Enhancing Knowledge Flow by Mediated Mapping Between Conceptual Structures

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Abstract. **Intra- and inter-institutional knowledge flow usually is hindered by a number of mutually related knowledge barriers. Removing some of these barriers may enhance knowledge flow and thus open new opportunities for cooperation. In this paper we illustrate how indirect conceptual mappings supported by a software tool can remove some of knowledge flow barriers and have a positive impact on the knowledge flow. The approach described in the paper is presented in the context of cooperation between industrial and educational institutions in the area of information and communication technologies.**

Keywords- knowledge flow, concept structures, competence framework; mediated comparison; study courses; job positions

I. INTRODUCTION

Knowledge flow is a process whereby knowledge is passed between people or knowledge processing mechanisms [1], [2]. There are a number of barriers that may hinder the flow of knowledge. In [2] these barriers have been grouped into 5 categories: knowledge characteristics (such as causal ambiguity and non-valid knowledge), knowledge source barriers, knowledge receiver barriers, contextual barriers, and insufficient mechanisms. This paper addresses only two of these categories, namely, knowledge receiver barriers and contextual barriers. The knowledge receiver barrier is minimized by raising absorptive capacity of knowledge flow receivers. Insufficient mechanism is addressed by proposing an information technology solution that facilitates knowledge exchange between two parties. The issues are discussed in the context of Information and Communication Technology (ICT) knowledge exchange between industrial organizations and educational institutions operating in European Union (EU) countries. The main focus is on the fit between knowledge/competence/skills demand of industrial organizations and knowledge/competence/skills offer by educational institutions.

Industrial organizations (further in the text - Industry) usually maintain the so-called job position framework that consists of a list of positions and their descriptions in terms of responsibilities and competencies. On the other hand educational institutions (further – Universities) maintain

course descriptions in terms of topics covered, learning outcomes, obtainable knowledge, and skills. Different concept systems are used for the description of Industry job positions and University courses. This causes a knowledge receiver barrier - low absorptive capacity (lack of sufficient related knowledge to assess the value of transferred knowledge) for both parties in exchanging competence knowledge. Because of this barrier University and Industry find it difficult to "understand" each other [3]. Taking into consideration that competence is becoming a kind of "currency" in the job market [4], there is a need to compare competence demand from Industry and competence offer from University in order to see if the university can satisfy competence needs of Industry. This requires improving absorptive capacity of both partners. The purpose of this paper is to show that comparison of competence demand and offer becomes possible (the absorptive capacity barrier can be lowered or removed) if standardized competence frameworks are utilized as a mediating conceptual structure between "languages" of Industry and University. The use of the framework is practically possible only if a supporting information technology is available. In other words – addressing the absorptive capacity as a cause of receiver barrier requires addressing the insufficient mechanism barrier, too.

The method proposed in this paper extends the mediated comparison method described in [5] by utilization of several mediating frameworks. The extension is made in order to facilitate knowledge exchange not only about competencies, but also about ICT tools and technologies used in University and Industry. In the paper the main emphasis is on a developed prototype supporting mediated competence comparison with respect to Industry job descriptions and University courses. The prototype is a part of a collaboration support system that has been designed with the purpose to maintain and exchange information between University and Industry [3], [6], [7], [8], [9]. It helps to remove another Industry-University knowledge flow barrier, namely, the lack of mechanism for knowledge exchange [7].

The paper is structured as follows. Related work is briefly discussed in Section II. In Section III, we describe how conceptual structures which have a potential to be absorbed by actors (people and technologies) of knowledge

flow [2] were identified. In Section IV, the method of mediated mapping between conceptual structures is discussed. In Section V, the prototype that is used for enhancing knowledge flow is described. In Section VI, preliminary results are presented. In Section VII, expected contributions, research limitations and some directions of future work are presented.

II.   RELATED WORK

Research in the field of knowledge exchange between University and Industry has already been done by developing the architecture of University-Industry collaboration support system and its services [3], [6], [7], [8], [9]. The architecture identifies the main areas of action to support knowledge exchange, i.e., (1) knowledge acquisition services, (2) study course services (including services for developing standardized study course descriptions), (3) knowledge representation services, (4) repository services, and (5) analysis services for the analysis of collected information. The architecture incorporates the following approaches to bridge the gap between University and Industry [8]: (1) the use of standardized competence frameworks, (2) the use of tools that automatically interpret ("translate") competences expressed in Industry terms into competences expressed in University terms, (3) giving an opportunity for industry to evaluate technology-oriented elective courses directly or indirectly (course evaluation prototype has been developed), (4) equipping Industry with University insights in skill development trends. The "gap" here means a difference between University and Industry in understanding the essence of knowledge, skills, and competences. The evaluation of technology-oriented elective courses revealed that Industry finds it hard to understand the terms used in course descriptions, thus in this paper we focus on knowledge exchange about knowledge/competence/skills demand and knowledge/competence/skills offer by utilizing (2), (3) and (5) areas of action: (2) by means of study course description with standardized competencies, (3) by using standardized competence frameworks and (5) by using prototype to identify courses corresponding to specific job position (see Section V).

Since the knowledge representation services is the core for maintaining knowledge flow between University and Industry in the architecture of the collaboration support system, some standards for representing knowledge should be selected. In the case of competence information exchange, competence standards (frameworks) should be considered. Several competence frameworks have been developed by different professional and academic organizations and societies, such as European e-Competence framework (e-CF, developed in the European Union) [10], Skills Framework for Information Age (SFIA, developed in the United Kingdom) [11], Club Informatique des Grandes Entreprises Françaises framework for job profiles (CIGREF, developed in France, a short description available in [12]), Advanced IT Training System (AITTS, developed in Germany, a short description available in [12]) as well as curriculum models developed by ACM [13]. Some of these frameworks can be mapped both to the descriptions of University courses and

job positions. Based on analysis of competence frameworks [5], [6] the e-CF was selected as the most appropriate framework because e-CF has from cooperation between representatives of Industry and University of several EU countries, therefore it can relatively easily be absorbed by Industry and University operating inside boundaries of EU [5], [14], [15]. Studies of related work did not reveal any approaches that would try to obtain mappings between University courses and Industry job positions by incorporating some standardized competence frameworks. In this paper we explain how mediated mapping is used to map courses and job positions.

Domain ontologies are commonly used for representing conceptualizations [16]. If the job positions and study courses are represented as ontologies and we intend to identify how they are related, then mapping between ontologies should be established. Before establishing the mapping we propose to add the competence context [17] that states that mapping is done based on competencies, tools, and technologies required for job position and acquired in University courses. As a result, mapping between job positions and study courses is becoming indirect. Instead of using ontologies (the approach still requires deeper research of ontology matching problems [18]), we propose to use hierarchical conceptual structures representing controlled vocabularies [19] for job position frameworks, university study programs, tools and technologies, and competence frameworks. This leads to the use of simpler hierarchical structures which are easier to compare by means of initial mapping between element values of conceptual structures (in further text we use "mapping of conceptual structures"). Because Industry does not maintain their own ontologies to formally define knowledge and skills, standardized competence frameworks were used to facilitate initial knowledge exchange and to obtain initial mapping between courses and job positions.

III.   IDENTIFICATION OF CONCEPTUAL STRUCTURES

Basic conceptual structures relevant to University and Industry include: (1) a job position framework (which provides systematization of job descriptions), (2) University study programs and (3) a competence framework (e-CF in this case). Describing a job position in Industry, information about knowledge of existing tools and technologies (T&T) is often included in descriptions. A similar situation is in University – knowledge about specific T&T is included in course content. Therefore it is relevant to include information about T&T in course descriptions. Due to the fact that competence frameworks do not include information about specific T&T used in particular competence, the development of T&T catalogue or selection of existing one should be considered in order to bring conceptually closer the descriptions of job positions and University courses. Several catalogues for describing T&T are available, e.g., Google directory, Yahoo directory, O*net Resource Centre [20] tools & technologies etc. We have selected a catalogue provided by the O*net Resource Centre for its simplicity that is a very important feature of a catalogue used for developing basic approach for mapping conceptual structures. It should
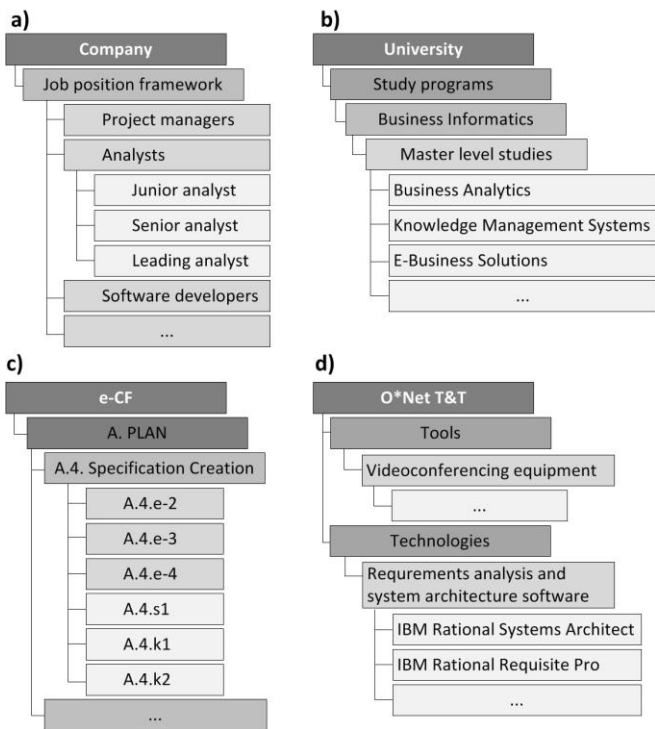
Figure 1. Examples of hierarchical conceptual structures of a) job position framework, b) study program, c) comptence framework and d) T&T catalogue

be mentioned that O*net has developed a list of job positions and the possible corresponding T&T used in the position. We have filtered out of it T&T used in job positions of ICT domain.

The basic conceptual structures mentioned at the beginning of this Section (a total of 4) usually are hierarchical (see Fig. 1) and this structural similarity is utilized in mapping study courses and job positions to corresponding competence framework and T&T catalogue.

IV. MEDIATED MAPPING BETWEEN CONCEPTUAL STRUCTURES

After the main conceptual structures (see Fig. 1) are identified, the next step is to consider how these structures could be mapped inside the organization to describe University study courses and Industry job positions. In general, two sets of structures are proposed. The first set (SET1) consists of conceptual structures used in Industry, and the second set (SET2) is used in University. Various competence frameworks and T&T catalogues can be used in organization, but in this paper we assume that Industry and
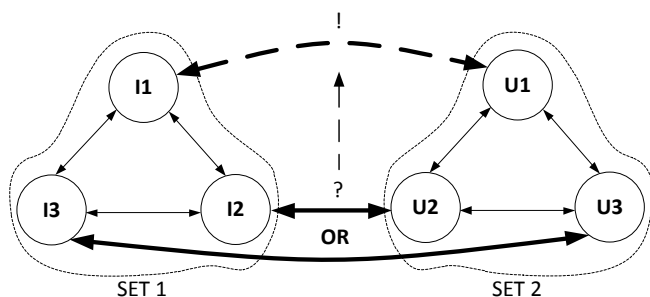

Figure 2. Illustration of basic approach. I – conceptual structures used in Industry, U – conceptual structures used in Univesity

TABLE I. MAPPING OPTIONS

Nr.	Option	Explanation
1	Direct mapping between job positions and university courses (see I1↔U1 in Fig. 2)	This option of direct mapping is not considered as useful because we intend to use mediating hierarchical structures to obtain mapping between job positions and study courses indirectly ensuring the actuality of indirect mapping.
2	Direct mapping between competence frameworks used in University and Industry (see I2↔U2 in Fig. 2)	Competence frameworks are used as mediating structures in order to indirectly map job descriptions to study courses.
3	Direct mapping between T&T catalogues used in University and Industry (see I3↔U3 in Fig. 2)	T&T catalogues are used as mediating structures in order to indirectly map job descriptions to study courses.
4	Direct mapping of both competence frameworks and T&T catalogues used in University and Industry (see I2↔U2 and I3↔U3 in Fig. 2)	Competence frameworks and T&T catalogues are used as mediating structures in order to indirectly map job descriptions to study courses.

University use the same conceptual structures for the description of job positions and courses (namely, e-CF and O*net T&T).

Considering that SET1 consists of such elements as a job position framework, e-CF and T&T catalogue, the following mappings between the elements can be introduced (see SET 1 in Fig. 2):

- Job position framework is mapped to e-CF (I1↔I2 in Fig. 2) because every position in the organization is described in terms of standardized competences;
- Job position framework is mapped to T&T (I1↔I3 in Fig. 2) because every position in the organization requires the knowledge of some tools and technologies;
- e-CF is mapped to T&T (I2↔I3 in Fig. 2) because potentially every competence requires some knowledge of tools & technologies.

The same options are in SET2.

Mapping between elements of SET1 and SET2 is necessary in order to identify courses relevant for a particular job position (and v.v.). The possible mapping options and explanation are considered in Table I. Options 2 - 4 identify the possible mediating conceptual structures that are needed to detect the courses relevant for a particular job position. "Mediating conceptual structure" implies that indirect mapping between a job position and university course is based on other conceptual structures, such as competence frameworks and T&T catalogues. Taking into consideration that different organizations can prefer different conceptual structures to formalize knowledge and skills, four mapping options have been identified to demonstrate that fact. The list of options can be extended by the needs of a particular organization. Further in the paper the focus is on option 2 because of emerging value of competences required by Industry and offered by University. Options 3 and 4 are under investigation and are not discussed in this paper in detail.

V. THE PROTOTYPE FOR MEDIATED MAPPING

The method discussed in Section IV is tested by implementing a prototype that serves as one of mechanisms for knowledge exchange between University and Industry.

The prototype has the following basic functionality:

- **Management of organizations** – prototype allows managing information about various organizations that attempt to collaborate in the context of competence information exchange (for example, Universities, partners from Industry).
- **Management of users** - prototype allows managing prototype users belonging to available organizations.
- **Management of hierarchical conceptual structures** – prototype allows managing hierarchical structures such as job position frameworks, University study programs, competence frameworks.
- **Management of mapping** - prototype allows to

define mapping between all hierarchical structures (example of mapping study courses to e-CF illustrated in Fig. 4).

- **Establishment of mediated mapping** – mediated mapping between information sources such as job positions and study courses based on mediating conceptual structure e-CF (see Fig. 5).

In order to indirectly map job positions and University courses the following mapping of conceptual structures should be presented:

- Mapping of job positions to Industry competence framework (Nr. 1 in Fig. 3).
- Mapping of study courses to University competence framework (Nr. 2 in Fig. 3).
- Mapping of the competence frameworks of Industry and of University (Nr. 3 in Fig. 3).

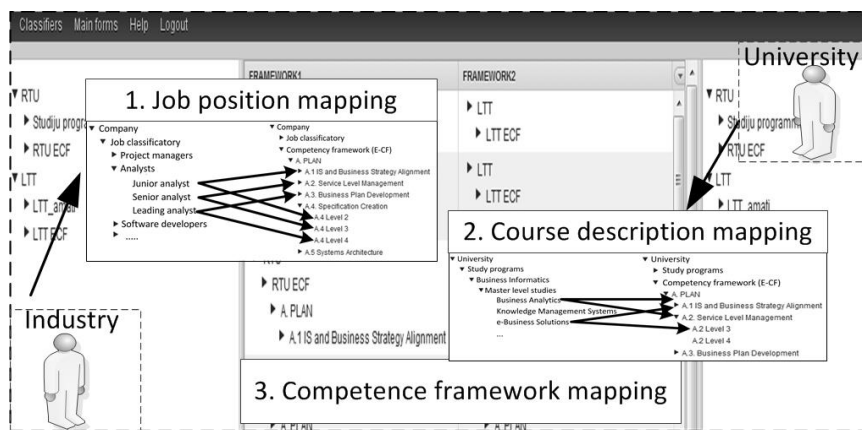When the mapped structures (Industry job positions to a

Figure 3.   Job position and university course mapping to competence frameworks using a common tool
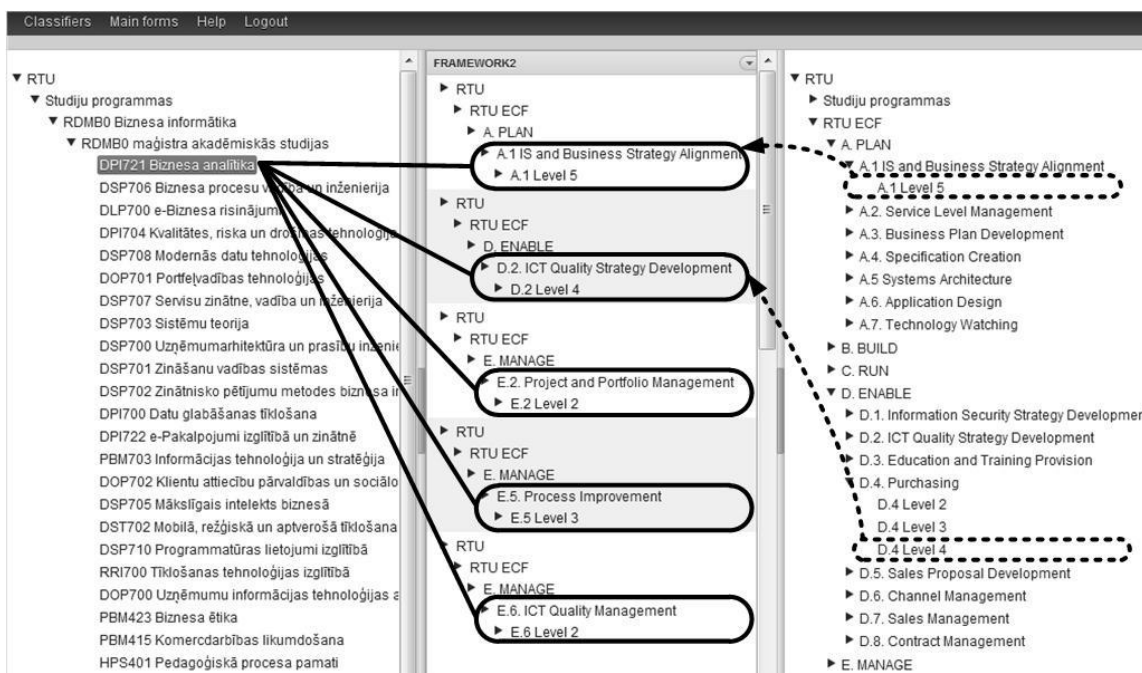

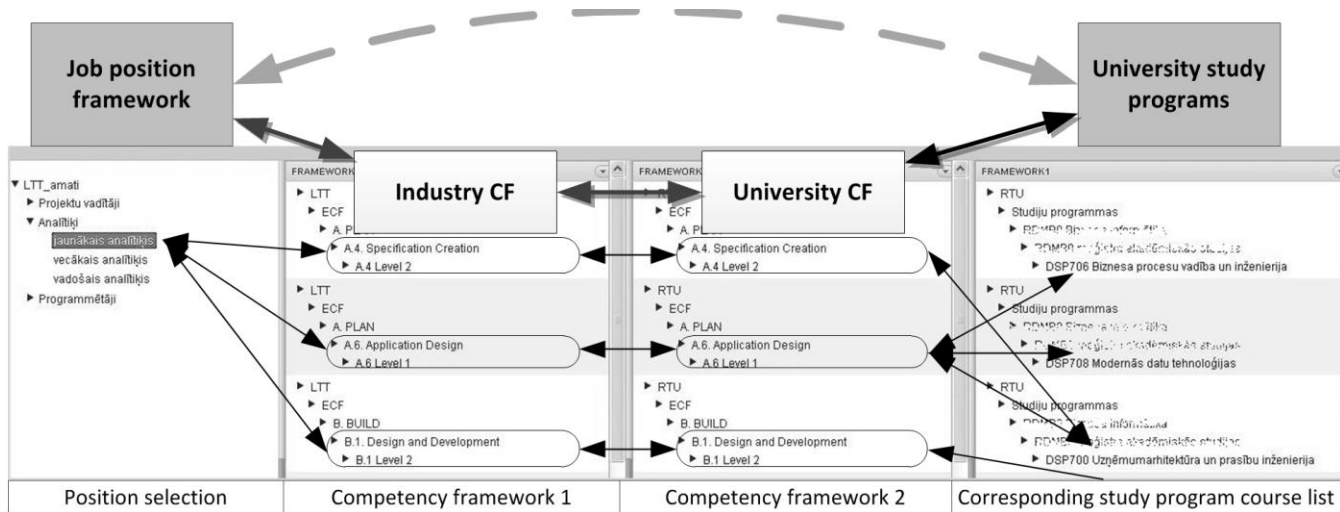Figure 4.   Mapping study courses to e-CF

Figure 5.   Establishment of mediated mapping

competence framework and University study courses to a competence framework) are available, the next step is to establish mapping between competence frameworks. In this paper we illustrate the case when both University and Industry are using e-CF as a competence framework therefore mapping 1:1 was done using the developed prototype of the tool (see Fig. 3) available for Industry and University.

We consider an example of knowledge exchange about courses corresponding to a particular job position based on e-CF as the mediating structure. Competences required in the job position of Industry job position framework "junior analyst" are mapped to the following e-CF competencies (see Fig. 5): *Specification creation Level 2, Application design Level, Design and development Level 2, Testing Level 1, and Process improvement Level 3.*

The list of courses that include at least one of the requested competences is as follows: Business Analytics; Business Process Management and Engineering; Advanced Data Technologies; Service Science, Management, and Engineering; Enterprise Architecture and Requirements Engineering; Customer Relationship Management and Social Network Technologies; and Artificial Intelligence in Business (in Fig. 5 the course titles are in Latvian).

VI.   PRELIMINARY RESULTS

Several representatives of Industry and University were asked to evaluate the prototype. In order to prepare the prototype for evaluation, representatives of one Industry were instructed how to use the prototype to produce mapping between competence framework and job positions/courses in Industry. The same was done on the university side. Afterwards the competence frameworks used in University and Industry were mapped (in the current situation when the representative from Industry and University uses the same competence framework, mapping between these frameworks

is 1:1; the developed method and prototype can also support the case when University and Industry use different mediating competency frameworks). This mapping was used to demonstrate the potential of the prototype to show linkage between particular job positions and corresponding study courses.

The results of evaluation revealed the following impacts of the prototype on knowledge exchange between University and Industry:

- Use of a standard mediating conceptual structure improves absorptive capacity of both partners, University as well as Industry.
- Use of IT support brings in transparency in knowledge exchange and considerably shortens the time of comparing the knowledge/competence/skills demand and offer.
- Removal (at least partial) of the above-mentioned knowledge flow barriers: (1) lack of absorptive capacity and (2) insufficient mechanism lower several other knowledge barriers [2] such as causal ambiguity, non-validated knowledge, lack of motivation, unawareness at both ends of knowledge flow, etc.

These results show that the use of the prototype may enhance cooperation between University and Industry if it is systematically used for tuning study programs and developing demand-based courses according to industrial needs.

VII.   EXPECTED CONTRIBUTIONS, RESEARCH LIMITATIONS AND FUTURE RESEARCH AVENUES

The method and the prototype presented in this paper were developed to help to remove some barriers of knowledge flow in University and Industry knowledge exchange about knowledge/competence/skills demand and knowledge/competence/skills offer. It was expected that (1) a mutually understandable, internationally recognized competence framework as the mediating conceptual structure

will improve absorptive capacity of knowledge to be exchanged and (2) information technology support will make knowledge exchange less time consuming and more transparent.

Preliminary results obtained from prototype evaluation show that ICT supported mediated mapping between conceptual structures can lower or even remove several knowledge flow barriers.

This research is limited to two knowledge flow barriers only. Hypothetically there is a possibility to improve the method and the prototype to address other knowledge barriers. Additional research in knowledge flow barriers is needed to do this. The discussion in this paper is based on the classification of knowledge flow barriers used in domain of healthcare [2]. Experiments with the prototype revealed that the spectrum of and dependencies between knowledge barriers in ICT sector might differ from those in healthcare. Therefore, in order to target properly further investigations, it is necessary to analyze deeper cause consequence relationships between knowledge barriers in the specific area of application – domain of knowledge exchange between University and Industry in ICT sector. Another direction of further research is automatic mapping based on string similarity [21] incorporated in mapping of hierarchical structures.

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