foster improvement in teaching capacities and capabilities.**

***Keywords*–Curriculum management; curriculum analysis; curriculum mapping; reference guidelines; information systems.**

I. Introduction

During the time I was working at the Faculty of Computer Science and Engineering, and at the Faculty of Natural Science and Mathematics in the past, both at the S-s Cyril and Methodius University in Skopje, Macedonia, I have witnessed several iterations of curriculum design and development processes. These institutions have focused on nurturing computer science since their beginning, but global trends in the past few decades were such that we have created separate study programs for software engineering, information technology, information systems and computer engineering, and respective reconstructions of the curricula. Beside this, since computing overall is a field in continuous flux, to have the benefits of the constant redefinition of technologies, new theories and algorithms, we have also undergone many curriculum redesign efforts, of which I have witnessed the ones that finished with the accredited study programs in 2001, 2005, 2009, 2011, and 2013.

Being in position of constant change, some provoked by new trends in the world, a quite a few mandated by legislative changes it became obvious that a structured solution is required that will enable to keep a record at least, of all the final results in all these curricula reconstructions and also to enable the institution to keep track of student progress through one or another version of a curriculum. According to Macedonian laws a student has the right to remain within the original study plans and programs, that were active at the moment of her admission for a minimum of 8 years. The effect of this is that students admitted in 2006/07 have the right to keep studying according to their study plan (which is the one that was accredited in 2005), until 2014. Although processes of accreditation have occurred in 2009, 2011 and 2013, bringing changes in the curricula, such students have the right to continue studying according to the plans from 2005. The effect is that at the same time we have to track each student according to their original program and if the student decides to switch to one of the newly accredited programs, we have to allow this change and enable the student to keep the past work in terms of credits and grades.

Why would a student want to study 8 years or more, for a 3 or 4-year undergraduate program? Well, our country is plagued with unemployment (30% of the population), and our system is such that allows the students to grasp opportunities as they come, and be able to continue studying with a decreased load (less than 30 ECTS per semester) or retake failed courses several times.

One might look upon all this as just a special case, that is not applicable to any other part of the world and hence not of wider interest. Since unemployment is a worldwide problem and the necessity to study part-time, online, as part of evening schools, or generally in programs with a decreased number of regular classes it is becoming obvious that this discussion is already or can become applicable to any university in the world. Since, these special circumstances ask for a solution that would be a flexible one, a solution that allows many scenarios. And in fact, such a solution has evolved as part of a long-term research project that originated from the 1990s and is still developed. The solution – ISIS (Integrated Study Information System) presented for the first time to a wider

This paper presents research and development that was part of the project ISISng [1] – The project was partially financed by the Faculty of Computer Science and Engineering.

audience in 2009, [2] was built to enable a university to have a record of all the institutions, study plans, programs and curricula from the past and also ones that are active at the moment, enabled to track the students enrollments in each semester (or more flexibly terms if there are more than two semesters) even for students that have been enrolled to two or more study programs at the same time, enabled to differentiate if a student has enrolled a course according to a specific study program and enabled to have all of this differ either at the level of the institution or at the level of a study-program within that institution.

The ISISng further evolved in several directions with some additional capabilities (see [3], [4]), but something that it never had – was the possibility to have a structured record on the specifics of what should be taught as part of curricula. This information was only recorded as a full-text document as part of the external documentation in the accreditation process and as such, it did not give many opportunities to be used for an in-depth curriculum analysis.

The design of a curriculum should involve a systematic process passing through several phases. First, a set of learning goals and objectives should be identified, then the core knowledge topics should be decided on, and subsequently learning activities and assessment activities should be identified and developed [5]. The whole of the process should be streamlined in such a way, that the learner is guided through the educational experience by the curriculum design itself.

In this paper, the results of the effort towards an extension of the ISIS system are presented, with an implementation of a structured process in which the curricula are mapped to the knowledge unit topics proposed as part of internationally known curriculum guidelines (such are the ones produced by ACM, IEEE, and AIS). This is a necessity that allows a more formal analysis of the existing curricula and their success, and should be considered as a prerequisite of a more formal process of curriculum design.

II. Related work

Curriculum mapping has been used and discussed by many authors for at least 3 decades. This section will point-out some references in this area that I consider to be of interest and relevant as comparison and context to the system that I propose.

The notion of curriculum mapping as part of a more formal process for review and analysis of the actual curricula being used at a certain institution has been extensively elaborated by Hayes Jacobs, as devised to be used at K-12 schools, but similar process can be performed also at higher-education institutions [6]. As discussed by Hayes Jacobs the mapping is a procedure for finding out what teachers actually do through the course of the calendar school year and putting it on a map in the form of a calendar. In contrast to this approach, the idea presented in this paper is to perform mapping topic-by-topic (which might be at the same time week-by-week, but it does not have to be so) in order to focus on understanding what is that one wants to teach, as opposed to what one really teaches.

Szabo and Falkner describe where techniques in curriculum mapping can be used to enable a fine-grain analysis in a course level on the timeliness of introduction of certain topics within the course. [5] While this can be of great use to certain teachers in certain courses, and can be used to analyze in much detail the inter-dependencies among courses, and the gain from it would be improvement of the definition of course prerequisites, the idea behind this paper is not to go to such level of depths of analysis, but to only discuss at the level of topics and how good of a coverage for the area or the field do they give.

Romkey and Bradbury discuss the process of curriculum mapping but from the point of view of students and how would they perform it [7]. But, the process that is described in this paper is bound to happen during new curriculum design, period when students can not be involved in wider scale, especially not by teachers and during courses. In the notion of the idea of mapping as proposed in this paper, student involvement might be possible to arrange as part of a collaboration between the higher-education institution and their respective student or alumni organizations, during the period of curriculum reconstruction.

Techniques for semi-automated or fully-automated curriculum analysis, mapping and comparison are also part of this research field. As a notable example, Sekiya, Matsuda and Yamaguchi developed a method of systematic analysis of curriculum syllabi by using LDA (latent Dirichle allocation) and Isomap, which they used as a basis for several research efforts [8] [9].

I believe that only when we are able to explicitly state what we believe to implicitly know, we might be able to claim the knowledge. So, if an institution undergoes an evaluation of the study programs based on automated tools, they will be able to calculate some useful indicators of the trends and situation, but sometimes the journey is equally or even more important than the destination. This is why I propose a tool and a system which main goal is the navigation throughout the curricula and knowledge space, as part of a learning process about the institutional self.

When discussing tools to enable manual curriculum mapping, I would point out the STOPS tool, as a graph based study planning and curriculum development tool [10]. This tool can be used both by students and developers and offers different point of views. While the authors of the STOPS tool focus on mapping the curricula outcomes and try to define the prerequisites from the outcomes, in this paper the idea is to map the curricula to a standard BoK topics (such as ones that are part of curricula guidelines) and the prerequisites are a more generalized notion that should be defined on the basis of the topics that are mapped within the curriculum.

III. Analysis of Curriculum Mapping Extent

The main vision behind the new curriculum mapping extension of the ISIS system that was described in the introduction, is that: the design of new curricula, reconstruction of the past curricula and assessment of the success of the implementation of current curricula – should define, keep and integrate tight associations between the respective curricula proposals and their contents on one hand, and the body of knowledge as defined in reference curriculum guidelines on the other hand.

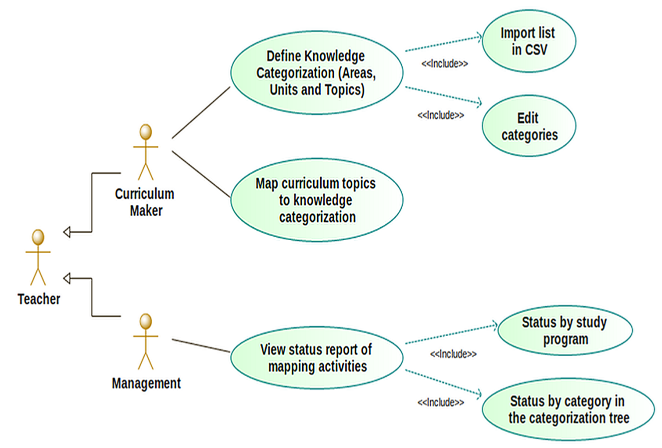

Fig. 1. Priority functional areas of the system: definition of body of knowledge categorical structure, mapping of curriculum topics to the knowledge categories and reporting functionalities.

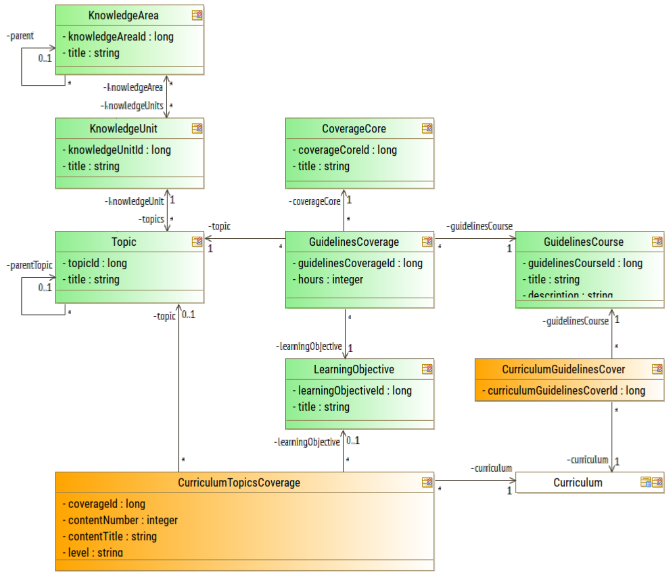

Fig. 2. Class diagram of the coverage mapping with definitions of knowledge areas, knowledge units per area, proposed topics in each unit, and the proposed coverage of each topic.

The system functionalities are grouped in 3 functional areas, as illustrated in the UML use-case diagram in Fig. 1:

- Definition of the Body of Knowledge
- Mapping of curricula to Body of Knowledge
- Reports on the status of the mapping effort

The definition of the Body of Knowledge is a relatively straightforward process since this categorical structure is usually organized as a hierarchical tree having the knowledge areas at the top-level, the knowledge units at the middle and topics at the bottom (leaves) of the tree. As such they are simple to implement, with the only complication is that it should be allowed to have in use several independent categorical structures or alternate definitions of the Body of Knowledge.

The mapping of the implementation of curricula to the relevant Body of Knowledge and the reference guidelines could be done at several levels:

- Mapping at the level of whole study programs to certain specific knowledge areas from the guidelines. This is too broad and would not allow gathering information on more details on how curricula are implemented
- Mapping at the level of whole curricula per subject domain, could be considered as a bare level of mapping, since it gathers info on the knowledge unit that one curriculum implements, but there is no information on how it is implemented.
- Mapping at the level of topic for each curriculum, allows much more details and fine-grained recording of how a certain curriculum is implemented and how does it relate to the other curricula. Such a solution gives the possibility to see if several curricula implement the same parts of the Body of Knowledge, and to investigate if there are curricula that are mere unwanted duplicates of each other or separate instances that in fact offer additional knowledge and better specialization. This will also allow to have a detailed account on the human resources and competencies that will be required to establish such a curriculum and teach it with success and to do it in the most optimal manner by eliminating possible duplicate coverage where it is not needed.

As an experiment, the analysis and design of this system started in the field of computing, with the investigation of the curriculum guidelines in several fields defined by ACM, IEEE, AIS and AITP (As an example see: [11]). During the design of the experimental system, this level of mapping per curriculum topic was chosen and its implementation is detailed in Figure 2. Note that the Curriculum class references parts of the class diagram in Figure 3.

IV. Software Construction

The new Mapping information system was designed to function as a sub-system of the ISIS (Integrated Study Information System), hence benefiting from the ability to use parts of its code-base and practices established within other projects to introduce curriculum management. This allowed a jump forward the development directly to the construction phase.

Fig. 3. Class diagram of the structure of study plans in each institution, with study programs and offered degrees, curricula per program for each subject domain, and graph structure showing the full graph of links between curricula allowing many types of links.

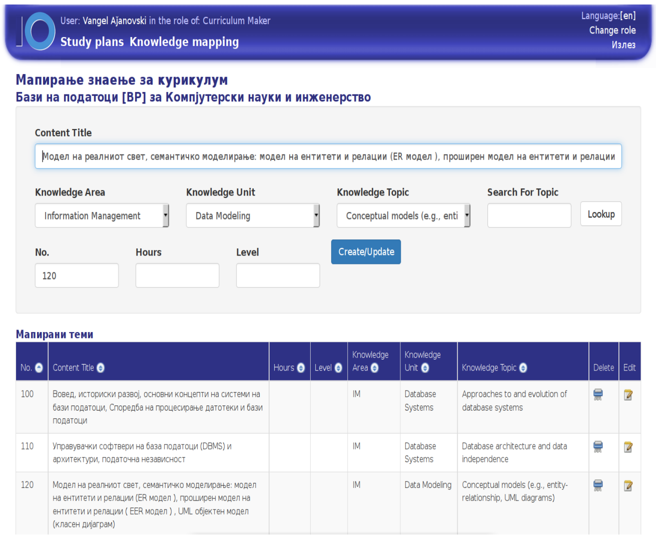

Fig. 4. The web page where all the content mapping occurs. The bottom part shows the list of content topics expected to be taught in a curriculum. In the top part of the screenshot there is a form for definition of new content topics, or editing already defined ones.

The construction phase included: design of new system use-case scenarios, new background and front-end services, new user interface and integration with the existing subsystems of the existing solution.

See Fig. 3 for more detail on the implementation of the structure of the study plans within the ISIS system.

The most important use-case scenario – *A Curriculum Maker maps content topics in a certain curriculum to the Body of Knowledge categorization* is defined as follows:

- The Curriculum Maker opens the list of curricula in a study program
- The Curriculum Makers selects the respective curriculum for editing
- The System displays the list of content topics that are defined for the curriculum
- For each of the content topics, the Curriculum Maker selects a Knowledge Area, Unit and Topic from the Body of Knowledge (or searches for the exact topic that mentions the given search word)
- Alternative: The Curriculum Maker can use specific KA, KU or KT to indicate that she has not yet decided on the most appropriate mapping
- Optionally, the Curriculum Maker specifies how many lecture hours are dedicated to the topic, what is the level of complexity expected for teaching this content topic

The screenshot on Fig. 4 displays an example implementation of the main scenario in a web interface form.

V. Deployment

The success of a project of this caliber at any institution depends on the strong willingness of the management and their concurrence to a single vision that such a system is truly needed and will make benefits to the institution.

Significant investment in both time and effort is required to fully map the entirety of an institutional curricula catalog. The main problem is that this can not be done by delegating the work to administration or technical staff since a sufficient level of competence has to be met in any given knowledge area in order to be able so successfully map the content topics from a certain course curriculum to the most relevant knowledge topics. This can only be done by the teaching or research staff and could take a significant amount of time (especially when designing new curricula).

Because of this, it is recommended to undertake a pilot project of the overall process, but in a real-life scenario at the institution in question, with specific Body of Knowledge per different subject domains. The pilot should include a representative sample of curricula chosen from several curriculum types and different subject domains. In that way, the management can be assured on the feasibility of the process, and a confident decision can be made on the transition of such a system to a production environment.

In order to be able to fully test the system, and assess the success, a complete functional test environment was designed to be performed on a real-life sample from the Curricula at the institution in question. This required that all the proposed categories from the Body of Knowledge tree for the relevant curriculum guidelines were already imported correctly into the system (Fig. 5).

Fig. 5. Imported ACM Body of Knowledge.

VI. Pilot Project and Test-Process Results

The test scenario included both editing of the body of knowledge and categorization trees and submitting curriculum mappings, topic-by-topic. This is a highly customized process and depends on the structure of the curriculum materials and how easy it is to turn them into structured list of topics and find the relevant categories from the tree of the body of knowledge.

As an experiment, this process was done by the author, as part of a real-life functional test for the benefit of the author's institution. The test was done by fully using the system and the proposed structure for mapping and as such it lasted a significant amount of time (measured in several hours per course), while requiring many consultations with literature in the relevant areas (even though the authors holds a PhD in the field). To formalize the process, and guarantee a timely finish – the following test-procedure was implemented:

- Open the curriculum for editing
- Find the study program accreditation elaborate and lookup the specific document for the chosen curriculum
- Convert the "description" part of the document to a list of sentenced, in order to convert each sentence into a curriculum content topic
- Each sentence is rephrased so that it can be read as a topic in the curriculum
- Number each of the sentences to enable sorting, but use tens or hundreds in order to allow splitting or joining the topics, and still be able to use the sorting
- Try to find relevant knowledge area, unit and topic from the Body of Knowledge classification tree
- If the content topic can be mapped to several knowledge topics in the Body of Knowledge tree, then split the topic to several sub-topics and repeat the step for each of them
- If several content topics map to a single knowledge topic from the Body of Knowledge tree, join them under a single overall topic
- Decide on the number of lecture hours that should be spent on each of the content topics, and the level of complexity.

Although a test-procedure of such does not prove the true feasibility of the introduction of this system, nor does it prove the effectiveness, it still gives an illustration on the amount of work required and gives hints towards proper planning and management decisions. With this test procedure, applied to a random-chosen curriculum that is not among the competencies of the author, it only took an hour to roughly sketch the content of the curriculum and categorize it to what seemed the most appropriate knowledge topics from the Body of Knowledge, but it would warrant additional effort of checking the mapping and refining it by competent individuals. For a curriculum that is part of the competencies of the author, it took much less time for a rough sketch of the content topics, but it took another 1-2 hours to finalize all the details.

This test, concludes that the average speed of a competent individual in the role of a Curriculum Maker could be up to 3 curricula per working day. The process could be completed in under a month for all curricula under the current accredited study program if their respective teachers are involved in the mapping. If there were many accredited study plan instances in the past, it might take up to that many months to finish the process for all the historical curriculum, but in reality it should take significantly less since more often than not – copies of curricula are created for new accreditation documents and the content is only partly changed, if changed at all.

VII. Reports

Crucial part of the system are several reports that enable to assess the status of the mapping project and analyze the curriculum mapping in order to decide on the quality of the mapping, on the degree of coverage of certain priority knowledge areas and units.

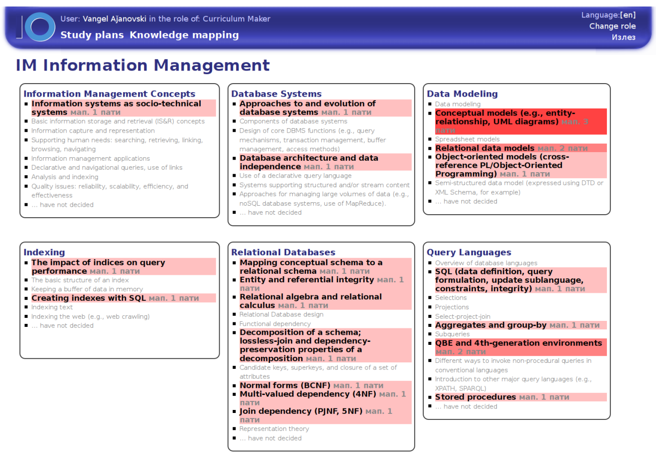

Fig. 6. Report of mapped Body of Knowledge topics.

The screenshot on Fig. 6 shows part of the report on the mapping effort as it goes underway. All Body of Knowledge Areas are displayed, with all Knowledge Units represented as boxes, while inside of them one can see the proposed Knowledge Topics that are part of the Curriculum Guidelines.

The topics are marked in the sense of a heat-map, indicated topics that are references by many curricula with bolder and more intense colors. The total number of lecture hours for each topic is also indicated in the report.

The screenshot on Fig. 7 shows another report displaying a side-by-side comparison of all curricula that map to a certain topic. This report is useful to investigate possible duplicate content across curricula. As an example, if we find that there are many curricula topics that map to a single knowledge topic from the Body of Knowledge, it can serve as an indicator that the same lectures are used over and over again in many courses and this should be investigated in more detail.

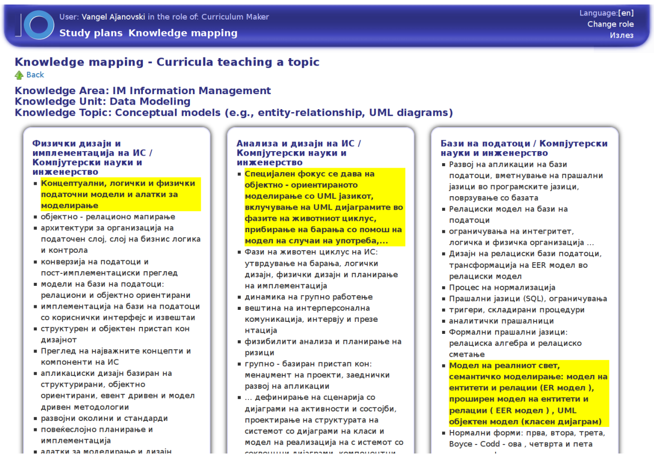

Fig. 7. The screenshot shows an example of a situation when several curricula map learning content to a single topic. The topic from the BoK is “Conceptual Models” and it is mapped to different learning content topics proposed by three different curricula – the image is in original macedonian language as part of the analysis of FCSE study programs.

VIII. Conclusion and Future Work

This paper explains the rationale behind the decision to design and implement an information system for mapping the coverage of reference curricula guidelines in the active study plans and programs of a higher-education institution, and reports on the result of this development. The developed system, includes solutions for the following problems:

- Keeping the structural description of all past, active and future study programs and their differences for a typical HE institution and its many departments, institutes, faculties and centers.
- Structure of the body of knowledge, with areas, units and topics can be defined and redefined and mapping can be established separately for each curriculum, for each subject and for each study program
- Assessment on the current state of curriculum mapping to guidelines, and state of the coverage of study program overall can be performed at any time
- Further analysis can be performed on the similarities and differences on various curricula and on programs overall, by using custom queries within the database.

As ISISng is envisioned as a multi-year project, work has already begun in converging the past efforts to other initiatives at the university related to the improvement of the quality of teaching and research, such as: tracking the implementation of reference curriculum guidelines in teaching week-by-week; monitoring student success and mapping their results to the Body of Knowledge; general human resource management and capacity development about teaching; and mapping and tracking researchers’ work to the proposed Body of Knowledge within reference curriculum guidelines.

Further work within the framework of the ISISng project will also continue in the area of curriculum assessment and analysis of the effects that the structure of the study plans and curricula has over learner success (see [12], [13]).

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