An ontology-based Recommender System to Support Nursing Education and Training

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Abstract

The need of healthcare organization on highly knowledgeable and qualified human recourses to guarantee quality of performance is indispensable. A desired performance level is tailored with obtaining competences and job knowledge, as the major influential factors. This is especially critical due to high rate of changes in knowledge domains and technological infrastructure over time i.e. before or within employment of job holders and applicants. Therefore, applicants as well as employees and practitioners are also dealing with upgrading their level of job knowledge and qualifications.

Adaptive Medical Profession Assessor (Acronym: Med-Assess) as a European funded project, proposes a knowledge based system for assessment of the competences and job knowledge of the applicant/employee to perform a certain job role in the domain of healthcare i.e. nursing and care giving to neuro-patients. In this context, recommendation of learning materials is an integral part. It subjects to the required training due to the lack of competence(s) for performing a specific nursing task(s). This paper presents the system architecture of Med-Assess, and discusses how the applied semantics i.e. ontologies and rules are developed. It especially presents the background in nursing education and training, and conceptually presents the design of the recommender components.

1 Introduction

With no doubt "humans are generally considered the most valuable resource in any organizations" [Lianga *et al.*, 2013; Hesketh and Fleetwood, 2006]. Therefore one of the vital requirements of organizations is to recruit competent applicants for announced job vacancies. Organizations examine and interview the applicants to find the most qualified one for a job vacancy. However, in most job fields, knowledge requirements are associated within the today's market with a moderately high rate of change over time [Pilz, 2012]. The causes are, for example, development of new technologies like smart phones or cloud computing, development of new know-how, or integration of organizational processes. Such changes raise the needs of individuals and organizations to regularly improve the level of job related knowledge, and to obtain competences continually before and within employment.

The importance of job specific knowledge is drastically increasing especially in the field of personnel selection [Mol *et al*., 2013]. In this way "general mental ability (or intelligence) is the single best predictor of job performance, regardless of job type" [Mol *et al*., 2013], [Schmidt, 2009], [Schmidt and Hunter, 2004]. Despite empirical evidences such as [European Commission, 2012a] and [Salgado *et al*., 2003], the associated rationales are not consistently figured out, and thus, considered as a progressive research topic in the fields of psychology [Mol *et al*., 2013]. The anticipation is in turn that "job knowledge therewith appears to be a more proximal predictor of job performance than general mental ability" [Mol *et al*., 2013]. In this paper, we consider the term of job knowledge to refer to domain specific knowledge required for obtaining (hard and soft) competences towards performing nursing jobs with desired qualities defined by the healthcare organizations. In this context, the stakeholder's points of view are classified in three categories.

The **first** is an organizational perspective. Organizations classify individuals in the two groups:
(1) employees of the organization as human resource and,
(2) applicants or potential employees, who apply for an announced job vacancy.
Obviously, the main concern of organizations is to recruit the qualified applicants, and simultaneously improve the professional levels of their employees to sustain and guarantee quality of performance, influence on the effectiveness of processes and deliver excellent outcomes.

The **second** is the applicant perspective. An applicant needs to possess certain knowledge to improve the level of his/her competences, based on the market requirements. The underlying reason is a hard competition on the job market towards being hired at a desired job with fair income and good reputation. In turn, employees concern with keeping their positions or getting promoted to higher levels of the organization.

The **third** perspective is in regard of educational institutes. They should provide teaching and training schemes (e.g. curriculum, courses, e-learning) for students, job applicants and practitioners. The training should also address the market needs subject to (further) vocational education and training [Pilz, 2012].

Blancero *et al.* [Blancero *et al*., 1996] and Parry [Parry, 1998] defined competences as knowledge, skills and attitude to perform a job. In the European Qualifications

Framework (EQF) for lifelong learning, the term *Competence* is defined as "the proven ability to use knowledge, skills and personal, social/methodological abilities, in work or study situations and in professional and personal development" [European Commission, 2008]. However, as job descriptions are changed over time, the competences cannot remain solid [Glosson and Schrock, 1985], [Pilz, 2012]. The realization of competences may differ based on organizations' requirements. Moreover, learning expresses the rate of transmitting and absorbing knowledge, which depends on cognitive abilities [Wu & Lee, 2007]. Weinstein and Underwood [Weinstein and Underwood, 1985] considered four main learning strategies, namely (1) information processing strategies, (2) affective learning strategies, (3) typical reading strategies, and (4) metacognitive strategies. In this sense, "typical reading" is a learning concept that addresses the development of the learning process through reading, learning materials, doing exercises and preparing for attending associated tests. There are meaningful relationships between learning materials, competences and job roles in each domain. The concept of Adaptive Medical Profession Assessor (Med-Assess) is developed for bridging these three aspects in nursing education [Mol *et al*., 2013]. One of the Med-Assess objectives are identifying the required competences to perform nursing tasks [Mol *et al*., 2013]. In addition, Med-Assess is used to assess and evaluate the competences of applicants (i.e. novice or experienced nurses), based on multiple-choice tests on domain knowledge and general mental ability [Mol *et al*., 2013]. Finally the system recommends respected learning materials e.g. courses, workshops, e-learning courses, textbooks. In this framework, a Recommender System (RS) is being developed, as a sub-system of Med-Assess, to suggest learning material(s), in case the test candidate lacks competence(s) in (a) certain task(s) [Mol *et al*., 2013]. Further details about the general concept of Med-Assess are discussed in [Mol *et al*., 2013].

Considering the given introduction, this paper consists of 6 sections. Section 2 discusses the background of Med-Assess. The Med-Assess system architecture and its components are presented in section 3. Section 4 and 5, respectively, describe the concept and related methodologies of RS, and related aspects of ontology engineering and the execution of rules. Finally, section 6 concludes the paper and indicates the future research steps.

2 Background

As mentioned one of the primary objectives of Med-Assess is to recommend learning material(s), if applications refer to lack of competence(s) to perform certain task(s). In the following sub-sections, firstly, the nursing job is discussed to clarify which nursing competences enable nurses to perform their tasks in a high quality. Secondly, the nursing education and training is described to elucidate what learning materials are available in different categories, based on the job classifications. Both sub-sections focus on market requirements in Germany. However, the geographical transfer of the project findings and product is not limited to Germany; thereby the entire European health sector is considered.

2.1 Nursing job role

"Deutscher Pflegerat (DPR)" (German care council) and Krankenpflegegesetz (KrPflG) (nursing act), as a special administrative law in the scope of the Federal Republic of Germany, noted the personal responsibility tasks of professional nurses as follows [KrPflG, 2003][1], [DPR, 2004][2]:

- Determine the need for care, planning, organization, conduction and documentation of care.
- Evaluation of care, protection and development of care quality.
- Advice, guidance and support of caregivers.
- Initiation of life-sustaining emergency measures until a doctor arrives.

In addition, the tasks which should be performed as assistance are [DPR, 2004], [KrPflG, 2003]:

- Independent implementation of medical interventions that were prescribed by a doctor,
- Provision of medical diagnosis, treatment or rehabilitation,
- Action in crisis and disaster situations.

Nurses should establish multidisciplinary solutions to health problems and work together with other professionals in hospitals [DPR, 2004].

Williams *et al*. [William *et al*., 2009] identified nursing tasks in four different categories based upon the daily workload.
(1) **Direct care:** defined as "all activities involving direct interaction between the nurse and patient/family" [William *et al*., 2009], namely, communication, medication, nutrition and fluid intake, elimination, personal care, positioning or turning, escorting patients, assisting other health professionals, routine checks, vital signs, collecting specimens, nursing procedures [William *et al*., 2009]. (2) **Indirect care:** defined as all activities related to the patients but execute away from the patient, namely, charting/form completion, reports, communication, meeting preparation [William *et al*., 2009]. (3) **Unit-related:** defined as all activities for handling the unit/ward namely, housekeeping, clerical errands, communication, and maintenance [William *et al*., 2009]. (4) **Personal time:** defined as all activities that lead to nurses' well-being, namely, education/training and meal break [William *et al*., 2009].

Furthermore Nursing Interventions Classification (NIC) provided a taxonomy to represent nursing constructs [Bulechek *et al*., 2013]. The NIC consists of 7 domains and 554 interventions. The 7 domains are: *Basic, Complex, Behavioral, Safety, Family, Health System, and Community* [Bulechek *et al*., 2013]. In the framework of Med-Assess, NIC is considered as one of the validation sources. Other methods are interviewing with nursing supervisors, educators and physicians in cooperation with the clinical partner of the project.

[1] Translated and adopted by the authors **according to Section 2 " Vocational Training",§ 3" training target", paragraph (1)**
[2] Translated and adopted by the authors **according to §2 "Tasks" paragraph (3)**

2.2 Nursing competence through education and training

In the literature on healthcare, competence is often used to only describe knowledge that enables practitioners to perform a particular task [Schroeter, 2008]. However, competence is more than knowledge [Norman, 1985]. It consists of understanding of various knowledge merging skills to have capability, and abilities to perform the clinical, technical and communication tasks, and also to solve problems successfully [Schroeter, 2008].

Obtaining the required competences can be integrated into curricular coursework [Rudolph, 1999]. Practitioners learn and practice certain cognitive results such as concepts, significations, principles, strategies, problem solving and having reversibility, (re) construction and improvement characteristics [Neacşu, 2011].

According to article 31 (6) of the European parliament and of the council on the recognition of professional qualifications: "Training for nurses responsible for general care shall provide an assurance that the person in question has acquired the following knowledge and skills" [European Parliament and Council, 2005]:

(a) Adequate knowledge of the sciences of structure, physiological functions and behavior of healthy and sick persons.

(b) Sufficient knowledge of the nature and ethics of the profession.

(c) Adequate clinical experience.

(d) "The ability to participate in the practical training of health personnel and experience of working with such personnel".

(e) Experience of team working with other professions in the hospital.

As listed in this treaty[3], the training program shall consist of theoretical instruction as well as clinical instruction [European Parliament and Council, 2005]. Theoretical instruction includes [European Parliament and Council, 2005]: (a) **Nursing**: nature and ethics of the profession, general principles of health and nursing, general and specialized medicine, general and specialized surgery, child care and pediatrics, maternity care, mental health and psychiatry, care of the old and geriatrics [European Parliament and Council, 2005]. (b) **Basic science**: anatomy and physiology, pathology bacteriology, virology and parasitology, biophysics, biochemistry and radiology, dietetics, hygiene. (c) **Social science**: sociology, psychology, principles of administration, principles of teaching, social and health legislation, legal aspects of nursing.

Furthermore, the "Ausbildungs- und Prüfungsverordnung für die Berufe in der Krankenpflege (KrPflAPrV)" as a vocational training and examination regulation of occupations in nursing in Germany, expresses two training parts[4] [KrPflAPrV, 2003]: (a) **Practical**: internal medicine, geriatrics, surgery, gynecology, neurology, birthing, newborn Care, psychiatry, pediatrics and ambulant care. (b) **Theoretical**: nursing and health science, natural science and medicine, human and social sciences law, politics and business.

KrPflAPrV [KrPflAPrV, 2003] mentioned that to assess the competences, skills and knowledge of the practitioners, they should take the national examination which is in written, oral and practical form[5]. The results of written and oral exams are graded[6] in 6 degrees: (1) **Very good**: (a nurse) who is particular competent (2) **Good**: who is fully competent (3) **Satisfactory**: who is generally competent (4) **Sufficient**: who has deficiencies in her/his competence, (5) **Poor**: who is not competent, however, it is possible to recognize that the necessary knowledge exists and the deficiencies can be solved in the foreseeable future (6) **Unsatisfactory**: who has not even the basics of the competences, the deficiencies are more than could be resolved in the foreseeable future.

In addition, many states of Germany defined their individual curriculum frameworks for training and educating nursing students in nursing schools. In general, while the curriculum frameworks are the same; they have some different point of views. Examples are [Oelke *et al.*, 1998] and [Müller-Klepper (Ed.), 2005].

3 Med-Assess System Architecture

The main functionality of Med-Assess is to provide adaptive tests for clinics, hospitals and nursing schools to assess the competences of their applicants, employees and practitioners. The aim is to provide recommendations of learning materials for further training and education. In this context, Med-Assess incorporates the core elements of the Onto-HR solution [OntoHR, 2009]. Onto-HR is a former European Project, where two of the Med-Assess project partners took part. It focuses on the assessment of IT-specialists. Med-Assess project is categorized as a transfer of innovation project [European Commision, 2012b], which indicates that a given innovative solution (i.e. Onto-HR) is customized and transferred to another domain or country while enhancing its functionalities and performance. Therefore, the transfer of Med-Assess is twofold, first from the IT to the medical sector, and second from the Netherlands and Hungary to Germany. Eventhough Med-Assess is developed based on Onto-HR, it differs in certain characteristics. The major improvements are the adaptivity of the solution, the focus on recommending based on the assessment results, and offering a decision component in the field of personnel selection. Compared to other existing technologies like KnowWE (Knowledge Wiki Environment) that "enables domain specialists and experienced users to build knowledge–based consultation systems collaboratively on the web" [Baumeister et al., 2007],or Experience Factories that aimed at "capitalization and reuse of life cycle experience and products" [Basili,2009], Med-Assess system focuses on the assessment of job knowledge and compensating the lacks through recommendation of further education and training.

The system architecture of Med-Assess is illustrated in Figure 1. It consists of the three modules *Adaptive Testing*, *Recommender* and *User Interface.*

The *User Interface* is developed in order to supply the user with a graphical interface for performing the tests and gathering user information. It ultimately transfers the test results, recommended learning materials and applicant ranking to the user.

[3] **ANNEX V, Point 5.2.1**

[4] Translated and adopted by the authors **according to § 1 (1)**

[5] Translated and adopted by the authors **according § 3 "State Examination"**

[6] Translated and adopted by the authors **according § 7**

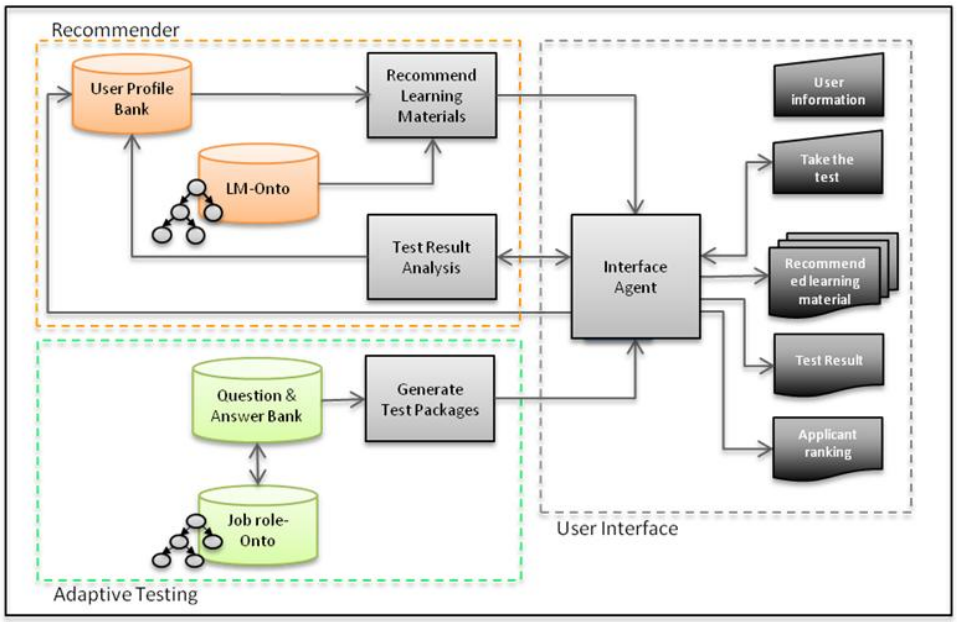

Figure 1 Med-Assess System Architecture

This component is connected to both, *Adaptive Testing* and *Recommender*, to receive the test package from *Adaptive Testing* and recommended learning materials as well as test results from *Recommender*. The *User Interface* also delivers the test package, which contains the questions as well as user information for *Recommender*.

The *Adaptive Testing* consists of a Job-role ontology (Job role-Onto), *Test Bank* and *Test Generator*. The Job role-Onto formalizes and represents all the nursing tasks and activities. Ontology is a means to structure and represent knowledge about a domain in a formal way [Guarino, 2009]. Ontology is discussed more in section 5.

To assess the required competence to perform a certain task, a group of questions is employed and stored in the *Test Bank*. In this context, the tests are classified into different groups based on their level of difficulty. The *Test Generator* provides the different test packages in the range of difficulties, refers to the profile of the user and considers especially the user's job experience and professional level. The Med-Assess *Recommender* is discussed in section 4.

4 Recommender System

"Recommendation systems are software tools and techniques providing suggestions for items to be of use to a user" [Ricci *et al*., 2011]. RS refers to a kind of Information System (IS) which analyzes "*User's Need*", collects the "*Items*", and suggests them to the "*Users*" [Ricci, 2011], [Klahold, 2009]. Recommendation techniques are made out based on knowledge source [Burke, 2007]. These knowledge sources can be fed by "the knowledge of other users' preferences" or "ontological or inferential knowledge about the domain, added by a human knowledge engineer" [Burke, 2007]. Burke [2007] distinguished six types of recommendation approaches (see Table 1).

Med-Assess utilizes the combination of content and knowledge-based recommendation approach i.e. hybrid recommender system. In particular, items are learning materials, which are gathered based on the analysis of the user's level of competence. Therefore, at first the needs analysis should be applied to identify the requirements for recommendation. Here the Items include domain knowledge to clarify how they meet the "User's Needs" [Ricci et al., 2011]. In knowledge-based recommender systems, the Users' Needs (based on the user profiling) are mapped to Items through involving the associated domain expert(s) (e.g. physicians, nursing educators, or nursing supervisors). The quality of the recommended items by content-based and knowledge-based recommender depends on the quality of the entered data in the system by knowledge engineers [Burke and Ramezani, 2011]. A knowledge-based recommender needs not only what features are associated with what items, but also an ontology over the item features to allow the system to reason about the relationship between the features [Burke and Ramezani, 2011].

Table 1 Types of Recommendation Approaches, Adopted by the authors from [Ricci *et al*., 2011].

Recommendation approach	Description
Content-based	The system recommends items refer to the user's likes and dislike based on product features.
Collaborative	The system provides recommendation refers to "users with similar tastes liked in the past".
Demographic	The system generates recommendations based on rating of users in those niches.
Community-based	The system recommends item with regard to the preferences of the user's friends.
Knowledge-based	The system does not gather user ratings. The system provides recommendation refers to specific domain knowledge about "how certain item features meet user needs and preferences".
Hybrid recommendation	The system is developed based on the combination of the above mentioned techniques.

As shown in Figure 1, Med-Assess *Recommender* module contains *Recommend Learning Materials*, *Test Result Analysis*, *Learning Material Ontology (LM-Onto)* and *User Profile Bank*. The *Test Result Analysis* receives the test package which is answered by the user. The incorrect answers show the lack of competence(s) of the respected task(s). In this term the rate of the incorrect or correct answers is considered as the level of competence of the practitioners to perform each task. This result is used as "User's Needs" and stored as information in the *User Profile Bank*. Additionally *Recommender* contains *LM-Onto* in order to formalize and represent the LM domain as "Items". To create semantic recommend, Med-Assess utilized ontology. "Ontologies are now used routinely in recommender systems" [Middleton *et al*., 2009]. In LM-Onto, the knowledge domain of "how to perform the nursing tasks" has been formalized in a hierarchically structure and it can be used as a basis for a knowledge base.With reference to the lack of competence(s) to perform (a) specific task(s), the Recommended Learning Material feature will recommend the appropriate LM(s) to practitioners via the User Interface.

5 Med-Assess Ontologies framework

As mentioned earlier, Med-Assess deploys ontologies as a knowledge representation method to establish the semantics e.g. between learning materials in *LM-Onto* and job profiles in *Job role-Onto*. In the implementation, an in-house software solution, providing features for ontology and test bank creation is applied. As shown in Figure 2, the ontology engineering of Med-Assess consists of three stages.

Stage 1 is the modeling of the nursing processes. The inputs of this stage are nursing literature studies (as partially discussed in sub-section 2.1), and knowledge acquisitions via interviews with the nurses, educators and physicians. The output of this stage is nursing master list of tasks and nursing process which indicates the sequential relation of the activities.

Stage 2 is transforming nursing tasks and processes to build the Job role Ontology (Job role-Onto). In this stage the nursing tasks and sub-tasks are formalized in a hierarchically structure. The output of this stage is Job role-Onto.

Stage 3 contains the modeling and development of Learning Materials Ontology (LM-Onto) refers to the nursing literature studies as partially discussed in sub-section 2.2, and interviews with the domain experts especially consulting with nursing schools. In LM-Onto the know-how to perform nursing tasks are formalized.

The methodology to develop *LM-Onto* refers to the "Ontology engineering methodology" which is provided by [Sure *et al*. 2009]. This process consists of five main steps [Sure *et al*., 2009];

(1) **Feasibility study**: to identify problems/ opportunities.

(2) **Kickoff**: to clarify what this ontology should support, what the valuable knowledge sources are to build a semi-formal ontology.

(3) **Refinement**: to formalize a refined semi-ontology into target ontology and to create a prototype.

(4) **Evaluation**: to evaluate technology, users, and ontology to ready for the roll-out into a productive system,

(5) **Application and evolution**: to apply the ontology and manage evolution and maintenance. Here, this point should be highlighted that "an ideal ontology is one whose models exactly coincide with the intended ones" [Guarino *et al*., 2009].

As the project of Med-Assess is still ongoing, not all aforementioned steps of creating *Job role-Onto* and *LM-Onto* have been established yet. The first steps in creating these ontologies have been done in the form of literature studies about nursing tasks and modeling of work processes and the rest is planned to be accomplished within work packages.

The concept of "Ontology" in general is part of the "Semantic Web" [Berners-Lee *et al.*, 2001], a structure, which according to his inventors "will open up the knowledge and workings of humankind to meaningful analysis by software agents, providing a new class of tools by which we can live, work and learn together" [Berners-Lee et al., 2001]. Med-Assess fulfills the aspect of *working together* with modeling the *Job role-Onto*, which formalizes nursing tasks i.e. creating a common understanding of the daily activities, commotions and requirements e.g.

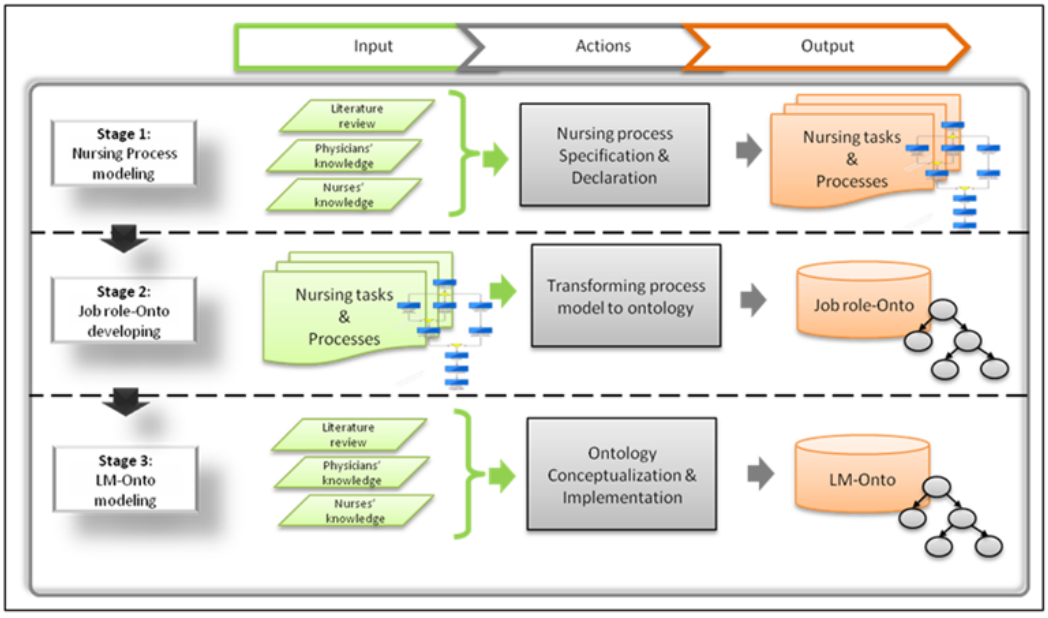

Figure 2 Med-Assess Ontologies Framwork

of a basic and a neuroscience nurse. *LM-Onto* meets the *learning aspect*, as this ontology represents learning material for the aforementioned job roles.

For the recommendation of corresponding learning material from *LM-Onto* to a test candidate, after acquiring his/her *Test Result Analysis*, an inference mechanism is required. Therefore, rules will be applied for establishing the reasoning processes. In addition to the project plan a research study was done by [Demuth, 2013] about the general interaction of ontologies and rules in the context of a medical scenario. This study [Demuth, 2013] contains a scenario, where exemplarily a competence ontology and the related rules have been created and executed, e.g. to filter the nurses, who need training in a specific topic, which is related to their area of work[7]:

```
worksIn(?nurse, ?area) ∩ lacksCompe-
tenceIn (?nurse, ?topic) ∩ topicRela-
tedToArea(?topic, ?area) → need-
sTraining(?nurse, ?topic)
```

Where the variables `?nurse`, `?area` and `?topic` may be a concrete test candidate, who works in the area of neurology and lacks knowledge in the topic of indirect care and as a conclusion is recommended for training. While this is a simple rule, this case study delivered first input results for the structures and associated rules, needed for building up *Job role-Onto*, *LM-Onto* and the executing of the recommendation of fitting learning material. Indeed, verifying such an approach requires several steps, like defining all rules and procedures to merge, aggregate or breakdown all rules in cooperation with the domain experts and knowledge engineers.

6 Conclusion and future research

This paper discusses the role of education and training in the development and improvement of nursing competence. It provides a contribution to (further) vocational education and training in the health sector. In particular, the paper holds the concept of Med-Assess and presents the design of RS as a component/sub-system in the framework of Med-Assess. In fact, Med-Assess is a gateway to bridging a synergistic approach using human resource, experience management and knowledge management methodologies to support nursing education and training. However, there are limitations in the concept and domain of application that should be addressed properly through the progress of the project and within the future research.

In particular, Med-Assess does not provide learning materials, instead it only recommends them. The reason for this approach is due to the lack of existing structured online learning systems in the field of neuroscience nursing. Therefore it is essentially important to establish in-house workshops and develop learning materials (e.g. text books) using online learning technologies and a combination of text-based and multi-media materials for learning and education. In this way, licensing of text-based materials is a major challenge which should be considered and handled through communication with the copyright holders and publishers.

Moreover, the recommendation result of Med-Assess does not reflect a kind of certificate yet. Integration of certification in the framework of Med-Assess might encourage the users to eagerly take part in the tests.

For implementation and evaluation of the performance, a pilot test with a number of test candidates (i.e. minimum of 200 candidates) will take place.If necessary, the solution will be adapted according to the feedback.

In the domain of application, one of the major challenges is the autonomy of nurses. For example, diagnosis is a task that should be fulfilled by the contribution of physicians and nurses. In this way, the authority of nurses is quite limited in Germany, while they have more freedom in other European countries or the United States. This issue should be fully considered in the development of the system and incorporating of learning materials.

Med-Assess also has an influence on the decision process of superiors in medical institutions. In fact, the secondary objective of the Med-Assess is to support superiors on integration of foreign job applicants (e.g. Chinese nurses in the German health sector).

Additionally Med-Assess has direct influence on continuous improvement of nursing performance through regular evaluation of the nurses. Improving nursing performance is directly reflected in doctor-nurse and nurse-patient communications as well as customer satisfaction in hospitals and clinics. Dealing with neuroscience patients and their relatives, this issue is very important and can affect the entire treatment process.

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[7] The rule is adopted from the original source [Demuth, 2013] to address the specific example in the framework of this paper.

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