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PROBLEM OF COMPATIBILITY OF COMPETENCES IN PROFESSIONAL LEARNING

Oleg Zaikin[1], Katarzyna Sikora[2], Przemysław Różewski[2], Emma Kusztina[2]

[1] *Warsaw School of Computer Science*
[2] *West Pomeranian University of Technology in Szczecin*

Corresponding author:
Przemysław Różewski
West Pomeranian University of Technology in Szczecin
Żołnierska 49, 71-210 Szczecin, Poland
phone: +48 91 4495672
e-mail: prozewski@wi.zut.edu.pl

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Abstract
As the amount of options regarding the possibility to start/continue higher education increases, due to such reasons as the development of European Higher Education Area, the decision about choosing one of them becomes even more difficult. One of the most important factors that need to be taken into account is how well the set of competences guaranteed by an education offer reflects the predicted requirements of the job market. In the article authors propose a formal model, based on an object database, that would enable evaluating compatibility of two chosen sets of competences while taking into account different aspects connected to market needs.

Keywords
required and guaranteed competence, compatibility, object model.

Introduction

In the life of every person come certain key moments which often include the need for a decision to be taken. One of such moments is the day we decide to dedicate the next few years of our lives to studying. This day may as well influence the rest of our lives. Choosing the right direction, the right university, the right education offer, gives us a better starting position on the job market afterwards. The main problem that occurs here is how to be sure we made the right choice.

Due to the introduction of the Bologna Process [1], one can study in any area within the united Europe with a guarantee that the obtained results will be recognised in all other countries that accepted the Bologna regulations. This means that not only possibilities grow in numbers, but also competition between education institutions increases, what allows us to assume that so will the quality of education. Nevertheless, there is still no easy way to analyse the available data and choose the option that gives the highest probability of actually getting a job after graduation. The fact of having a diploma becomes less important than the information about what this diploma represents and thus what competences one has obtained during the education period.

The need to have a uniform look at education through the point of view of actual achievements and competences lead to the development of several different standards and frameworks, such as the Qualifications Framework of European Higher Education Area [2], and resulting national qualification frameworks and standards, as developed e.g. by the Polish Ministry of Science and Higher Education [3], or resulting European standards for different education fields as developed within the Tuning Project [4]. Accordingly, standard descriptions were created to describe the required competences, abilities and knowledge connected to different jobs and positions (e.g. as developed by Polish Ministry of Labour and Social Policy [5] or within projects like European ICT Jobs [6]).

Not only the content-related meaning of competences connected to a job or a field of study are being standardised. The same thing is happening regard-

ing the way of describing competences, required to enable comparison between them. This includes such standards and approaches as RCD (Reusable Competency Definition) [7], HR-XML [8], OntoProPer [9], SRCM [10], as well as work of the TENCompetence project [11] and related (e.g. [12]).

The existence of all the mentioned standards and frameworks creates a basis for reference and comparison. However, there is still no mechanism allowing for automation of this process. Considering the dynamic changes of the requirements of the job market (which respond pretty quickly to new developments, new methodologies, standards or technologies) and the much slower response of the education market (due to more restrictions connected to education plans, legislation etc.) one has to make sure, that the education he/she decides to complete will be as close to the situation on the job market after graduation as possible. And the best way to do this would be to use the main tool present on both markets right now – the competences – and to analyse their compatibility in an efficient, automatic way, which includes also the factor of presence, or lack thereof, of new developments in the considered domain.

The rest of the paper is organised as follows: in the Sec. 2 the research problem is presented. In the Sec. 3 the comparison model is formulated. The comparison model takes the form of object database, where the objects are related with corresponding procedures. In the Sec. 4 the formal model is presented.

Presentation of the problem

There are several situations in which we can see the use for a mechanism that allows assessing compatibility of competences, let us consider them from the point of view of who they relate to:

- university candidate – evaluating the compatibility of an education offer with the desired job profile,
- graduate – continuing education (lifelong learning), searching for employment,
- university – assuring competitive position among other universities,
- employee – choosing a vocational development path, changing jobs,
- enterprise – creating a staff development plan, looking for an employee with the desired profile.

All of these cases include one additional desired aspect of assessing the compatibility of competences – the possibility to assess the topicality of the considered competences regarding a chosen point of reference. This aspect is especially important when beginning higher education, as it helps in assessing usability of the knowledge and abilities that are to be acquired in the education process once this process is completed. High usability of the acquired knowledge is undoubtedly good motivation for starting education, and good justification for all the related cost.

From this point of view we can say that what has to be compared are competences represented (guaranteed) by a graduation diploma and competences required on the market to fulfil a certain job, as was illustrated in Fig. 1.

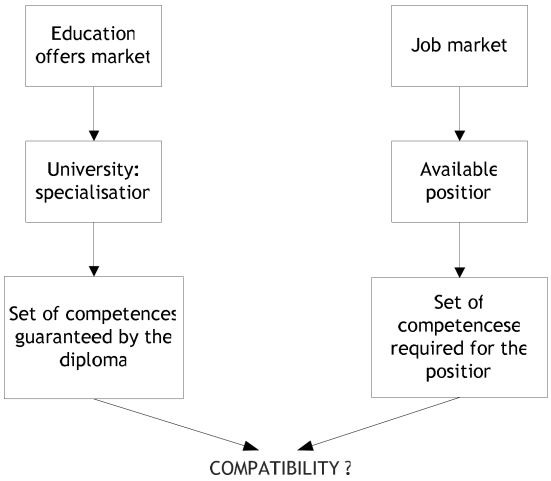

Fig. 1. The problem of competence compatibility [13].

Defining compatibility allows for creating a sort of bridge between both sets of competences, so that they can be mutually understood and related to.

The research problem is to create formal model which allows to evaluate the compatibility of two chosen sets of competences. The detailed problems addressed by the model are: coverage of the minimum required for being accepted for studies by the basic competences of a candidate and concordance of an education offer with the requirements of the chosen profession. The proposed model is adapted to the object database framework and taking into account different aspects connected to market and educational needs. The discussion is limited to the European educational market.

Proposition of a comparison model

In order to solve the stated problem the following have to be considered:

- current standards regarding competences and vocational qualifications (as mentioned earlier in the paper),
- the contexts of both sets of competences must be similar (otherwise a layer of common understanding cannot be created).

Additionally, to evaluate whether a certain set of competences is up to date, information about the technologies and methodologies involved in it, regarding the current trends, should be included.

Currently, the comparison of competences and evaluation of their compatibility is performed by people, in one-time actions (as needed), often giving different results each time and requiring a significant constraint on the possible number of options taken into account in one analysis. Therefore, it is important to create an automated comparison mechanism.

Competences are usually reflected in a textual form, thus it is important to establish their semantic meaning. The only instrument that allows defining borders of semantics is ontology [14]. Competences can be compatible only if they belong to the same ontology.

Since in order to allow an automatic comparison the competences have to be stored and described in some form that facilitates that, after considerations and studies, the authors decided to use a dedicated object database. As a static object model of the current state of competences, the object database allowing for comparison of two competence sets has the following characteristics:

- provides the possibility to describe and store data structures, as well as methods and procedures for their usage within one object,
- gives the possibility to inherit characteristics of individual objects due to description of their interrelations (e.g. an education offer can only describe its content, without repeating all information about the university it is connected to),
- is flexible, therefore when the need arises, the existing structure and hierarchy can be adjusted and changed, elements can be added, deleted or modified.

Additionally, the collected data can be used also for a retrospective analysis of the situation in the education and job market and its changes over time. The database can also be understood as a base of facts regarding the considered area of competences, together with procedures used for their processing and analysis.

The considered database should include information describing the presented market situation and allowing for finding solutions of the described problems regarding the compatibility of competences. Additionally, to evaluate whether a certain set of competences is up to date, information about the technologies and methodologies involved in it, regarding the current trends, should be included.

The proposed content structure of the database was presented in Fig. 2.

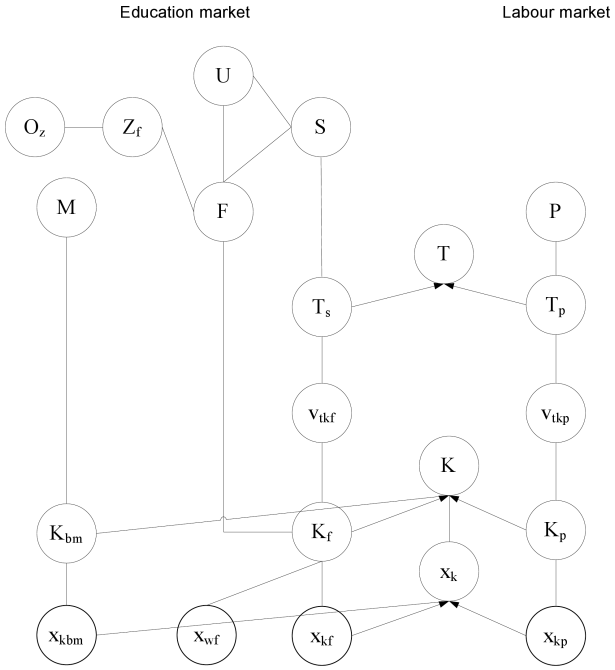

Fig. 2. Object model.

The presented object model (including all the symbols used) was described in a mathematical form in the following part of the paper.

Formal description of the model

Using the language of mathematics to described the proposed object model we received the following formal model:

General assumptions

$\mathbf{K} = \mathbf{\{k\}}$, $k = 1, \ldots, k^*$ – competence set

All competences belong to one common set of competences. Depending on whether we look at them from the point of view of the job market or of the education market, we will talk about, respectively, the required and the guaranteed competences. A given competence may be regarded differently on each market (e.g. fewer or different technological references), or under a different name, but still remain the same competence.

Example: knowledge of English language.

$\mathbf{x}_k$ – strength of competence k

As the strength of a competence we understand the level of fluency in the competence (see e.g. in [15] or [16]) described by projecting a linguistic or numerical description of the evaluation of this level on a unified scale. In order to guarantee ac-

curacy, a detailed method of transforming other scales into the uniform one should be developed with the help of specialists of the considered domains, cognitive science, semantics etc.

Scope: <0..1>

0 signifies lack of any knowledge regarding the competence, while 1 signifies a complete set of knowledge and abilities included in the competence (expert level).

Example: "fluent knowledge of English" can be described for example as $k =$ "knowledge of English" and $x_k = 0.9$ (level similar to a native speaker).

$\mathbf{T = \{t\}}$, $t = 1, \ldots, t^*$ – set of technologies, methodologies and tools connected to the competence.

All technologies, methodologies and tools belong to one common set. Their connection to competences, however, maybe different depending on where they are used.

We talk about technologies, methodologies and tools since they can all become outdated, thus their connection to required and guaranteed competences is important for evaluating usability of an education offer.

Example: a project manager has to know such project methodologies as e.g. PMBOK, for which every few years an update is released, therefore knowledge about the version might be quite important.

Job market

$\mathbf{P=\{p\}}$, $p = 1, \ldots, p^*$ – ser of professions

As a profession we understand a job/position sought on the market.

$\mathbf{K}_p = \mathbf{\{k}_p\mathbf{\}}$, $k_p = 1, \ldots, k_p^*$, $K_p \subset K$ – set of competences k required in profession p

Each profession is connected to having a certain set of competences, what is usually described in a linguistic way, e.g. "very good knowledge of English".

$\mathbf{x}_{kp}$ – strength of competence k require in profession p

For each competence required in a certain profession a minimum acceptable strength of the competence should be specified.

Scope: (0,1> – competences with strength equal 0 are simply not considered.

$\mathbf{T}_p\mathbf{=\{t}_p\mathbf{\}}$, t_p=$1, \ldots, t_p^*$, $T_p \subset T$ – set of technologies, methodologies and tools connected to profession p

Each profession is connected to knowledge about a certain set of technologies, methodologies and tools required and the ability to use them. E.g. for a computer graphic designer this might be Photoshop or Corel, while for a project manager that could be PMBOK or PRINCE2.

$\mathbf{v}_{tkp}$, $t_{kp} = 1, \ldots, t_{kp}^*$; $k_p = 1, \ldots, k_p^*$; $p = 1, \ldots, p^*$ – participation of technology t in the required competence k_p

Scope: (0..1>

0 means that a certain technology (methodology, tool) is not used in this competence, thus we do not consider this option; 1 signifies that the profession is dominated completely by one technology.

Education market

$\mathbf{S=\{s\}}$, $s = 1, \ldots, s^*$ – set of specialisations

$\mathbf{U}_s = \mathbf{\{u\}}$, $u_s = 1, \ldots, u_s^*$ – set of universities which offer specialisation s

$\mathbf{f}_{us}$, $u = 1, \ldots, u^*$, $s = 1, \ldots s^*$ – education offer of university u referring to specialisation s

$\mathbf{Z}_f = \mathbf{\{z}_f\mathbf{\}}$, $z_f = 1, \ldots, z_f^*$ – set of subjects connected to offer f_{us} (curriculum)

Information about the set of subjects can help in defining the set of competences consisting for the considered specialisations.

$\mathbf{Q}_z$ – parameters of subject z in offer f_{us} (e.g. the number of hours, form of classes, form of evaluation etc.)

Parameters of a subject can be used for establishing the strength of a competence guaranteed by an education offer

$\mathbf{K}_f = \mathbf{\{k}_f\mathbf{\}}$, $k_f = 1, \ldots, k_f^*$, $K_f \subset K$ – set of competences guaranteed by offer f_{us} when teaching speciality s at university u.

$\mathbf{x}_{kf}$ – strength of competence k guaranteed by offer f_{us} after graduation.

Each offer should define the level of mastery of a competence upon graduation. One can assume that the simple fact of teaching a certain scope of knowledge guarantees its mastery at a basic level. The strength of the competence may be established basing on the number of hours of teaching a given subject.

Scope: (0,1> – competences with strength equal 0 are simply not considered.

$\mathbf{x}_w$ – strength of competence k required in order for a candidate to be accepted for studying specialisation s in the frames of the education offer f_{us}

Each education offer can be characterised by a set of requirements, without the fulfilment of which it is impossible to be accepted. The requirements refer to the scope and the level of competences one needs to possess before starting the studies. The regarded set of competences is K_f.

Scope: <0,1> – competences that are not important in the recruitment process have the required level of competence strength equal of 0.

$\mathbf{T}_s = \{\mathbf{t}_s\}$, $t_s = 1, \ldots, t_s^*$, $T_s \subset T$ – set of technologies, methodologies and tools connected to specialisation s.

A certain specialisation may be connected to different technologies, but their participation in this speciality depends on a specific education offer

$\mathbf{v}_{tkf}$, $t = 1, \ldots, t_s^*$; $k = 1, \ldots, k_f^*$; $f = 1, \ldots, f_{us}^*$ – participation of technology t_s in competence k_f guaranteed by offer f_{us} when studying specialisation s at university u.

Scope: <0..1>

0 means technology t_s is not present in offer f_{us}, but the technology might be present in a different offer, thus it is still considered; while 1 means the offer is completely dominated by the technology.

Candidate for studies

M={m} – set of candidates for studies

Although in ODL we talk rather about a student flow than about a set of students, in the situation for which the described model was developed, at a single time we are only dealing with one candidate for studies. Using the concept of a set has meaning mainly in case of creating statistics based on the data collected in the database, while the flow of student itself is never considered.

Each candidate is characterised by:

$\mathbf{K}_{bm} = \{\mathbf{k}_{bm}\}$, $k_{bm} = 1, \ldots, k_{bm}^*$ – set of basic competences of candidate m

At any given time each person possesses a certain set of competences on the basis of which his/her knowledge and abilities can be further developed. We call these the basic competences.

$\mathbf{x}_{kbm}$ – strength of the basic competence k_b of candidate m

Each of the possessed competences was mastered to some level. This lever of mastery is reflected by the strength of the basic competence.

Scope: (0,1> – competences with strength equal 0 are simply not considered.

Procedures

Certain procedures can be identified for performing the most important tasks on the data included in the database. These include:

1. Coverage of the minimum required for being accepted for studies by the basic competences of a candidate.

   Application:

   This procedure is used to assess whether a candidate can start studies proposed by a given education offer.

   Input data:

   m – candidate for studies,

   u – specific university,

   s – specific specialisation,

   f_{us} – specific education offer for specialisation s at university u,

   K_f – set of competences guaranteed by offer f_{us},

   x_w – strength of competence k_f required to be accepted for studies,

   K_{bm} – set of basic competences of student m,

   x_{kbm} – strength of competence k belonging to set K_{bm}

   Procedure:

   $\forall k_f \in K_f \exists k_{bm} \in K_{bm}$,such as $k_f = k_{bm}$and $x_{kbm} \geq x_w$

   Result:

   The result is given as **true/false**, showing whether a candidate possesses the required set of competences at the required level, or not.

2. Concordance of an education offer with the requirements of the chosen profession.

   Application:

   The procedure is used for evaluating the level of concordance of competences guaranteed by the education offer with the competences required for a certain profession. This refers to the competences themselves as well as their strength and the participation of technologies etc. in them.

   Input data:

   p – specific profession,

   u – specific university,

   s – specific specialisation,

f_{us} – specific education offer for teaching specialisation s at university u,

K_f – set of competences guaranteed upon graduation from studies described by offer f_{us},

x_{kf} – strength of competence k belonging to set K_f,

K_p – competences required for profession p,

x_{kp} – strength of competence k belonging to set K_p,

v_{tkp} – participation of technology t in competence k connected to profession p,

v_{tkf} – participation of technology t in competence k included in offer f_{us}.

Procedure:

FOR ($i = 0..k_p^*$ AND $j = 0..k_p^*$; i++,j++)
IF ($\exists k_i \in K_f$ AND $k_j \in K_p$ such that $k_i = k_j$)
THEN
IF ($x_{ki} \geq x_{kj}$) THEN
IF ($\forall z = 1..t_p*, v_{zki} \geq v_{zkj}$) THEN
NoCoveredCompetences ++;
ELSE
NoComWithLowerTechPart ++;
ELSE
NoComWithLowerStrength ++;
ELSE
NoMissingCom ++;
END FOR
FullyCovered = (NoCoveredCompetences / k_p) * 100%
NotCoveredTech = (NoComWithLowerTechPart / k_p) * 100%
NotCovStength = (NoCompWithLowerStrength / k_p) * 100%
NotCoveredAtAll = (NoMissingCom / k_p) * 100%

Result:

The result defines the percentage of competences required in the profession that are fully covered by the guaranteed competences and the percentages of competences for which the participation of technologies or the strength level are too small, as well as the percentage of competences not covered at all.

It is possible to further split the calculations in order to identify the participation of technologies not covered by the education process in a level required for the considered profession.

Several other interesting procedures can be created for the described object model:

1. Defining the difference between the set of candidates basic competences and the set of competences guaranteed by an education offer.
Application:

   The procedure may be used for evaluating the scope of knowledge increase as a result of competing the education as described in the education offer, by calculating the number of competences not possessed by the candidate or not mastered to the offered level (optionally: including outdated content).

2. Coverage of a profession by a certain education offer (or specialisation, in which case small change in the mathematical assumptions would be needed).
Application:

   The procedure could be used for finding education offers (specialisations) that are, on the level of competences, most consistent with a given profession.

3. Defining the difference between competences offered in the frames of different education offers.
Application:

   The procedure could be used by universities to evaluate difference with other offers in order to become more competitive in a certain field or to identify a "niche" which could be filled in by a new offer

Conclusions

As was discussed in the article, providing an automated tool for evaluating compatibility of competences is the first step in facilitating the choice of higher education. The proposed model solves the basic issue of not only assessing whether a certain set of guaranteed competences contains competences required on the job market, but by including the technological aspect it also helps decide whether the education offer is up-to-date concerning the content of each competence. The next step would be incorporating the model in a system that would also give each user the possibility to personalise the results.

References

[1] Bologna Process, http://www.bologna-bergen2005.no, 2007.

[2] Bologna Working Group on Qualifications Frameworks, A Framework for Qualifications of the European Higher Education Area, report: http://www.bologna-bergen2005.no/, 2007.

[3] Minister of Science and Higher Education, The list of qualification standards, http://www.bip.nauka.gov.pl/bipmein/index.jsp?place=Lead07&news_cat_id=117&news_id=982&layout=1&page=text, 2008 – in Polish.

[4] Tuning Educational Structures In Europe Project, http://www.relint.deusto.es/TuningProject/index.htm, 2007.

[5] Ministry of Labour and Social Policy, Qualification and training standards, http://www.standardyiszkolenia.praca.gov.pl/mgpips/strona_g1.html, 2008 – in Polish.

[6] European ICT Jobs, CompTrain, R4.2 Catalogue of competences - European competence profiles for Multimedia jobs v 1.0, http://www.annuaire-formation-multimedia.com/catalogue.pdf, 2008.

[7] IEEE, P1484.20.1 Reusable Competency Definitions Draft 8, http://www.ieeeltsc.org/working-groups/wg20Comp/wg20rcdfolder/IEEE_1484.20.1.D8.pdf, 2008.

[8] HR-XML Measurable Competencies, http://www.hr-xml.org, 2004.

[9] Sure Y., Maedche A., Staab S., Leveraging Corporate Skill Knowledge – From ProPer to OntoProPer, In: Proceedings of the Third International Conference on Practical Aspects of Knowledge Management, 30–31, 2000.

[10] IEEE, Proposed Draft Standard for Learning Technology – Simple Reusable Competency Map, rev 4, http://ieeeltsc.files.wordpress.com/2009/03/reusablecompetencymapproposal.pdf, 2006.

[11] TENCompetence, http://www.tencompetence.org/, 2007.

[12] De Coi J.L., Herder E., Koesling A., Lofi C., Olmedilla D., Papapetrou O., Siberski W., A model for competence gap analysis, In: WEBIST 2007, Proceedings of the Third International Conference on Web Information Systems and Technologies: Internet Technology / Web Interface and Applications, Barcelona, Spain, INSTICC Press, 2007.

[13] Ciszczyk M., Sikora K., Kusztina E., Zaikin O., Tadeusiewicz R., Didactic process based on the repository system, EUNIS 2010, http://www.eunis.pl/, 2010.

[14] Gomez-Perez A., Fernandez-Lopez M., Corcho O., Ontological Engineering, Springer, 2010.

[15] Wang H-F., Wang C.H., Modelling of optimal expansion of a fuzzy competence set, International Transactions in Operational Research, 5, 1998.

[16] Yu P.L., Zhang D., A foundation for competence set analysis, Mathematical Social Sciences, 20, 1990.